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Operations Management for Social Good

2018 POMS International Conference in Rio

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LATIN AMERICA & CARIBBEAN CHAPTER

Preface

The Production and Operations Management Society, POMS (http://www.poms.org), is an international professional organization representing the interests of production and operations management professionals and academicians all over the world. The society aims at (i) extending and integrating knowledge in the field of POM and (ii) disseminating information on production and operations management (POM) to managers, scientists, educators, students, public and private organizations, national and local governments, and the general public.

The POMS was founded on June 30, 1989. Since then, the society has organized annual conferences in the USA and international meetings in several countries. Through POMS Chapters (in China, Hong Kong, India, Taiwan, and Caribbean and Latin America), the society remains active in organizing events all over the world.

The POMS Caribbean & Latin America Chapter was given the responsibility in 2017, through a provisional council, to prepare the chapter's bylaws, organize the final elections of the chapter board and organize a POMS conference in the region. Starting in 2018, the chapter board aims to hold a conference biennially in Caribbean and Latin America.

The 2018 POMS International Conference is organized to provide an opportunity to faculty, doctoral students, and practitioners to share knowledge and insights through research presentations, tutorials, and plenary discussions that contribute to the improved understanding of research and practice of POM.

The “2018 POMS International Conference in Rio” was held on December 10 to 12, 2018, at PUC-Rio, Rio de Janeiro, Brazil. The conference theme was *Operations Management for Social Good*. The event lasted 2.5 days and had 3 plenary sessions, 3 tutorial sessions, and 167 works presented in 47 sessions by 164 participants.

The 115 full papers presented in the proceedings were organized in the following tracks:

- Humanitarian Operations and Crisis Management
- Healthcare Operations Management
- Sustainable Operations

- Artificial Intelligence and Data Analytics in Operations
- Product Innovation and Technology in Operations Management
- Marketing and Operations Management
- Service Operations and Servitization
- Logistics and Supply Chain Management
- Resilience and Risk in Operations
- Defense, Tourism and other Emerging OM Issues.

These papers represent a good sample of the research work undertaken in Caribbean and Latin America and can be used as a reference for researchers in POM. The work also shows the growth potential of the POMS Caribbean & Latin America Chapter. Given the great success of the conference at PUC-Rio, and the momentum generated by it, we are convinced that the 2020 POMS International Conference in the Caribbean & Latin America region will be even more successful.

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Contents

Part I
Artificial Intelligence and Data Analytics in Operations

Chapter 1
Evaluating Order Picking Efficiency Under Demand Fluctuations

Jens Bürger

Abstract Storage location assignment is a dynamic problem due to product life cycles and time-varying demand patterns. We demonstrate the impact of demand fluctuations on order picking times for frequency-based and genetic-algorithm-based storage assignment policies. Our results provide the base for developing re-warehousing strategies to maintain order picking efficiency over time.

Keywords Order picking · Storage location assignment problem · Genetic algorithm

1.1 Introduction

Order picking, the process of collecting and sorting a set of products according to customer orders, is the main cost driver in warehouse operations [15]. Some estimates go as far as assigning 65% of operational costs of warehouses to order picking [3]. Order picking consists of travel between product locations, retrieval of the specific stock keeping unit (SKU), and sorting of SKUs according to customer orders. Travel is estimated to contribute approximately 50% of the total order picking costs [15]. In sum, efforts to reduce warehouse operation costs depend strongly on efficient order picking. Reducing order picking time and costs can be achieved through a set of mutually dependent strategies. Warehouse layout, with the spatial definition of racks and aisles, predetermines the possibility to optimize travel routes within a warehouse [1]. Closely related are routing strategies that aim to traverse the warehouse as to minimize total travel distance required to fulfill orders [14]. Efficiency of warehouse traversal can be improved further by order batching [6]. Efficient storage location assignment policies that take product demand statistics into account can further improve order picking [2].

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While all these order picking optimizations present valid approaches for any given moment, they typically do not present insights into the dynamics of warehouse operations. Having a warehouse inventory consisting of a larger number of products, potentially distributed across various different product categories, picking efficiency is a time-dependent function. Due to daily, weekly, monthly, seasonal, and yearly demand fluctuations, order picking efficiency can vary greatly under such time-varying dynamics [8]. The recognition of order picking as a dynamic problem, for the very same reasons as outlined so far, has been recently addressed by Kofler et al. [9]. For demand patterns obtained over a period of four months, the relation between slotting strategies (turnover, affinity) and optimization strategies (re-warehousing, healing) was investigated with respect to finding a compromise between picking efficiency and costs incurred by rearranging product locations. As the authors mentioned, the objective was to evaluate the effectiveness of the different strategies, not to evaluate robustness over a longer period of time.

In this paper, we investigate in more detail the time-dependent dynamics of order picking efficiency in relation to slotting (or the storage location assignment problem (SLAP)). Based on a 5-year demand dataset, we investigated how picking efficiency is degrading with time for different slotting policies. Based on a near-optimal storage assignment for an initial period, we show how time-varying demand fluctuations effect order picking efficiency. In connection with different picker capacities, we show the trade-off between initially optimized solutions and solutions that are more robust to demand fluctuations.

1.2 Methodology

1.2.1 Storage Location Assignment Problem

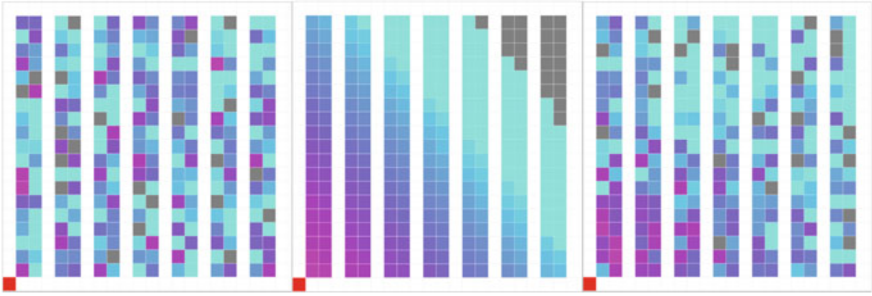
Storage location assignment searches an order-dependent configuration from a list of products $P = \{p_1, p_2, \ldots, p_{n-1}, p_n\}$ of length n and is akin to the traveling salesman problem (TSP). Due to the time complexity of $O(n!)$ of this class of problems, it is not feasible to exhaustively search the solution space for an optimal configuration. The TSP has been extensively studied, and while effective search algorithms exist, none of them can guarantee optimality of the found solutions [10]. Similarly, defining a storage location assignment for any realistic warehouse with n products requires the use of constrained or heuristic search methods that produce near-optimal solutions in a reasonable amount of time [13]. To study order picking efficiency of a given storage location assignment in response to time-varying product demand, we implement three assignment policies: random slotting, turnover-based slotting, and a genetic-algorithm-based slotting policy. The random assignment is completely unaware of product demand or product correlations (affinity). The turnover slotting strategy evaluates product demand over a given period and assigns products to storage locations as a function of their total demand and their distance to the depot. In theory, this optimizes picking efficiency as products in highest demand are located closest to the depot. As a third method, we implement a genetic algorithm (GA) for the SLAP. Based on a set of reference orders over an initial period, the GA tries to optimize the total picking distance, intrinsically taking into account product turnover and order correlations. As a heuristic, it does not guarantee an optimal solution, but can calculate near-optimal solutions in a reasonable amount of time even for large numbers of products. The GA implements a set of possible storage locations as chromosomes with specific products encoded as genes. In such a genetic representation, a chromosome represents a specific permutation of the available genes (products assigned to specific locations). We initialize the GA with a population size of 30 randomly generated individuals defined by their chromosomes. The GA then evolves the population for 200 generations through fitness evaluation, selection, crossover, and mutation. According to Mitchell [12], we use common GA parameters of 0.9 for the crossover rate and 0.01 for the mutation rate. All parts of the GA were implemented with python's *deap* package [5].

1.2.2 Warehouse Modeling

As the demand dataset in our experiments did not contain information about specific product details, other than demand, we model the warehouse in a generic manner assuming homogeneous storage cells and product properties. We define the warehouse as a two-dimensional grid with storage cells on only one level (no vertical storage). We design the warehouse shape parameter r with an x/y ratio of 1 [7]. The basic distance metric in our model, for x and y dimensions, is a unitless grid cell. Accordingly, each storage cell occupies exactly one grid cell and the picker can move one grid cell at a time. In total, the warehouse contains m racks with s storage cells on each side of the rack as to satisfy $2ms \geq n$, which assures that there are at least as many storage cells as there are products. An illustration of the warehouse and corresponding storage assignments is shown in Fig. 1.1 for the random, turnover, and GA slotting policies.

1.2.3 Order Picking

For the process of order picking, we define a single picker. The picker receives a daily demand from a set of P products with a total unit demand D. According to the picker capacity i, this order is then split into B batches so that $B * i \geq D$. As the used dataset did not contain information on specific customer orders, but only on daily demand we randomized the generation of the batches B and evaluated order picking over the total daily demand D. We model each product as having equal size and weight, and the picker has a capacity to collect i items per batch (an item is a single unit of a given product demand). In this project, we will evaluate order picking efficiency as



(a) Random Policy (b) Turnover Policy (c) GA Policy

Fig. 1.1 **a** Random storage assignment, **b** turnover storage assignment and **c** an instance of the genetic algorithm storage assignment. Warmer colors indicate products in high demand, cooler colors in low demand. As the product demand differs by orders of magnitude across products, the color represents the log demand

a function of picker capacity for $i = 100$, 250, and 500. When collecting items, the picker follows a midpoint routing strategy [7] and overall order picking efficiency is measured as average distance per product for any given order list with n products.

1.2.4 Product Demand

The general hypothesis of our presented work is that order picking efficiency will degrade with time as product demand patterns change due to daily, weekly, monthly, seasonal, and/or yearly fluctuations. To test this hypothesis, we use a demand dataset obtained from kaggle.com [16]. This dataset contains product demand for over 5 years for more than 2100 products across 4 different warehouses. For our analysis of the operations of a single warehouse, we select "Whse_C" with a total of 244 products. We therefore model a warehouse typical for manual picking and of the size of a small-to-medium-sized enterprise. The patterns present in the dataset provide both temporal and quantitative differences relevant for our analysis as given in Table 1.1. Order frequency ranges from bi-daily to a single time per year with a median of 99 sales days over a 5-year period. The number of products sold per day ranges from 1 to 81 with a median of 26. Order quantity (unit demand) ranges by several orders of magnitude from a single unit up to 33,000 units of a specific product per day.

Table 1.1 Demand statistics

	Min	Median	Max
Product order frequency	4	99	674
Products per day	1	26	81
Unit demand per day	1	1727	33,195

These statistics provide the base for the time-varying demand patterns affecting the efficiency of order picking.

1.3 Results

1.3.1 Single Optimization

As a first reference analysis, we have computed order picking efficiency for all three slotting policies over a five-year range with only a single optimization based on an initial 30-day period. The evaluation was done for the three different picker capacities i of 100, 250, and 500 items, and the results of order picking efficiency are given in Table 1.2. We can note that the turnover policy generally performs best for all picker capacities i. The data also shows that with increasing picker capacity, the advantage of dedicated slotting policies over a random one becomes smaller. This confirms the results from de Koster et al. [4] and Lu et al. [11]. What the table does not clearly illustrate are the changes in order picking efficiency over time. To better understand the dynamics of picking efficiency, we have to look at the time-series plots. In Fig. 1.2, we show order picking efficiency for all three policies with a picker capacity $i = 250$. We can point out two conclusions. First, while the picking distance for the random policy (after an initial period of lower overall demand) does not indicate an apparent long-term upward or downward trend despite seasonal fluctuations, the turnover and GA policies show a continuous degradation of picking efficiency. And second, while in average the turnover policy is preferable, the GA policy showed higher efficiency for the initial period of 30 days. The difference of initial order picking efficiency between the turnover and GA policies becomes more pronounced as we increase the picker capacity. For $i = 100$, 250, and 500, the GA performed 2, 5.5, and 24% better, respectively. This confirms the assumption that the GA intrinsically exploits product correlations which has increasing benefits the more products are picked along a single route.

1.3.2 Continuous Optimization

With single optimization as reference, we now present results for continuous storage location optimization. Every 30 days, we updated product storage locations based on the turnover and GA policy (as random assignment is not to be optimized, we leave this policy out for this analysis). The results for picking efficiency under continuous optimization are given in Table 1.3. Confirming the results of the initial optimization from the previous section, the GA significantly outperforms the turnover slotting policy. For all picker capacities, the GA exhibits lower mean and standard deviation in the picking distance per product. We can attribute these results to the fitness

Table 1.2 Average per product picking distance for different slotting policies and picker capacities

	Capacity $i = 100$				Capacity $i = 250$				Capacity $i = 500$			
	Min	Mean	Max	Std	Min	Mean	Max	Std	Min	Mean	Max	Std
Random	8.00	29.27	72.0	7.43	10.00	24.47	74.0	6.35	6.95	21.79	74.0	8.02
Turnover	**2.00**	**18.45**	**52.0**	5.80	**2.00**	**16.91**	**52.0**	**5.05**	**2.00**	**15.29**	**52.0**	**4.95**
GA	6.75	20.41	74.0	**5.38**	7.33	18.57	66.0	5.64	4.00	17.03	70.0	5.88

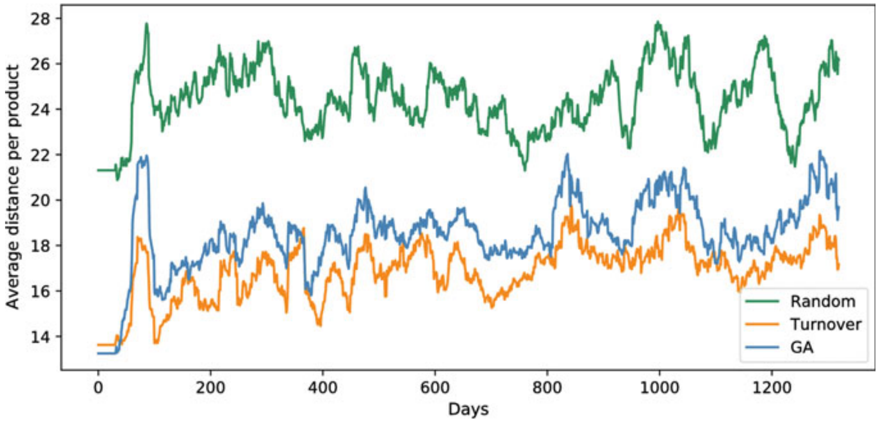


Fig. 1.2 Average per product picking distance for different slotting policies and a picker capacity of 250 with single initial optimization

evaluation of the GA. While the turnover policy only takes the summed-up demand of each product into account, the GA, based on evaluating fitness through the actual travel distances for a set of reference orders, implicitly evaluates product demand, demand correlations across products, and the routing strategy as a multi-objective optimization problem. As one can see in Fig. 1.1, the GA assigns some high-demand products further away from the depot. While this implies frequent longer distances for high-demand products, it is offset by placing correlated products nearby. The time-series plot for continuously optimized storage assignment (with $i = 250$) is shown in Fig. 1.3. We can note that with continuous optimization, the initial picking efficiency can be roughly maintained (though subject to seasonality in product demand, we cannot determine a clear trend).

1.3.3 Sensitivity to Demand Changes

Based on the two presented results for single and continuous optimization, we can point to an important design criteria impacting re-warehousing strategies (while Kofler et al. [9] made a distinction between re-warehousing and healing, we use the term re-warehousing in a general sense where healing is considered an incremental re-warehousing). Under single optimization, we have seen that the turnover method performs best, if evaluated over a longer period of time. With continuous optimization, the GA (as one example of a heuristic search method) shows clear advantages independent of how demand patterns change over time. Therefore, warehouse operations are faced with the compromise between efficiency and robustness. The efficiency obtained with the GA was based on exploiting demand correlations across products (in accordance with results from Kofler et al. [9]). As order patterns and

Table 1.3 Average per product picking distance for different slotting policies and picker capacities under continuous optimization

	Capacity $i = 100$				Capacity $i = 250$				Capacity $i = 500$			
	Min	Mean	Max	Std	Min	Mean	Max	Std	Min	Mean	Max	Std
Turnover	4.00	15.20	48.00	4.07	4.00	14.40	48.00	3.96	4.00	13.07	48.00	4.24
GA	**1.78**	**14.54**	**23.35**	**3.08**	**1.71**	**13.01**	**22.64**	**2.92**	**1.77**	**11.81**	**19.99**	**3.07**

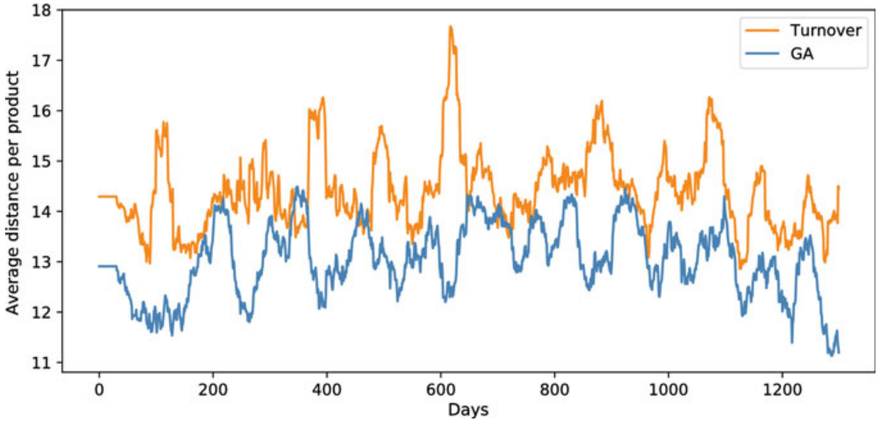


Fig. 1.3 Average per product picking distance for different slotting policies and a picker capacity of 250 with continuous 30-day optimization

therefore correlations change, the GA assignment loses its efficiency. On the other hand, while the turnover policy did not capitalize on some deeper relations between products, it made the approach more robust to demand changes. As discussed earlier, the random policy is the only one fully insensitive to changes in demand patterns, at the expense of being far from efficient, especially for smaller picker capacities. In Fig. 1.4, we plot the cumulative additional picking distance per product between single and continuous optimization as an indicator for the sensitivity to changing demand patterns. For both, the turnover and the GA policy, we see a constant linear increase in distance per product with the difference that the GA increases at a faster rate due to the larger difference in optimized and non-optimized performance. It

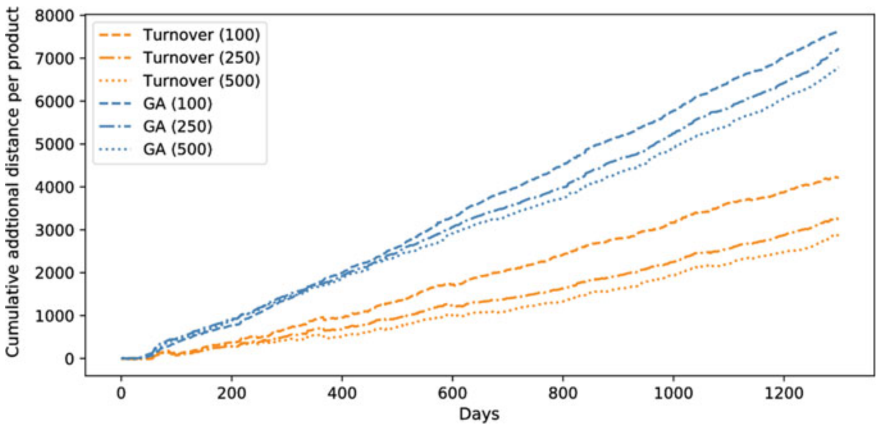


Fig. 1.4 Cumulative additional distance per product of single initial warehouse optimization as compared to continuous optimization. Values in parenthesis are the different picker capacities

is interesting to note that, while demand patterns show clear and pronounced seasonal variations in order quantity, the decrease in picking efficiency follows a very linear function. Under considerations of warehouse-specific re-warehousing costs, re-warehousing strategies and policies can then be derived based on the picking efficiency baseline (picking distance with continuous optimization), the loss in picking efficiency (cumulative additional distance), and re-warehousing costs.

1.4 Conclusions

In this work, we analyzed order picking efficiency as a time-dependent function that can inform re-warehousing policies. The presented time-series plots have shown in much more detail how changing demand patterns affect order picking efficiency. We have pointed to the differences in efficiency of different slotting policies as well as their robustness to changes in demand patterns. The presented insights into optimality and robustness therefore complement previously published work on the dynamic storage location assignment problem [8, 9]. A future aspect is the further complexification of the used framework. In this work, we have reduced complexity of the warehouse model and the picking process as to study the impact of demand fluctuations and slotting policies on picking efficiency. We expect that the general conclusions of our study remain valid, but inclusion of further aspects such as vertical storage, heterogeneous storage cells, different routing strategies, datasets with different demand patterns, etc., can alter the relative results to some extent. In summary, re-warehousing strategies will have to be designed around the compromise between optimality and robustness. In general, we can say that if re-warehousing can be done at relatively low costs (such as the healing strategy [9]), then efficiency is preferable over robustness. If re-warehousing is a costly and disruptive process, one might choose more robust slotting policies that can maintain a somewhat stable order picking efficiency.

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Chapter 2
Product Demand Forecasting Based on Reservoir Computing

Jorge Calvimontes and Jens Bürger

Abstract Common forecasting methods fail to accurately model the nonlinear and time-varying fluctuations of product demand. Reservoir computing (RC) utilizes a dynamical system to project time-series data to a higher-dimensional state representation extracting mathematical relations within complex demand functions. We demonstrate forecasting accuracy of RC on a multivariate product demand dataset.

Keywords Demand forecasting · Reservoir computing · Time-series analysis

2.1 Introduction

In production and operational management, demand forecasting is an important method as it helps to develop better approximations of future operations under the presence of uncertainty. Forecasting extracts mathematical relations from within past data that can be used to inform decision-making. In supply chain management, efficient coordination of resource acquisition, production and warehousing strongly depends on accurately predicting future product demand in particular and market dynamics in general. Accurate demand forecasting therefore reduces investment risks in uncertain environments. The challenges of demand forecasting lie in the complexity of demand dynamics. In general, demand data can be decomposed into deterministic patterns and random fluctuations. While it is impossible to predict random fluctuations in demand, deterministic patterns can, in theory, be learned or approximated by corresponding forecasting models.

Among the most commonly applied forecasting methods are exponential smoothing (ES) [5] and the *autoregressive integrated moving average* (ARIMA) [6]. These models fit parameters to polynomial functions in order to approximate the time-

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dependent demand data. Applications of ES and ARIMA have been shown for forecasting urban freeway traffic flow [18] and electricity demand [3, 15]. While such models work well for demand patterns composed of few frequency components, due to their fixed mathematical structure, their applicability and accuracy are limited when approximating complex demand patterns described by a wide frequency spectrum and nonlinear patterns [9].

As non-explicit mathematical models, artificial neural networks (ANN) are a powerful tool to approximate complex nonlinear relations from a set of input variables as to map them to a target output. Through nonlinear kernel functions, ANN create a higher-dimensional representation of an input signal so that input–output relations become more evident and easier to approximate. The most common ANN is the multilayer perceptron (MLP) which passes data in a unidirectional way from the input layer to an output layer. Applications of MLP to time-series forecasting have been shown to achieve lower mean-squared error than ARIMA [9]. However, due to the unidirectional flow of data through the MLP, it presents a memory-less model which has limited applicability to time-series data.

More suitable for time-series data are recurrent neural networks (RNN), which implement a memory of past data through recurrent connections within the neural network. The higher-dimensional representation within the RNN is therefore determined by nonlinear combinations of data points obtained from a temporal sequence. The main difficulty with RNN is the training of their parameters known as the vanishing gradient problem, which has limited the application of RNN to rather simple problems [1]. In order to facilitate training, regularization techniques have been proposed [4], which impose constraints for training or limitations to the architecture itself. Such techniques include stability constraints, automata rules and locally recurrent architectures (with LSTM being the most popular [4]). Under automata rules, it has been proposed that a random initialization of the network has a bias towards a finite memory and good generalization properties [4], which implies that training of RNN can be simplified.

In this chapter, we present the application of reservoir computing (RC) [7, 11] to product demand forecasting. RC utilizes a randomly initialized RNN that implements the mentioned finite memory and generalization. Under these conditions, it is sufficient to reduce training complexity to only a single linear output layer and achieve accurate forecasting results. The output layer is therefore able to derive a simple linear relationship between the input data and its projection into a higher-dimensional feature space. The general suitability of RC to time-series data has already been demonstrated in numerous publications [8, 10, 14]. In the following sections, we demonstrate the advantages of RC over common mathematical forecasting models applied to a complex demand dataset.

2.2 Methodology

2.2.1 Exponential Smoothing

Exponential smoothing (ES) is a collection of methods that forecast based on weighted averages of past observations with exponentially decaying weights as the observations get older [5]. This collection offers different methods to forecast, depending on if the data contains trend or seasonal patterns. Simple smoothing (no trend or seasonality) can be expressed in a recursive way:

$$\hat{y}_t = \alpha y_t + (1 - \alpha)\ell_{t-1}, \tag{2.1}$$

where α is the smoothing factor ($0 \leq \alpha \leq 1$), ℓ_0 is a parameter for the first fitted value, y is an observed, and $\hat{y}_t$ is a forecasted value of the series at time t.

When data contains trend or seasonality, additional smoothing equations are considered and Eq. (2.1) will include additional factors. If data contains a trend, a term b_t is used, which considers trend dynamics. For seasonality, depending on if patterns change in a constant or proportional way [6], an additive or multiplicative term s_t is used. s_t is configured by a periodicity parameter m, which determines seasonal patterns. The mentioned equations use smoothing factors β and γ, for trend and seasonality, respectively. These, in conjunction with α, determine the smoothing level for each function. This determines how well the model captures patterns present in data.

Complex data will likely contain trend and seasonal patterns. In this case, a combination of the trend and seasonal equations are used to compute a number of forecasted steps, with h being the number of steps into the future. Depending on seasonal characteristics, an additive or multiplicative equation (s_t) can be used.

$$\hat{y}_{t+h|t} = \ell_t + hb_t + s_{t+h-m(k+1)} \tag{2.2}$$

$$\hat{y}_{t+h|t} = (\ell_t + hb_t)s_{t+h-m(k+1)} \tag{2.3}$$

Equation (2.2) illustrates a model that considers trend and an additive seasonality, whereas Eq. (2.3) shows a multiplicative case. An integer k is used in the form: $k = (h - 1)/m$ to ensure consistency of the seasonal indices.

2.2.2 ARIMA

The autoregressive integrated moving average (ARIMA) is the combination of autoregressive (AR) and moving average (MA) methods. AR models are constructed according to the difference between the series and a shifted (lagged) version of itself.

MA methods are constructed based on the error between consecutive time intervals. Both methods can be expressed as a weighted sum of past events. Integrated in this sense means the sum of the coefficients of the AR and MA models in the form:

$$y'_t = c + \phi_1 y'_{t-1} + \cdots + \phi_p y'_{t-p} + \theta_1 \varepsilon_{t-1} + \cdots + \theta_q \varepsilon_{t-q} + \varepsilon_t, \tag{2.4}$$

where y'_t is a differentiated version of the data for time t. Constants c and ϕ correspond to the AR model, while ε_t and θ correspond to the MA model.

The notation used to express the model is: ARIMA(p, d, q), where the values of p, d and q, will determine the behaviour of the ARIMA model. The parameters p and q are the number of steps to consider for the AR and MA models, respectively. In order for ARIMA models to forecast, data must be stationary [6]. To achieve stationarity data can be differentiated. Parameter d determines the order of differentiation. Although the conventional ARIMA model only works with non-seasonal data, it can be extended to work with seasonal data by adding four more parameters: P, D, Q and m, where the first three correspond to the same parameters as the conventional method. The difference only being is that their regressions are based on a seasonal scale according to the periodicity m. In that context, a seasonal ARIMA model will forecast based on seasonal and non-seasonal patterns of the data, with the notation being: ARIMA (p, d, q)(P, D, Q, m)

2.2.3 Reservoir Computing

Reservoir computing (RC) is a paradigm that harnesses untrained dynamical systems (most commonly recurrent neural networks) for computation [7, 11]. Basic components of RC are the input layer, the reservoir and the readout layer. The input layer applies a time-dependent input signal $\boldsymbol{u}(t)$ via a fixed weight matrix $\boldsymbol{W}^{\text{in}}$ to the reservoir. Reservoir nodes (artificial neurons) perform nonlinear computation in order to create a higher-dimensional representation of the applied input signal. Reservoir nodes are connected internally through a random (untrained) weight matrix $\boldsymbol{W}^{\text{res}}$ that implements recurrent loops allowing input data to persist within the reservoir and therefore creating a short-term memory. Each node of the time-dependent reservoir state $\boldsymbol{x}(t)$ evolves according to:

$$x_i(t+1) = f_i\big(\boldsymbol{W}_i^{\text{res}} \cdot \boldsymbol{x}(t) + \boldsymbol{W}_i^{\text{in}} \cdot \boldsymbol{u}(t)\big), \tag{2.5}$$

where $\boldsymbol{W}_i^{\text{res}}$ and $\boldsymbol{W}_i^{\text{in}}$ are the ith row vectors of the reservoir weight matrix and the input weight matrix, respectively. f_i is the activation function of node i. The output signal $\boldsymbol{y}(t)$ of the system is derived by the readout layer through a linear combination of the reservoir states.

$$\boldsymbol{y}(t) = \boldsymbol{W}^{\text{out}} \cdot \boldsymbol{x}(t) \tag{2.6}$$

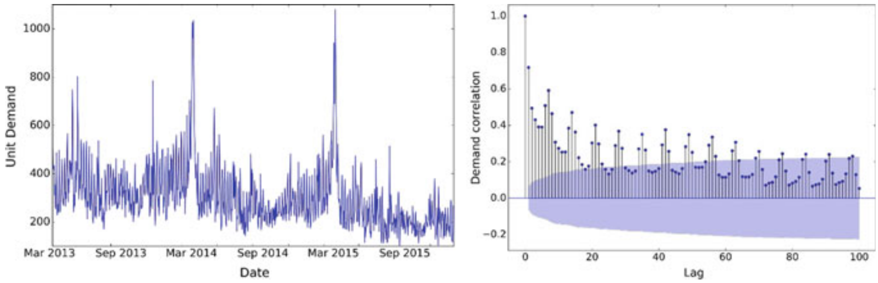
Assuming good generalization properties of random projections within the reservoir, learning takes place by adjusting the output weight matrix $\boldsymbol{W}^{\text{out}}$ only. This reduces the training complexity of recurrent neural networks to the output matrix, which is commonly done by using simple regression techniques. In general, the recurrent structure of the reservoir represents a dynamical model that creates features from the time-series data applied to it. RC has already found widespread application for various types of time-series problems such as speech recognition [16], motor control [12] and forecasting problems [2], to name just a few.

2.2.4 Dataset

Regardless of the forecasting method, the obtainable accuracy will strongly depend on the dynamics and the complexity of the dataset. In the literature, it is a common practice to use simple data with evident patterns (either in trend or seasonality), when trying to explain the dynamics involved for each method as it has been shown by Hyndman and Athanasopoulos [6]. Given the periodic properties of ARIMA (seasonal) and ES, the accuracy with simple data is expected to be high. However, when dealing with complex data, the ability of static mathematical models to achieve accurate forecasting is questionable. As the aim of this study is to compare traditional and dynamic forecasting methods for real-world applications, a dataset of a real company containing rich (consecutive) data with non-evident patterns will be used.

The dataset corresponds to sales of one of the largest Russian software firms *1C Company*, which was used for the kaggle course *How to win a data science competition*. This dataset presents daily historical demand data from January 2013 to October 2015 with relevant data fields of shop ID, item ID, item price, date and number of products sold (per day). As the kaggle challenge is aimed to forecast future sales for each shop, the data will be preprocessed so that the aggregate demand for each shop is obtained.

In Fig. 2.1a, we can see the aggregate demand for the shop with the most data samples (shop 31). The shown data highlights that the demand function is composed of various dynamics with shorter- and longer-range periodic behaviour. Through an autocorrelation plot (Fig. 2.1b), we can derive that the data contains a trend, indicated by a decrease on the correlation values, and seasonality, indicated by the presence of wave-like shapes. Peaks every 7 lags suggest that there are strong weekly patterns. Additionally, through STL decomposition, we also determined that data contains random fluctuations that will compromise the ability to perfectly predict future demand.



(a) *Aggregate Demand* (b) *Autocorrelation Plot*

Fig. 2.1 **a** Aggregate demand: shop with most samples (shop 31), **b** autocorrelation plot: with confidence interval of 95% (shaded area), as lags increase, the overall correlation values decrease, on a wave-shaped form, related to trend and seasonality

2.3 Results

The overall forecasting accuracy of each method will be evaluated based on results obtained for the aggregate demand of each shop. This requires each forecasting method to be parameterized as to generalize over the set of independent product demand functions of each shop. We parameterized ES with two values. The periodicity m commonly refers to the number of seasons within a given time series. While the used dataset clearly showed various temporal fluctuations in mean and standard deviation, no clear seasonality could be determined. We therefore empirically determined m to be 7. This corresponds to the autocorrelation plot (Fig. 2.1b), which shows weekly patterns to be the most dominant. Likewise, as the data exhibits various seasonalities, we empirically determined the seasonal adjustment method to be additive [6]. As most of the shops share similar temporal characteristics, the mentioned parameters were used for all shops. The parameters P, D and Q for ARIMA were obtained through grid search and corresponding minimization of the Akaike's information criterion (AIC) [6]. It was determined that for most sequences, the parameters were in the range $[0, 2]$. The periodicity m used to determine the seasonal component was set in accordance to what was determined for ES. The parameters influencing the predictive capabilities of RC are the number of artificial neurons (N), input scaling (β), spectral radius (λ), average in-degree (k) and reservoir output nodes (N_{out}). N defines the reservoir's theoretical memory and computational capacity, β determines the level of nonlinearity that is exploited within the network, λ sets the length of the fading memory, k determines the number of incoming connections to each neuron in the reservoir, and N_{out} defines the number of randomly selected nodes passed from the reservoir to the readout layer. Table 2.1 summarizes the parameters used for all methods. All experiments where conducted in a Python environment using the modules *stats models* [13] for the conventional forecasting methods and *Oger* [17] for reservoir computing.

Table 2.1 Parameters used for each forecasting method

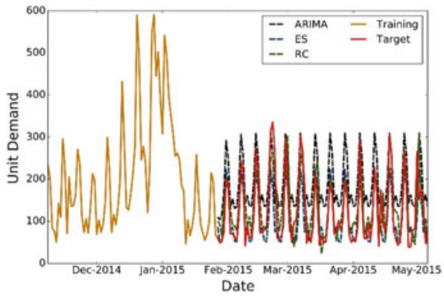
ES		ARIMA							RC				
Type	m	p	d	q	P	D	Q	m	N	β	λ	N_{out}	K
Additive	7	0–2	0	1	0–2	1	1	7	500	0.05	0.95	50	15

Error evaluation was done for all methods using normalized root-mean-square error (NRMSE) between the forecasted and the actual data. Normalization is done by dividing the RMSE by the target signal's standard deviation (STD). Considering that STD is sensitive for sequences of small sample size, we define a minimum sample length n of 100. This value also corresponds closely to quarterly planning cycles often found in industry. We then performed forecasting for all shops and calculated the individual NRMSE for each one. As RC initializes the neural network with random connectivity, we can expect some fluctuations in the RC results. In order to quantify the stochastic impact of connectivity on RC results, we performed each experiment 10 times with different reservoir initialization. The reported results for RC are therefore the mean and STD over the repeated experiments. Forecasting accuracy was evaluated for four different horizons. We define the forecasting horizon as the number of days we predict into the future (with respect to the autocorrelation plot, the horizon corresponds to the lag value). Table 2.2 shows the results obtained considering four different horizons.

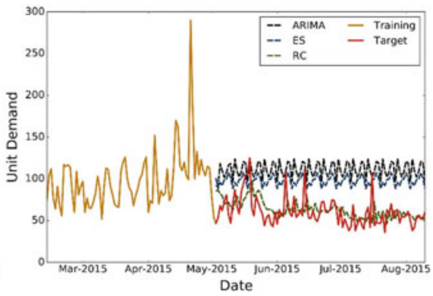
From the results in Table 2.2, it can be observed that conventional methods do not exhibit a significant change as the horizon increases. This is due to the fact that these models fit parameters directly onto the training signal and not to a relation between a training and a target that is a shifted training signal. On the contrary, RC is more sensitive to an increase in the horizon as can be observed from increasing errors. This sensitivity is the result of the readout layer of RC trying to fit the dynamic, input-driven reservoir state to a target output function with a shifted horizon. As can be seen from Fig. 2.1b, with increasing horizon (lag), the autocorrelation decreases. This implies that with longer horizons, more uncertainty is added to the relation between the reservoir state and the target output. Nonetheless, for up to 14-day horizon, autocorrelation was still significant and allowed RC to outperform the conventional methods. While the advantage of RC over the conventional methods (measured through mean and max results) slightly reduces with increasing horizon, it is noteworthy that it maintained significant smaller standard deviations. Especially if forecasting is bound to, i.e., large investments in resources and/or production capac-

Table 2.2 Forecasting results

Horizon	1				2			
	Min	Max	Mean	STD	Min	Max	Mean	STD
ES	**0.58**	2.57	1.15	0.33	**0.61**	2.76	1.17	0.35
ARIMA	0.83	3.16	1.23	0.39	0.84	3.17	1.24	0.40
RC	0.61 (0.01)	**1.48** (0.14)	**1.03** (0.01)	**0.14** (0.01)	0.68 (0.02)	**1.48** (0.12)	**1.07** (0.1)	**0.14** (0.01)
Horizon	7				14			
ES	**0.62**	2.79	1.18	0.36	**0.65**	3.03	1.21	0.39
ARIMA	0.83	3.19	1.27	0.41	0.86	3.28	1.33	0.44
RC	0.69 (0.02)	**1.59** (0.07)	**1.11** (0.01)	**0.16** (0.01)	0.75 (0.02)	**1.89** (0.06)	**1.18** (0.02)	**0.22** (0.01)



(a) *Case minimum error for ES*



(b) *Case Regime shift*

Fig. 2.2 **a** Case minimum error for ES: with horizon 1, error of 0.58 for ES, 0.68 for RC and 0.98 for ARIMA, **b** case regime shift: with horizon 1, error of 0.99 for RC, 2.40 for ES and 3.15 for ARIMA

ities, low STD reduces operational risks. This suggests that input-driven dynamical systems, such as RC, are more responsive to sudden fluctuations or regime shifts within the demand function.

In Fig. 2.2, we present two scenarios that help us to better qualify the functional differences between the three methods. The first scenario represents the case where ES achieved the best results across all methods (Fig. 2.2a). The data for this example presented a continuous pattern until mid-December 2014 after which we could observe a temporary increase in demand. Mid-January the demand returned to its previous pattern. The ES approach, by fitting its parameters over the full length of the training data, showed little sensitivity to the short-term demand fluctuations and approximated the test signal accurately. On the contrary, the ARIMA model, by giving higher priority to more recent data and by evaluating shorter sequences, was affected more strongly by the temporary demand fluctuations. The RC approach, similarly to ES, was not affected by the fluctuations and predicted accurately as well, which is confirmed by the qualitative analysis of the match between target and RC output signals.

The second scenario represents a regime shift with resulting significant prediction errors for ES and ARIMA (Fig. 2.2b). In this example, with the beginning of May 2015 (which coincided with the beginning of the test signal), we could observe a lasting change in demand pattern indicated by a different mean and standard deviation of the signal. While ES and ARIMA are not input-driven models, they were completely unaware of the regime shift and continued to predict according to the demand function of the training signal. On the contrary, the RC adapted to the regime shift. While it could not perfectly capture the dynamics of this new demand pattern, it could approximate overall trend and scale of the demand to the benefit of forecasting accuracy.

2.4 Conclusion

In this work, we have shown that forecasting accuracy on sets of time series with conventional and dynamic methods greatly depends on the complexity of the presented data. When time-series data can be sufficiently characterized by a single or a few dominant patterns, conventional methods and RC achieve comparable forecasting results. For demand patterns with more complex behaviour, such as temporal fluctuations or sudden regime shifts, conventional methods fail to accurately forecast due to their static nature. To reduce the overall forecasting error of the conventional methods would require parameter tuning for each individual time series as well as constant re-training as to alleviate the effects of fluctuations or regime shifts. In contrast, RC as a dynamical system poses a forecasting framework that (a) can achieve lower errors (with significant lower standard deviation), (b) utilizes a general set of parameters over a range of time series and (c) is able to more accurately predict temporal fluctuations and can adjust to changing demand patterns (regime shifts). Therefore, conventional mathematical methods create static fits to the actual demand signal, assuming constant repetition of the same pattern. This is similar to the concept of overfitting of neural networks. RC, on the other hand, is not directly learning the input signal, but the relation between a random projection of that signal into a feature space and a target output. It harnesses generalization properties of random projections and memory of the recurrent network structure in order to learn dynamic relations rather than static sequences. We can therefore conclude that for most complex (real-world) demand functions dynamical models are preferable as they can more accurately and reliable capture demand dynamics.

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Chapter 3
Quality of Service Evaluation of a University Library Using Text Mining and Kohonen Self-organizing Maps

Anderson Guilherme de Freitas Rodrigues, Jose Alfredo Ferreira Costa and Sanderson Santos Azevedo da Silva

Abstract Artificial neural networks were used to segment users from their responses to a questionnaire, which explored their perceptions/expectations in some dimensions of the library, as well as praise/criticism. Made that, text mining was applied at segmentation in order to identify the main shortcomings of the service offered by the entity.

Keywords Clustering · Text mining · Quality

3.1 Introduction

One of the main goals of who offer a service is trying to pleasure the consumer under its quality. However, this purpose is increasingly more difficult once the term "quality" has myriad of meanings in different conditions and environments [12].

Kotler et al. [6] introduce satisfaction as being the feeling of pleasure or disappointment resulting from the comparison of performance expected by the product in relation to the expectations of the person. Already for Gupta [5], for example, satisfaction is not defined only momentarily but results from the experience of consumption of a product or service while using it.

In that way, Parasuraman et al. [9] developed the SERVQUAL, which is a tool that try to measure the quality of offered services, quantitatively, establishing the

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difference between two visions: the client's perception and expectation of any service [10].

In the point of view of current management, appreciating and understanding the client are the keys to survive at the business world [4]. Thus, beyond trying to measure the quality of services, another crucial point to the institution is to segment your clients in order to explore some specifics characteristics. Once segmented, the institute can plot business profiles and create marketing specifics strategies for each profile found in order to better serve them [1].

In this point of view, artificial neural networks (ANNs) were used to segment users of a university library in order to detect different groups of users based on their answers to a questionnaire based on SERVQUAL scale and, after this, text mining was used to detect the main service shortcomings for each group found by artificial neural networks.

Although many researches have been conducted applying SERVQUAL to service quality evaluation [7], the joint application of this method with the use of self-organizing maps (SOM) was found in a few cases [3, 8]. In the environment of an academic library, the authors of this research did not find any joint application of SERVQUAL and SOM to measure the service quality and do the segmentation of users applying text mining.

Thus, the present study shows itself to be innovative in joining an important instrument of quality measurement, SERVQUAL, with an advanced data clustering technique, the Kohonen's SOM, and text mining. In addition, this study shows that it is relevant to apply this innovative methodology to an environment common to thousands of people, being present in almost any university, the academic library.

The object of the study was the library of the Federal University of Rio Grande do Norte (UFRN), which is called BCZM. The BCZM has nowadays two individual study rooms, seven group study rooms, besides one hundred and thirty-three (133) tables and four hundred and fifty-one (451) seats for group study.

3.2 Methodology

To obtain the data used at this research, a questionnaire based on SERVQUAL scale was developed and applied electronically in order to detect different profiles of users. The period of collection occurred from September 6, 2017, to September, 30, 2017. Some questions were adapted from the model created by Zeithaml et al. [14] to the current reality of the library. According to Carman [2], it has long been agreed that for the application of SERVQUAL in some service contexts, adaptations are necessary, excluding or adding new issues.

The questionnaire had 22 questions proposed by the SERVQUAL scale, which were adapted to the local reality. For each question, the respondent could mark values from 1 to 9, both for perception and expectation, being 1 few important and 9 very important, analogous to Likert scale. In addition, at the end of the questionnaire, the user could send praises and criticisms about the library quality services. Table 3.1

Table 3.1 SERVQUAL'S inquires used in questionnaire

Question	Assertive
1	Adequate and updated collection
2	Physical installations visibly adequate
3	Silent space for individual study
4	Community space for group study
5	Print and copy facilities available to the user
6	Employees with good professional appearance (dressing, cleaning, and posture)
7	Helpful and polite staffs
8	Availability of information materials (books, periodicals, etc.) listed in the library catalog
9	Website that allows the user to easily locate information (clear and friendly interface)
10	Provision of services as promised (quality, time, etc.)
11	Employees who readily meet user demands
12	Employees who are willing to help the user
13	Ease of finding informational materials (books, periodicals, etc.) on the shelves
14	Employees who have the knowledge and skills necessary to meet user demands
15	Employees who know the collection well
16	Tools that allow the user to find information on their own (digital repositories, application, catalog, etc.)
17	Employees who show confidence (security) to the user
18	Employees who understand user needs
19	Availability of computers with Internet
20	Convenient operating hours
21	Electronic resources (books, periodicals, etc.) accessible from home or work
22	Meeting user accessibility needs (ramps, platforms, etc.)

shows the 22 explored inquires at the questionnaire.

After the questionnaire was applied, which 824 people answered it, ANN (self-organizing maps) was used to segment the users. Three groups were found after this clustering to both areas: perceptions and expectations. The software which applied the ANNs is called Viscovery SOMine [13].

The clustering was made for the users' answers given to the expectation field and to the perception field, generating two SOMs. Made this, the SOMs founded were crossed between itself to generate four clusters classified by people which had: high expectation (HE) and low perception (LP); high expectation and high perception (HP); low expectation (LE) and low perception; low expectation and high perception, creating, therefore, four groups profiles for users of the library.

Finally, after the segmentation and the creation of the users profiles, text mining was applied in each one of these four groups at criticism and praises to detect the main services shortcomings for them, and, so, making possible to the library manager improve the service quality of the library creating specifics strategies to the entity operation.

To prepare the fields of criticism and praise, there was a preprocessing of the texts. The first step was to insert the "stop-words" and withdraw the pronouns, prepositions, articles, and conjunctions of the data, which are words that mean nothing to the text mining analysis. After these steps, all the words were passed for lowercase, to avoid the differentiation of the same words just because one letter of one of them was in uppercase.

After this, all the numbers and punctuation were excluded of the database. Besides that, the value TF-IDF was applied in the analysis. Finally, the k-means algorithm was used to segment the words for each group: HE and LP; HE and HP; LE and LP; LE and HP. Then, the word clouds were created with the twenty more significantly words. All these steps were made in R language.

3.3 Results

The two maps generated when Kohonen's SOM was applied in the expectation and perception fields were the following (Figs. 3.1 and 3.2).

To create the users profiles, the yellow clusters were excluded because they were the database outliers, probably people who answered the questionnaire without seriousness. So, the maps were crossed in order to create four users profiles (Fig. 3.3).

From this intersection, as already mentioned, it is possible to organize the groups into four profiles, as Fig. 3.4 shows. The name given for each group was inspired at the graphic "importance × performance," proposed by Slack et al. [11].

In front of this intersection, a new visual representation emerges with the characteristics to be more presentable and easiest comprehensible to the library manager. Table 3.2 shows the number of people of each group, beyond the outliers excluded.

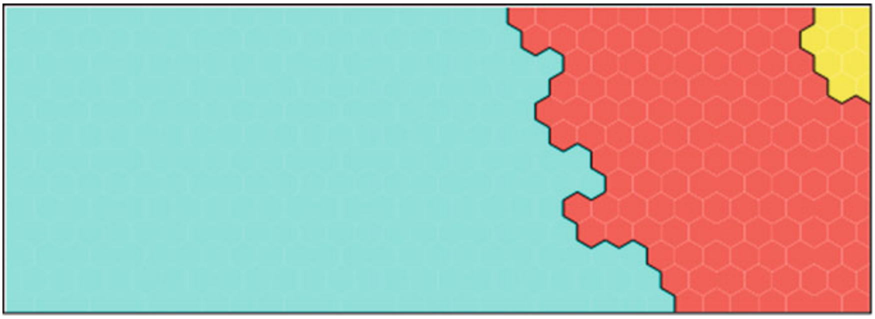

Fig. 3.1 Kohonen's SOM of expectations

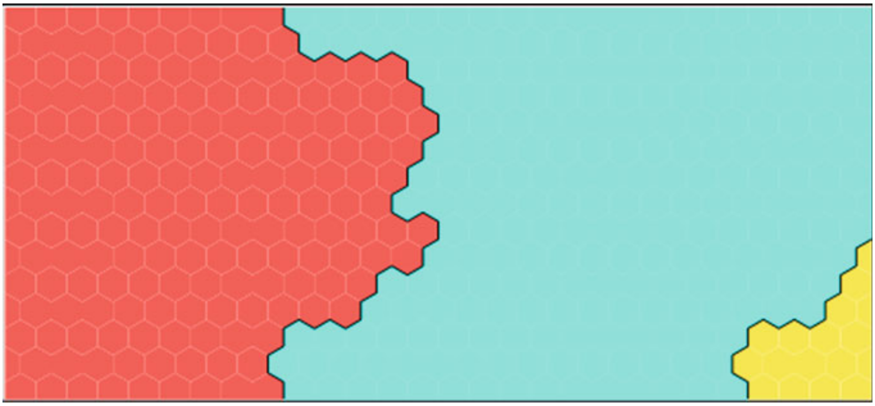

Fig. 3.2 Kohonen's SOM of perceptions

Fig. 3.3 Kohonen's SOM crossing

Text mining was applied at people replies of each group at the praises and criticism fields in order to find the main shortcomings services for each one.

Once the questionnaire was in Portuguese, the results will be shown with the original terms and after the main terms found will be evidenced in English. The text mining results are shown below.

Table 3.3 shows the main words and terms in English for each group. These terms come from Figs. 3.5, 3.6, 3.7, and 3.8 and are shown below sequenced according to the most relevant for analysis.

Analyzing the words above, it can be inferred that one of the main shortcomings of the library is its temperature, once the terms like "conditioning" and "hot" appear in all fields of criticisms of all groups. The term "noise" appears twice, which can be deduce that many people feel the library noisy.

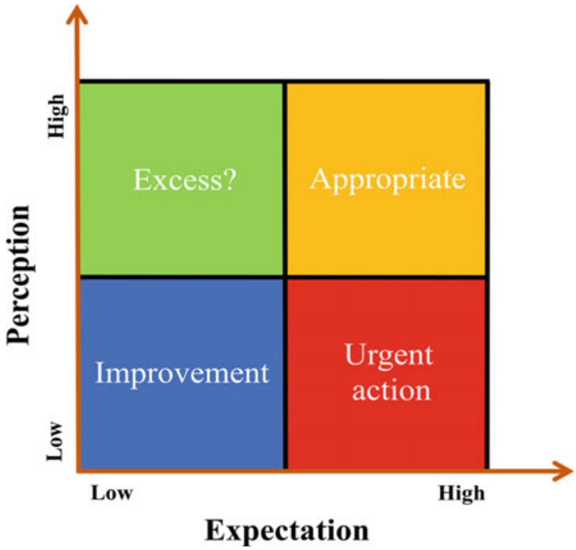

Fig. 3.4 Expectation versus perception graph

Table 3.2 Number and data about respondents

Category	Respondents	Percentage (%)	Quantity of praises (%)	Quantity of criticisms (%)
Excess	49	6	51	49
Appropriate	332	40	46	40
Improvement	109	13	41	52
Urgent action	281	34	46	50
Outliers	53	7	–	–
Total	824	100	–	–

Another lacks and shortcomings in the library's services can be detected just looking at the words, for example, canteen, rooms, spaces, and collection, among others.

3.4 Conclusion

In view of the results, it is possible to detect the main shortcomings of the library by the criticisms found by text mining as well the main praised items. It is interesting to realize that it does not matter what group it is being analyzed, but it will present criticisms and praises. This can be checked in the "excess" group, which, even having a high perception about the SERVQUAL's inquiries, nevertheless had suggestions and praises about the library services.

Table 3.3 Main translated terms resultants from text mining for each group

Main terms found							
Excess		Appropriate		Improvement		Urgent action	
Praises	**Criticisms**	**Praises**	**Criticisms**	**Praises**	**Criticisms**	**Praises**	**Criticisms**
Great	Conditioning	Big	Hot	Employees	Spaces	Excellent	Study
Ample	Office hours	Collection	Find	Helpful	Insufficient	Employees	Rooms
Welcoming	Saturdays	Tables	Book	Organized	Material	Environment	Hot
Services	Places	Clean	Difficulty	Collection	Catalog	Structure	Old
Library	Help	Attendance	Noise	Materials	Acquisition	Physical	Collection
Space	Studies	Installations	Canteen	Great	Purchase	Organization	Noise
Satisfaction	Cold	Silent	Site	Friendly	Book	Attendance	Study tables
Polite	Editions	Accessibility	Rooms	Updated	Bags	Variety	Books localization
Environment	Books	Climatized	Mold	Study	System	Services	Climatization
Books	–	Comfortable	Vacancies	Books	Conditioning	Working time	Individual areas
Study	–	Group	Tables	Team	Sigaa	Space	Spaces

Praise Criticism

Fig. 3.5 Text mining for excess cluster

To reach these results, this work presented as a solution a model that uses the SERVQUAL instrument to evaluate the quality of services, adopting together Kohonen maps, or self-organizing maps (SOM), as a tool for data clustering. In addition to the merging of SERVQUAL with the Kohonen maps in a joint analysis, this work also brought the text mining analysis applied to clustered data, separating and identifying the main deficiencies for each specific group found allowing the manager to create metrics marketing and strategic planning for future library expansions.

Fig. 3.6 Text mining for appropriate cluster

Fig. 3.7 Text mining for Improvement cluster

Fig. 3.8 Text mining for urgent action cluster

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Chapter 4
Data Analytics for the Selection of Wind Turbine Power Curve Models

Gabriel Almeida Hammes, Paula Medina Maçaira and Fernando Luiz Cyrino Oliveira

Abstract Once energy is a social good, this study proposes a methodology to select the most appropriate wind turbine power curve models for Brazilian wind farms. To do so, we compare our proposal with the observed values in a monthly and annual base.

Keywords Wind power · Power curve · Renewable energy

4.1 Introduction

Brazil is a country known for its abundance in water and, therefore, hydroelectric power stations are the largest and main source of electricity generation. However, in the last decade, wind power plants have played an important role in the Brazilian energy matrix, growing rapidly and increasing from 1 TWh, produced in 2010, to a significant 42 TWh in 2017. According to an estimative made by National Electric Energy Agency [1], in 2018, approximately 8% of all electricity generated by the country will came from wind farms and, in comparison with other energy sources, is the one with the largest investment for the construction of new projects, adding around 4.6 GW of installed capacity in the medium term.

As it is a country with continental dimensions, the Brazilian electricity sector is divided into four submarkets, interconnected, corresponding to the geographic regions of the country: North, Northeast, South and Southeast/Midwest. Figure 4.1 shows the concentration of 80% of wind farms in the Northeast, a consequence of the presence of strong winds in the region, in contrast to what happens in the

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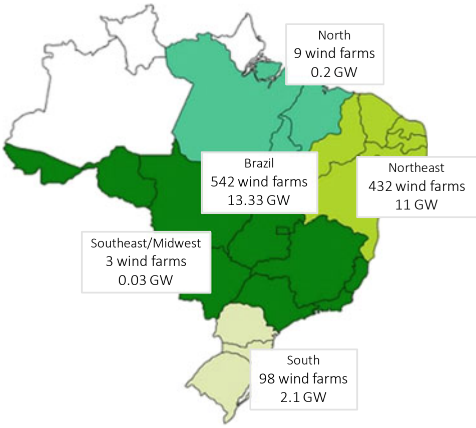

Subsystem	Under Construction		Construction Not Started	
	Units	Installed Power (GW)	Units	Installed Power (GW)
Northeast	103	2,26	104	2,49
Southeast/Midwest	0	0,00	0	0,00
South	3	0,05	2	0,03
North	4	0,10	0	0,00
Total	110	2,41	106	2,52

Fig. 4.1 Location of wind farms in Brazil. *Source* ONS [2, 3]

Southeast/Midwest, which has only 0.55% of the projects. Most of the plants already under construction or planned for construction are also located in the Northeast, totaling 207 new ventures in the region and 216 in Brazil. As expected, the plant with the largest installed capacity, in operation, in Brazil is also located in the Northeast region, in the city of Camocim, Ceará, and is called Praia Formosa.

Wind energy is produced from the force of the winds and so is susceptible to the volatility characteristic of a natural phenomenon [4]. To make wind power a reliable source, accurate models are needed to predict power generation and monitor the performance of wind turbines. The theoretical power captured by a wind turbine (Eq. 4.1) is given by an equation that depends on many parameters, such as: velocity (v) of wind, air density (ρ), power coefficient (C_p), and rotor area (A) of the turbine, making the resulting power evaluation a process extremely complex.

$$P = \frac{1}{2} \times C_p \times \rho \times A \times v^3 \tag{4.1}$$

A convenient way to obtain the resultant power output of a given wind turbine is through its power curve, which relates the resulting power of the turbine to specific wind speed, as shown in Fig. 4.2. Turbine manufacturers provide the power curves in tabular or graphic form. However, a generic equation that accurately represents this curve is needed in many problems involving wind power. The work of Mathew [5] and Kusiak et al. [6] identified that the proper selection of power curve models is essential for predicting power and online monitoring of turbines accurately. Such models can be classified as discrete, deterministic/probabilistic, parametric/non-parametric, and stochastic. In Gupta et al. [7], a literature review present the existing methodologies for the approximation of the power curve and the advantages and disadvantages involved in each one.

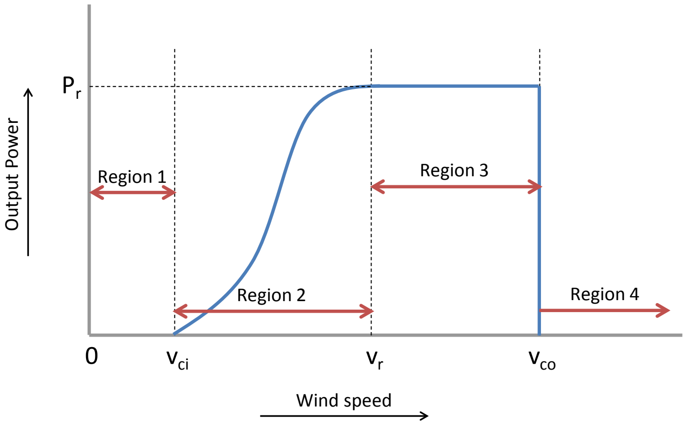

Fig. 4.2 Typical power curve. *Source* Gupta et al. [7]

Regardless of the methodology, the main goal is to adjust Region 2 as closely as possible (Fig. 4.2). This region comprises the wind speed range where the power starts (v_{ci}) to be generated until reaching the speed at which from that point (v_r) any velocity generates the same power.

In order to obtain accurate models for the modeling and prediction of the Brazilian wind generation series, this study develops, from the so-called parametric methods, a methodology that allows the selection of the best approximation of the power curve of a specific power plant when comparing the theoretical generation obtained by the approximation and the observed real generation. This paper is organized as follows: Sect. 4.2 explains the proposed methodology and the necessary mathematical details; Sect. 4.3 presents the case study with results and, finally, in Sect. 4.4, the work is concluded with the suggestion of continuation.

4.2 Methodology

A parametric model defines the relationship between input and output through a set of mathematical equations with a finite number of parameters. The parametric model of the power curve of wind turbine can be expressed as in Eq. (4.2).

$$P = \begin{cases} 0 & v\langle v_{ci}, v\rangle v_{co} \\ q(v) & v_{ci} < v < v_r \\ P_r & v_r \le v \le v_{co} \end{cases} \tag{4.2}$$

where, v_{ci} is the initial velocity at which wind power begins to be generated,v_r is the cut velocity delimiting that from that point to the final speed v_{co} the power generated will be the same and equal to the rated power P_r of the turbine. For any speed less

Table 4.1 Equations for estimated power calculation

Linear	$q(v) = \left(\frac{v - v_{ci}}{v_r - v_{ci}}\right) P_r$	(4.3)
Quadratic	$q(v) = \left(\frac{v^2 - v_{ci}^2}{v_r^2 - v_{ci}^2}\right) P_r$	(4.4)
Cubic	$q(v) = \left(\frac{v^3}{v_r^3 - v_{ci}^3} - \frac{v_{ci}^3}{v_r^3 - v_{ci}^3}\right) P_r$	(4.5)
Annual Weibull	$q(v) = \left(\frac{v_{ci}^k}{v_{ci}^k - v_r^k} + \frac{v^k}{v_{co}^k - v_{ci}^k}\right) P_r$	(4.6)
Monthly Weibull	$q(v) = \left(\frac{v_{ci}^{km}}{v_{ci}^{km} - v_r^{km}} + \frac{v^{km}}{v_{co}^{km} - v_{ci}^{km}}\right) P_r$	(4.7)

than the initial speed v_{ci} and greater than the final velocity v_{co}, there is no power generated.

The relation between the resulting power and the wind speed between the initial velocity (v_{ci}) and the cutting speed (v_r) is nonlinear, as can be seen in Region 2 (Fig. 4.2) and is represented by $q(v)$ in Eq. (4.2). However, this relation can be approximated by different functions, polynomial or not.

The simplest approach found in the literature is through the linear function, which describes Region 2 as a straight line connecting the initial velocity and cutting speed points (Eq. 4.3) [8]. The quadratic model uses a function of degree 2 (Eq. 4.4) and the cubic model uses a function of degree 3 (Eq. 4.5) [9, 10]. There is also a methodology based on the parameter of shape (k) of Weibull (Eq. 4.6) [11, 12] (Table 4.1).

The parameter k of the annual Weibull model is obtained by adjusting the maximum likelihood of the Weibull distribution function to the wind speed data. The monthly Weibull we have that the parameter k is recalculated based on the information of each month. The tabular are the expected powers provided by the turbine manufacturer.

The root mean squared error (RMSE) error metric, formulated in Eq. (4.8), was used to compare the expected power and the observed power.

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{t=1}^{n}\left(\hat{y}_t - y_t\right)^2}{n}} \tag{4.8}$$

where $\hat{y}_t$ is the power calculated from one of the approximations in the period t, y_t is the power observed in the t, where $t = 1, \ldots, n$ and n is the total number of observations.

4.3 Application

To validate the proposed methodology, ten wind farms from the Southern Region of Brazil were selected as a case study. The selection of these plants is due to the fact that it is possible to obtain technical information, such as the number of turbines observed, the operational data of each turbine (location, cut in speed and cut off, rated power) for a period of one year.

As seen in Sect. 4.2, some technical information about the turbines of the wind farm and also the wind speed in the location and the desired period are necessary to calculate the approximations of the power curves. From [13], the data about the turbines of Elebras Cidreira were obtained (Table 4.2).

To obtain the wind speed series on hourly basis for the period from 01/01/2016 to 31/12/2016 (61,224 values), the web page was used: *Research Data Archive—Computational and Information Systems Laboratory* [14].

Once a general methodology was developed to avoid repetition, the Elebras Cidreira plant was used, as an example, because it has the greater installed capacity.

The Elebras Cidreira wind farm is located at Latitude: 30° 8′ 24″ and Longitude: 50° 13′ 44.4″, but the closest locality with information history is at 8.70 km from the original location. In addition, the data are measured at 10 m high, while the turbines are at 108 m from the ground, and therefore a transformation of the type $V = \frac{\log(A_\mathrm{t})}{\log(A_\mathrm{m})} \times v$ [5] was applied, where A_m is the height of the measurement, A_t is the height of the turbine, and v is the speed in the original measurement.

In the image below, it is possible to visualize the differences between the estimated and observed power in the Elebras Cidreira plant for the cubic model that obtained the best RMSE results as it can be seen in Table 4.3. In Fig. 4.3, it is possible to visualize that the estimated values are in fact very close to the historical values of power generation. This shows the efficiency of the estimation methodology.

With the technical data of the turbine and the historical series of wind speed available, it was possible to obtain the expected power with each formulation: linear, quadratic, cubic, monthly, and annual Weibull and also from the curve table provided by the manufacturer. With the presence of a seasonal pattern in velocity data, it is interesting to allow the applied models to adapt to this type of change, however, the only model among the tested variables that allowed this variation was monthly Weibull because it sets a parameter for each month instead of a single for the whole year. Table 4.3 presents the RMSE results calculated by comparing the expected values through each model and the generation observed, obtained through the web page: ONS—Operation Results: Operation History, Power Generation [2].

Quadratic and cubic methodologies were the only ones that presented lower RMSE metrics. Although conceptually we expect a better result for the monthly Weibull, the presence of only one year of information was not enough to capture the monthly movement of the wind seasonality.

4.4 Conclusions

Due to the accelerated entry of wind energy into the Brazilian energy matrix, models that approximate turbine power curves and consequently, the actual generation of energy is extremely important. This job tested the application of five formulations:

Table 4.2 Wind turbine information

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Sangradouro 3	Enercon E82/2300	12	2300	2	14	25	108	−29.96	−50.32	2.03
Sangradouro 2	Enercon E82/2300	13	2300	2	14	25	108	−29.94	−50.31	2.03
Sangradouro	Enercon E82/2000	25	2000	2	13	25	108	−29.94	−50.31	2.03
Osório 3	Enercon E82/2000	13	2000	2	13	25	108	−29.98	−50.25	2.03
Osório 2	Enercon E82/2300	12	2300	2	14	25	108	−29.95	−50.25	2.03
Osório	Wobben E70/2000	25	2000	2	14	25	98	−29.97	−50.29	1.99
Indíos 3	Enercon E92/2350	10	2350	2	13	25	111.5	−32.19	−52.19	2.04
Indíos 2	Enercon E92/2350	13	2350	2	13	25	111.5	−32.19	−52.19	2.04
Indíos	Wobben E70/2000	25	2000	2	14	25	98	−30	−50.29	1.99
Elebras Cidreira	Enercon E82/2300	31	2300	2	14	25	108	−30.14	−50.23	2.03

(1) Model; (2) Quantity; (3) Rated Power (P_r); (4) Initial speed (v_{ci}); (5) Cut speed (v_r); (6) End speed (v_{co}); (7) Height; (8) Latitude; (9) Longitude; (10) Correction factor

Table 4.3 RMSE (GWh) for each methodology

	Linear	Quadratic	Cubic	Weibull (M)	Weibull (A)	Tabular
Sangradouro 3	0.137	**0.075**	0.081	0.078	0.079	0.091
Sangradouro 2	0.142	**0.088**	0.097	0.089	0.088	0.098
Sangradouro	0.308	0.160	**0.143**	0.176	0.186	0.216
Osório 3	0.137	**0.080**	0.081	0.084	0.085	0.097
Osório 2	0.142	**0.082**	0.086	0.086	0.086	0.101
Osório	0.280	0.138	**0.132**	0.150	0.156	0.169
Indíos 3	0.234	0.178	**0.165**	0.176	0.179	0.211
Indíos 2	0.313	0.239	**0.221**	0.233	0.241	0.283
Indíos	0.279	0.131	**0.124**	0.144	0.151	0.164
Elebras Cidreira	0.442	0.245	**0.219**	0.261	0.269	0.346

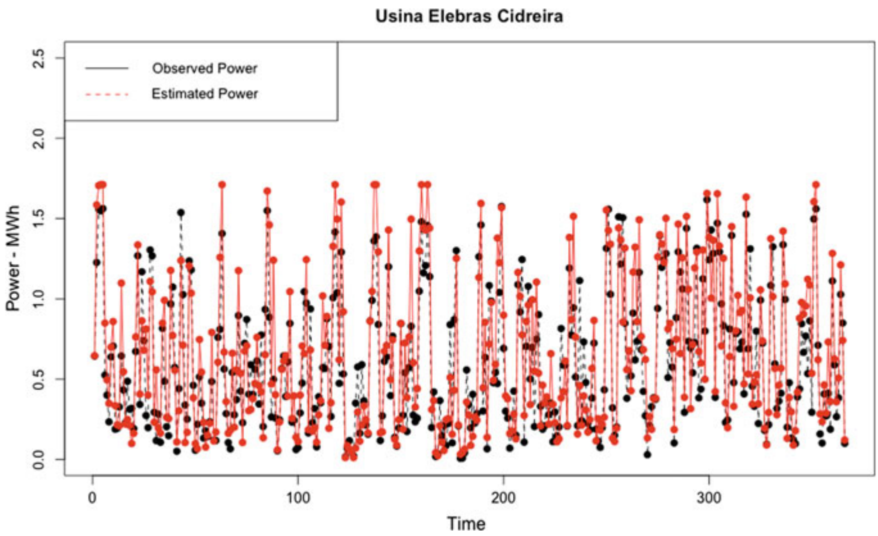

Fig. 4.3 Estimated versus observed power

Tabular, Linear, Quadratic, Cubic, and Weibull with the objective of developing a methodology to select through the root mean squared error metric the one that best replicates the observed power generation of a wind power plant.

To validate the developed methodology, the application involved ten wind farms in the southern region of the country, since it has the second-largest installed capacity in Brazil. In the context of the models tested, due to the flexibility of the Weibull formulation and the presence of a seasonal profile of the winds, it was expected that the monthly Weibull had the best results. However, since we had data of only one full year, it was not able to capture the seasonality of the data. The best methodologies for each plant were Cubic and Quadratic.

It is concluded that this work fulfilled its objectives of proposing a methodology for the selection of models of wind energy curve approximation for a given period of time. It is suggested as future work the extension of the application to other plants with a greater observable horizon and also the use of other forms of approximation.

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Chapter 5
Forecasting Electricity Generation of Small Hydropower Plants

Margarete Afonso de Sousa, Paula Medina Maçaira, Reinaldo Castro Souza, Fernando Luiz Cyrino Oliveira and Rodrigo Flora Calili

Abstract In order to ensure competitiveness in the market, electricity distribution companies must accurately estimate future electricity generation. To do so, this work uses time series models that correlate future inflow and past generation in space and time. The methodology proposed shows reduced errors and satisfactory predictability.

Keywords Forecasting · Electricity distribution · Time series

5.1 Introduction

Nowadays in Brazil, hydroelectric plants are responsible for about 70% of the energy produced; however, as a consequence of the generation variation throughout the year due to the low precipitation, other sources of electricity generation are necessary, such as thermoelectric and wind power to meet the demand [10].

The various energy sources comprise the national interconnected system (SIN), which is a system for the generation, and transmission of electric energy composed of hydroelectric, thermal, and wind power plants. Several studies are carried out by

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the National Electric System Operator (ONS) and for this purpose. In particular, medium to long-term forecasts are carried out for a five-year horizon, on a monthly base [10].

In recent years, the Ministry of Mines and Energy has encouraged the installation of small hydroelectric power plants (SHPs), which are hydroelectric plants that produce between 5 and 30 megawatts (MW), they do not require reservoirs for energy generation which have a low environmental impact. Today in Brazil there are 436 SHPs in operation and 683 CGHs (hydropower plants smaller than SHPs, producing between 0 and 5 MW), 192 SHPs and 93 CGHs are located in the state of Minas Gerais [1].

The electric generation forecasting for SHPs is a challenge for generation and distribution utilities due to the fact that inflow data are not always available, making hard for them to assert better estimates. There are also many variables that influence prediction such as maintenance schedule, capacity, and precipitation [6].

The objective of this work is to use time series models that correlate inflow data available at ONS from river basins located in Rio de Janeiro, Espírito Santo, and Minas Gerais states and the past generation to adjust and predict the electric power generation of five SHPs. The past generation data were provided by a company located in Minas Gerais that owns the SHPs concession analyzed. From this study, it will be possible to verify the model with reduced error and satisfactory predictability for replication in the others 27 SHPs from the energy company to help them to plan their operations and technical losses.

The five SHP time series were selected from 32 available, and it was considered their locations and their historic length. For each river basin from the company's concession area, one SHP was chosen with a different number of observations to have different cases to analyze the method application. Operation start date, river basin, capacity of electric power generation, and number of observations of each plant are shown in Table 5.1. All series have observations till December 2017.

Table 5.1 Small hydroelectric power plants considered

SHP	River basin	Operation start date	Capacity (MW)	Number of observations
Benjamim Batista	Rio Manhuaçu	Apr/01	9	201
Santa Cecília	Rio Bom Sucesso	Jan/99	0.28	264
Nova Usina Maurício	Rio Pinho	Jan/01	19.80	204
Limeira	Rio Fumaça	Out/12	1	63
Zé Tunin	Rio Pomba	Dez/12	8	61

To carry out this research, the inflow data of 34 hydroelectric plants from Rio de Janeiro, Espírito Santo, and Minas Gerais states, available in ONS [11], were analyzed. Figure 5.1 displays the hydroelectric location in blue bullets and the company's concession area in green.

A correlation study between the inflow (m^3/s) and generation (kWh) data was made for each SHP from Table 5.1 with all inflow series from the neighboring basins shown in Fig. 5.1 and the HPP selected are described in Table 5.2.

This work is organized into four sections. The first section is the introduction where the motivations of this study are presented, in Sect. 5.2 the methodology used to develop the study is presented, Sect. 5.3 presents the results of the work and discussions, and in Sect. 5.4 the final considerations.

Fig. 5.1 Localization of hydroelectric plants with inflow data available at ONS website. *Source* The authors

Table 5.2 Hydroelectric power plants selected

HPP	River basin	First observation date	Number of observations
Batalha	Rio São Marcos	Dec/11	73
Picada	Rio Peixe	Jan/06	144
Sobragi	Rio Paraibuna	Jul/00	210

5.2 Methodology

After initial research, some time series forecast studies were identified that used inflow data as well as the application of exogenous variables in their analyses.

Foley [3] studied the correlation between precipitation and generation of electric energy in five hydroelectric plants proving that there exists a correlation among them. Lima et al. [6] analyzed some Brazilian basins and presented a dynamic linear model for inflow forecasting using climate variables. These papers indicate that it is possible to forecast electric energy by using precipitation or inflow data as an exogenous variable. When talking about inflow series for SHP plants sometimes, these data are unavailable, so Lohmann et al. [7] proposed a space–time model for inflow forecasting and carried on a case study with three Brazilian basins using, in some cases, data from neighboring basins. Maçaira et al. [9], through a systematic literature review, presented the state of the art of research involving exogenous variables and time series analysis, mainly in environmental sciences. Regression models were widely employed what justifies the choice of these models in this study.

In another paper, Maçaira et al. [8] present a study with exogenous variables, proposing a model named "Causal PAR(p)" to improve prediction of inflow series. The model uses El Niño and Sunspot variables for Brazilian reservoir. Huang et al. [4] study the relationship between climatic variables and natural inflow comparing methods of causality detection.

Then to attend the objective of this study, five methods have been applied: (1) seasonal average; (2) seasonal naïve method; (3) seasonal autoregressive integrated moving average—SARIMA; (4) linear regression; and (5) periodic regression and are presented as follow. Although methods 1 and 2 are simple, they could be very assertive; so they have been used as benchmarks to compare with SARIMA (without exogenous variable) and regression methods [5].

5.2.1 *Seasonal Average*

In this method, future values assume the historic month average, and it means that next forecast, for instance, for the next January, will be the average of all January. It can be written as:

$$Z^m_{t+h} = \frac{1}{T}\sum_{t=1}^{T} Z^m_t \tag{5.1}$$

where

Z^m_{t+h}—Forecast on period m, h lags ahead.
Z^m_t—Last observation of period m.
T—Number of observations of period m.

5.2.2 Seasonal Naïve Method

For this method, the next estimation assumes the last observation of the previous year for the same month. For example, the prediction of the next April will be equal to April from the previous year [5]. It can be written as:

$$Z_{T+h}^{m} = Z_{T}^{m} \tag{5.2}$$

where

Z_{t+h}^{m}—Forecast on period m, h-lags ahead.
Z_{t}^{m}—Last observation of period m.

5.2.3 Seasonal Autoregressive Integrated Moving Average—SARIMA

Autoregressive integrated moving average model (ARIMA) proposed by Box and Jenkins [2] is a univariate model using its history to forecast future for stationary or non-stationary series, and in this second case, a non-seasonal differencing will be applied. For series with a seasonal component, the multiplicative ARIMA model or SARIMA $(p, d, q)X(P, D, Q)$ is appropriated.

The multiplicative ARIMA can be defined as [13]:

$$\Phi\left(B^{S}\right) * \phi(B) * \nabla_{S}^{D} * \nabla^{d} Z_{t} = \Theta\left(B^{S}\right) * \theta(B) * a_{t} \tag{5.3}$$

where

$\Phi\left(B^{S}\right) = \left(1 - \Phi_{1} B^{S} - \cdots - \Phi_{P} B^{PS}\right)$, $\Phi_{i}, i = 1, 2, \ldots, P$—seasonal autoregressive operator.
$\phi(B) = \left(1 - \phi_{1} B - \cdots - \phi_{p} B^{p}\right)$, $\phi_{i}, i = 1, 2, \ldots, p$—non-seasonal autoregressive operator.
$\nabla_{S}^{D} = \left(1 - B^{S}\right)^{D}$, $D = 0, 1\, ou\, 2$ in most of the time—seasonal differencing operator.
$\nabla^{d} = (1 - B)^{d}$, $d = 0, 1\, ou\, 2$ in most of the time—non-seasonal differencing operator.
$\Theta\left(B^{S}\right) = \left(1 - \Theta_{1} B^{S} - \cdots - \Theta_{Q} B^{QS}\right)$, $\Theta_{i}, i = 1, 2, \ldots, Q$—seasonal moving average operator.
$\theta(B) = \left(1 - \theta_{1} B - \cdots - \theta_{q} B^{q}\right)$, $\theta_{i}, i = 1, 2, \ldots, q$—non-seasonal moving average operator.

Box and Jenkins methodology proposes the accomplishment of four steps: model identification, parameters estimation, verification, and finally forecasting.

5.2.4 Linear Regression

Sometimes an exogenous variable can explain the behavior of a time series of interest. When these variables have a linear relationship, the regression can be written as [5]:

$$Z_{T+h} = \beta_0 + \beta_1 X_{T+h} \tag{5.4}$$

where

Z_{T+h}—Explained or dependent variable h lags ahead.
X_{T+h}—Explanatory or independent variable h lags ahead.
β_0—Intercept.
β_1—Slope.

5.2.5 Periodic Regression

To improve accuracy in prediction, this method joins a periodic component. In this study, time series have a seasonal component, so a periodic regression can be useful. In this case, parameters will be estimated for each period m and forecast will considerate the estimation of the exogenous variable of the period.

$$Z_t^m = \beta_0^m + \beta_1^m X_t^m \tag{5.5}$$

where

Z_t^m—Explained or dependent variable on period m.
X_t^m—Explanatory or independent variable on period m.
β_0—Intercept.
β_1—Slope.

In order to check the out-of-sample results of all methods, the series were divided into training data and verification data. The year of 2017 was used to validate if the methods have satisfactory predictability. The software R was used to fit all models and to calculate results [12].

The mean absolute percentage error (MAPE) out of sample was used to compare the results. It can be written as:

$$\text{MAPE} = 100\frac{1}{N}\sum_{t=1}^{N}\left|\frac{y_t - f_t}{y_t}\right| \tag{5.6}$$

where y_t is the observation, f_t is the predicted value, and N is number of observations.

5.3 Results and Discussions

To apply the five methods described in Sect. 5.2, the inflow series that present greater correlation with generation series were used. In Table 5.3, it is possible to see the correlation results, and this metric shows that values near to 1 have a stronger positive correlation and near to zero has a weak positive correlation. Note that for these plants only *Santa Cecília* has a lower correlation. Another interesting point observed is that the inflow data from *Sobragi* located at *Paraibuna* River in Rio de Janeiro correlated with three SHPs. *Batalha* and *Picada* are located in Minas Gerais at *São Marcos* and *Peixe* Rivers, respectively.

The line's graphics in Fig. 5.2 shows power generation (blue line) and inflow data from ONS (red line). It is possible to see the behavior of the two series. The

Table 5.3 Correlation between inflow and generation

SHP	Correlation	HPP
Santa Cecília	0.62	Batalha
Nova Usina Maurício	0.82	Sobragi
Benjamim Batista	0.85	Picada
Limeira	0.78	Sobragi
Zé Tunin	0.91	Sobragi

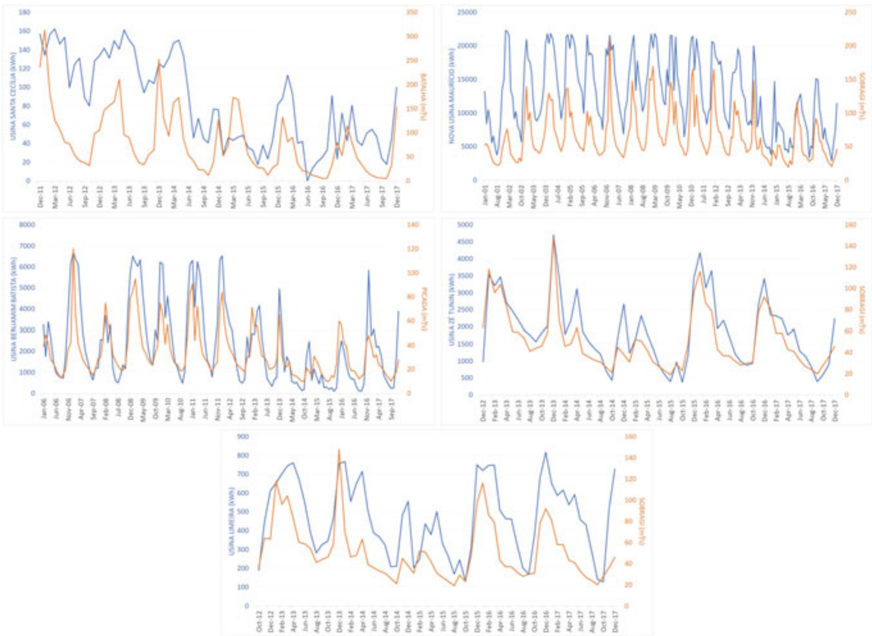

Fig. 5.2 Inflow and generation time series line's graphic. *Source* The authors

Table 5.4 MAPE out-of-sample comparation between methods

SHP	MAPE				
	Seasonal average (%)	Seasonal naïve (%)	SARIMA (%)	Linear regression (%)	Periodic regression (%)
Santa Cecília	99	61	49	64	70
Nova Usina Maurício	90	38	44	52	28
Benjamim Batista	81	47	59	48	26
Limeira	21	33	50	39	23
Zé Tunin	44	57	74	32	15

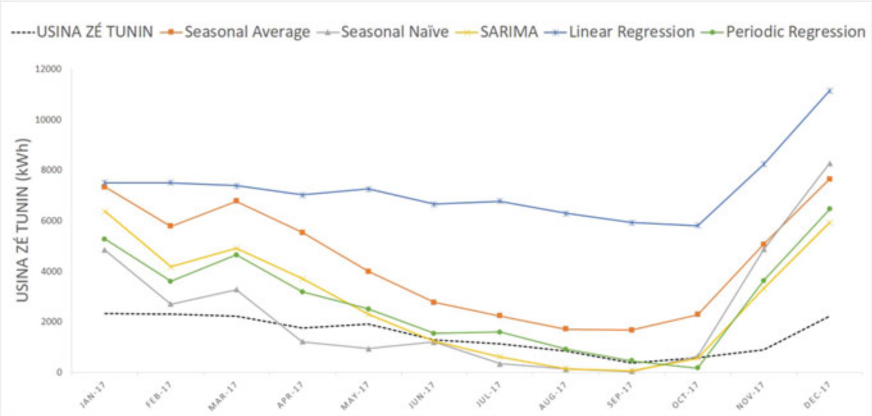

Fig. 5.3 Twelve lags ahead forecast to compare methods of Zé Tunin SHP. *Source* The authors

third graphic, for example, shows the generation of *Benjamim Batista* and inflow of *Picada* and their behavior are similar.

As it is possible to see in Fig. 5.2, during June/2016, the generation observed at *Santa Cecília* was zero kWh. That observation could be a maintenance period, but for this study, these outliers were not treated.

Table 5.4 presents the MAPE for each method. Note that the use of an exogenous variable with a periodic component improves the MAPE out of sample in three cases, only the two SHP with low correlation have a different result. For *Limeira,* the best result was the forecast with the seasonal average (MAPE—21%) followed by the results of periodic regression (MAPE—23%) that considers the exogenous variable. In the case of *Santa Cecília*, the errors were greater than 45%. The best method for this plant was SARIMA.

Zé Tunin presents the best correlation and the methods with exogenous variables fits better than traditional methods. Figure 5.3 presents 12 lags ahead forecast for all methods comparing with the observed values of 2017.

5.4 Final Considerations

Competitive companies need to improve their results, and they are always seeking methods that help achieve their goals. For energy companies, predictability is an important value in planning, and their operations depend on good forecasts to avoid losses. When they have distributed energy, an important issue is the prediction of technical losses and to do so they must forecast power generation to attend the energy market.

An important contribution of this research is the use of inflow data from hydroelectric plants located near a river basin when the inflow from an SHP is not available. By the correlation study, it is possible to find useful data to increase assertiveness in prediction.

In general, the periodic regression that considered the inflow data from a neighboring basin as an exogenous variable with a periodic component has the best result. For series with correlation inferior than 0.80, another method shows better results. That is the case of *Santa Cecília* with 0.62 correlation with SARIMA method and *Limeira* with 0.78 correlation and the best result are from the seasonal average.

One limitation of this study is due to the fact that the outliers were not treated. For instance, *Santa Cecília* in some months has some structural breaks (zero kWh), and these untreated breaks can affect forecast results. In this case, the use of dummies variables can explain periods of low generation although high inflow is observed and maybe maintenance periods.

Another approach to resolve low correlation problems between inflow and generation can be the use of precipitation as an exogenous variable.

For further studies, other approaches can also be tested, for example, dynamic regression or transfer function to understand how one variable can be affected the behavior of a time series of interest.

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Chapter 6
Evaluation of the Efficiency of the Solar Energy System of the Brazilian States

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Abstract This article aims to evaluate the hybrid efficiency of solar and electrical energy for all Brazilian states. This assessment required a financial and economic analysis. From this model, we used the network data envelopment analysis to identify the most efficient state and formulate improvements.

Keywords Network DEA · Solar energy · Economic analysis

6.1 Introduction

Despite the wealth of energy resources and the detention of regions favoring the implementation of renewable energy generation systems, Brazilian energy policy is still based on large hydroelectric plants. Although hydroelectricity constitutes a renewable source of energy, environmental and social impacts, and the costs of implantation, operation and maintenance are high. In this way, it is necessary to diversify and advance the generation of electricity in the country.

Considering the climatic factors, the potential for solar power installation is very promising. Considering the climatic factors, the potential for solar power installation is very promising. In this case, few days of rain throughout the year and great incidence of solar radiation characterize some regions as favorable, especially to the exploitation of this energy matrix and to the dissemination by adopting this type of energy to the population. Regarding geographic location, the closer to the equator, the greater the incidence of solar energy, which makes it even more attractive to invest in these areas.

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Though being strategic, the use of solar energy has been an alternative to supply the growing demand for consumption of the nation. Several Brazilian states have held small installations to capture solar energy, but the country is extensive and has different conditions for each region. For this reason, this article proposes to analyze the potential of transformation (of solar energy in electricity) for each state, determining the efficiency scores. After this analysis, the installation process will be analyzed considering factors intrinsic to the electrical sextor, thus constituting a hybrid evaluation.

We structured this study in five sections. The first, built here, was the introduction. The next one refers to the theoretical basis of the technique of efficiency analysis adopted in this research and the operation of residential systems of electric power generation through the solar source. In a third section, the method will be established to reach broadly the determined objectives. Subsequently, the results obtained with the use of this procedure will be exposed. Finally, the conclusion provides an overview of this study.

6.2 DEA, Network DEA and Solar Energy

Data envelopment analysis (DEA) is a nonparametric and deterministic technique that allows the evaluation of efficiency considering multiple inputs and outputs with different units. Charnes et al. [3] were able to develop the first procedure proposing a model that assumes constant returns of scale (CRS or CCR), where any variation in the inputs produces proportional variation in the outputs. Then, Banker et al. [2] developed a second model the so-called BCC that assumes variable returns to scale (VRS), that is, allows decision-making units (DMUs) that operate with low input values to have increasing returns to scale, whereas DMUs that are operating with high values may have decreasing returns of scale.

In the case of solar energy, we identified in the academic literature, more clearly, five main strands for DEA application: to evaluate the efficiency of already existing firms or energy power plants [5, 14, 18]; to determine the best geographic location for setting up solar plants [1, 16, 19]; to compare photovoltaic stations in different countries [4, 9]; to incorporate an impact analysis of environmental factors and conditions [8, 17]; to integrate other renewable sources in the analysis [6, 15].

Despite the flexibility of the model, classical DEA studies envision systems as a whole by measuring efficiency, ignoring the operation of individual processes within a system [11]. According to Färe and Grosskopf [7], the system is comparable to a black box, since the actual transformation process is not usually modeled explicitly. Kao and Hwang [13] point out that ignoring the operations of component processes can lead to misleading results. As a result, Färe and Grosskopf [7] proposed opening the black box and introduced the network DEA or “NDEA” model. NDEA measures system efficiency (overall efficiency) and efficiency of processes/stages, considering their interrelationships and identifying the causes of eventual efficiency gains.

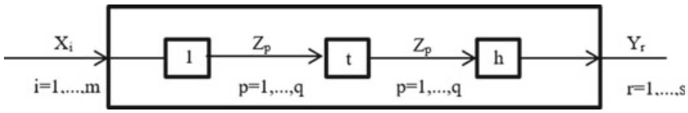

Fig. 6.1 Serial network structure

In NDEA, a variable can be output in one stage and input in another stage. This is because of the series relational model of Kao [11]; each step in the series has a structure composed of processes in sequence. In this model, system efficiency is the product of process efficiencies. Figure 6.1 presents a series structure, where the inputs x_i are provided for stage 1 to generate Z_p intermediate products, which will be entered for the next stage in order to produce the final outputs, y_r.

As warned by Kao [12], the NDEA is applicable in more complex situations, where the whole operation can be divided into more than one process. This occurs in a solar energy system, or grid-connected photovoltaic system (SFCR), composed of a set of equipment capable of transforming the Sun's energy into electricity by sending it to the electric grid. This system basically contains solar panels and interactive inverters.

The light energy is absorbed by the photovoltaic modules (plates) and converted into electrical energy in direct current that is transformed by the inverter of frequency in the alternating current, so that it can be used by the user again. This energy will be distributed by the inverter primarily to equipment that is in operation at the time of generation. Throughout the month, there will be days when the energy generated will be greater than that needed to supply the operation of the residence, generating energy credits, so if this generated energy is greater than the consumption, the surplus is injected into the electric grid of the distributor and accounted for by the residence energy meter. On other days, the consumption may be higher than the energy generated by the photovoltaic system, being necessary the capture of the energy through the concessionaire; in this case, the consumption is recorded in the meter as energy consumed.

Thus, each month, the distributor will check how much electricity was consumed from the grid and subtract from that amount the energy that was injected into the grid. The result of this subtraction will be the amount of energy that will have to be pay at the end of the month. If more energy is injected than consumed, the account will be reset and the injected energy surplus will be transformed into energy credits that can be discounted in the next energy bills for the 5-year period.

In an investment project in solar energy for own generation, the financial return is given through the savings resulting from the decrease in the volume of purchase of energy supplied by the concessionaire. With the return on investment obtained from installing solar energy, the cost reduction process is directly proportional to the amount of energy generated by the photovoltaic system. Energy inflation generated increase in price per kWh charged by the distributor over time.

6.3 Method

To carry out this study, we adopted four central steps: (a) bibliographic review, (b) data collection, (c) implementation of the modeling, (d) results of the efficiency and viability analysis. The bibliographic research is used for theoretical basis on the analysis of efficiency in solar energy and to foster a systematic analysis of the information about the production model, contributing to the understanding of the impact of larger investments in the sector.

The Brazilian Electricity Regulatory Agency (Agência Nacional de Energia Elétrica//ANEEL) seeks to encourage the generation of energy by renewable sources in Brazil, mainly for residences and trades, were used for the analysis only the residential roofs that can receive systems power generation photovoltaics. To develop the model, we used the data available by ANEEL, the Brazilian Institute of Geography and Statistics (IBGE) and the Energy Research Company (EPE).

The development of photovoltaic systems and the generation of electrical energy of the modules are complex processes, making the performance of the generation system depends on many factors. Developing a model that includes all these factors would be impossible or very complex. In this study, we will introduce two main inputs, one intermediate variable (or intermediate output) and one final output to capture the most salient characteristics of the use of the solar source by the Brazilian states in the distributed generation of electrical energy.

Therefore, the adopted NDEA modeling has the purpose of measuring efficiency through a two-stage system. The first one aims at evaluating the potential of solar energy transformation that the states have in filtering out of their total areas only the areas available for the implementation of photovoltaic systems of distributed generation. The second stage targets the potential of generation by solar radiation, but not all states contemplate sufficient infrastructure to transform into energy. The conceptual model of analysis can then be observed is shown in Fig. 6.2.

The first input variable is the area ($X1$), in km^2, corresponding to the territorial extension of the state in the analysis. If this study compared only the areas of the states among themselves certainly, some states would be benefit or impair. To analysed the process from solar energy, we include a intermediate variable that can mensure this process with capacity ($Z1$) was used. The second input, in turn, is represented by the peak sun-hours ($X2$). Due to the variations of the times of birth and sunset between the states, which could influence the analysis, this period of the higher generation known as hours of peak sun was considered, so that these differences between the states did not come to intervene in the result of the performance of the DMUs. Therefore, only the total energy produced ($Y1$) is used as the final product of this system.

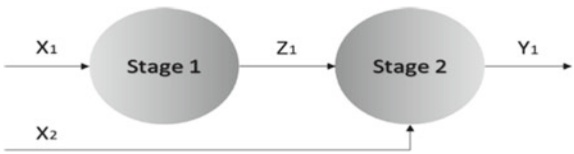

Fig. 6.2 Model for evaluation of network efficiency

The network DEA model will be implemented from the perspective of CCR, or CRS, with input-oriented modeling. Considering a series structure, the system efficiency of a DMU k can be calculated according to the generalized model of Kao and Hwang [13], as presented in Frame 6.1.-NoValue-

Frame 6.1 Mathematical modeling for calculating network efficiency

$$E_k = \max \sum_{r=1}^{s} u_r * y_{rk}$$

$$\sum_{i=1}^{m} v_i * x_{ik} = 1$$

$$\sum_{r=1}^{s} u_r * y_{rj} - \sum_{i=1}^{m} v_i * x_{ij} \leq 0 \quad j = 1, \ldots n$$

$$\sum_{p=1}^{q} w_p(1) * z_{pj}(1) - \sum_{i=1}^{m} v_i * x_{ij} \leq 0 \quad j = 1, \ldots n$$

$$\sum_{p=1}^{q} w_p(2) * z_{pj}(2) - \sum_{p=1}^{q} w_p(1) * z_{pj}(1) \leq 0 \quad j = 1, \ldots n$$

$$\sum_{r=1}^{s} u_r * y_{rj} - \sum_{p=1}^{q} w_p(2) * z_{pj}(2) \leq 0 \quad j = 1, \ldots n$$

$$u_r, v_i, w_p \geq \varepsilon \quad r = 1, \ldots, s \quad i = 1, \ldots, m \quad p = 1, \ldots, q$$

where E = efficiency; k = observed DMU; i = input; r = output; X_{ik} = amount of input in the DMU k under analysis; Y_{rk} = amount of output in the DMU k under analysis; p = intermediate output; m = number of inputs; q = number of intermediate outputs; s = number of outputs; Z_{pk} = amount of p intermediate output in the DMU k under analysis; v and w = weights

Given the Kao [12] considerations, it is evident that the overall efficiency of a DMU is equivalent to the product of the efficiency levels achieved by the same DMU in each process. For the two-stage model, the efficiencies E_k^1 (stage 1) and E_k^2 (stage 2) are calculated by using Eqs. (6.1) and (6.2), respectively.

$$E_k^1 = \frac{\sum_{p=1}^{q} w_p(1) * z_{pk}(1)}{\sum_{i=1}^{m} v_i * x_{ik}} \tag{6.1}$$

$$E_k^2 = \frac{\sum_{p=1}^{q} w_p(2) * z_{pk}(2)}{\sum_{p=1}^{q} w_p(1) * z_{pk}(1)} \tag{6.2}$$

Considering this relational behavior between the stages and variables employed in the model, the feasibility of implementing a solar electricity generation system in all the federative units will also be analyzed. However, it was chosen to present in this study the case of the state of Amazonas, located in the north region. This is because this is the largest state in the country in terms of territorial extension and is one of the ones that most faces difficulties of access to electrical energy by its inland population, due to the isolation in relation to the capital, the city of Manaus. With this analysis, it will be possible to validate the importance of variable X1 in detriment to the others, since this state has relatively low installed capacity and generated energy, considering its large extent, which explains the lack of investments in the state.

The viability analysis developed after implementation of the NDEA will be carried out through the financial tools: (a) net present value method (NPV)—able to determine the current value of an investment through an appropriate interest rate; (b) internal rate of return (IRR)—a hypothetical rate that zeroes in the NPV and is used as a reference to indicate whether the investment returns financial benefits or not; and (c) discounted payback—calculates the payback period considering a discount rate (TMA—minimum attractiveness rate). To calculate these factors, data will be consulted, mainly from ANEEL, which encompass consumption patterns, equipment, rates and other financial aspects of the operation.

6.4 Results

6.4.1 Efficiency Analysis

The implementation of the presented modeling resulted in the efficiency scores is shown in Table 6.1. Analyzing the global performance, the only efficient state was Rio Grande do Sul (100%), followed by the states of Santa Catarina (93.08%), São Paulo (90.22%), Minas Gerais (84.30%) and Rio de Janeiro (75.96%). Except for the median performance of Pernambuco (56.34%) and Federal District (51.07%), the other federative units presented values below 30%, which indicates a poor performance in most of the country. It can be noted, therefore, that the states with the greatest global efficiency are located in the south and southeast regions of Brazil, while states of the Center-West, such as Mato Grosso, and the north, such as Amazonas and Pará, are not able to stand out in the generation potential.

Regarding the performance in the stages, it is observed that because it is a generational potential, stage 2 presents higher levels of efficiency, while stage 1, which considers only the area for the implantation of photovoltaic systems and the capacity of state, has lower scores. These differences are mainly due to the infrastructure of the units for the transformation of solar energy into electrical. Figure 6.3 graphically represents this dispersion.

Table 6.1 Results of network DEA model

DMU	Cod.	Overall	Stage 1	Stage 2	DMU	Cod.	Overall	Stage 1	Stage 2
Acre	1	0.0021	0.0356	0.0021	Paraíba	15	0.0578	0.0000	0.0578
Alagoas	2	0.0482	0.2556	0.0534	Paraná	16	0.2819	0.0000	0.2819
Amapá	3	0.0497	0.0000	0.0497	Pernambuco	17	0.5634	0.5698	0.5634
Amazonas	4	0.0082	0.0000	0.0082	Piauí	18	0.0065	0.0000	0.0065
Bahia	5	0.2522	0.0000	0.2522	Rio de Janeiro	19	0.7596	0.0000	0.7596
Ceará	6	0.1972	0.0000	0.1972	Rio Grande do Norte	20	0.0301	0.2147	0.0301
Distrito Federal	7	0.5107	1.0000	0.5107	Rio Grande do Sul	21	1.0000	0.0000	1.0000
Espírito Santo	8	0.0946	0.2079	0.0946	Rondônia	22	0.0104	0.0000	0.0104
Goiás	9	0.2585	0.0000	0.2585	Roraima	23	0.0106	0.0000	0.0106
Maranhão	10	0.0071	0.0000	0.0071	Santa Catarina	24	0.9308	0.0291	0.9308
Mato Grosso	11	0.1163	0.0000	0.1163	São Paulo	25	0.9022	0.0000	0.9022
Mato Grosso do Sul	12	0.1741	0.0000	0.1741	Sergipe	26	0.0089	0.2251	0.0097
Minas Gerais	13	0.8430	0.0000	0.8430	Tocantins	27	0.0056	0.0000	0.0056
Pará	14	0.0026	0.0000	0.0026					

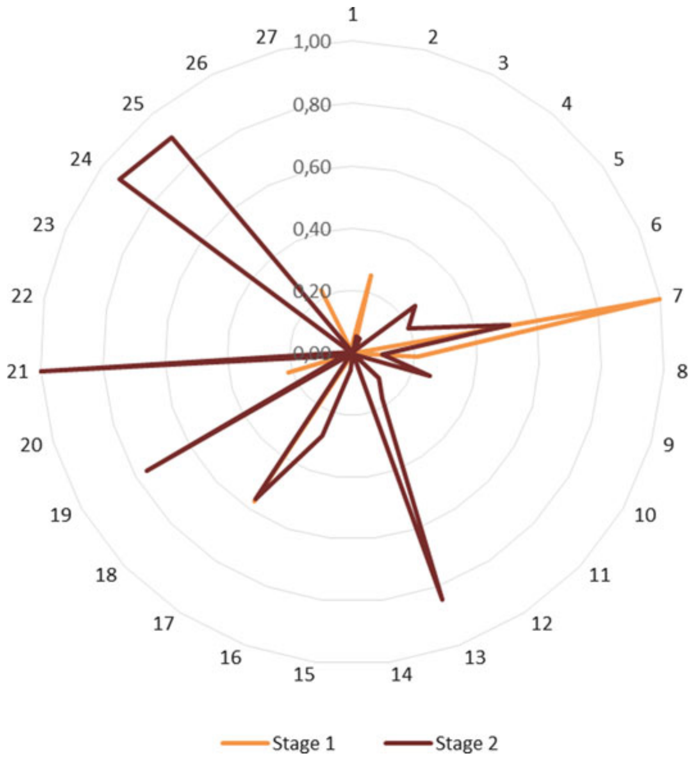

Fig. 6.3 Representation of efficiencies in stages 1 and 2

6.4.2 *Viability Analysis*

In view of the results presented and as explained in the research method, the viability of the electric power generation through the solar source in the state of Amazonas was evaluated; considering the following parameters, a residential system connected to the electrical distribution network (grid-tied), 220 V network voltage, 20 modules with 260 W of power each totaling an installed power of 5200 W and that has a nominal power inverter of 4600 W that will be the effective power connected to the network. It is noteworthy that, according to Groth [10], solar plates lose 0.074% of their efficiency per month. It means that in its 20th year, the performance falls 17.75%. After the research, a total of R$ 33,010.00 of investment to be realized initially, as summarized in Table 6.2, is calculated.

The electrical project may be carried out by a specialized organization and should be forwarded to the Energy Company of Amazonas for evaluation and approval in order to ensure the safety and proper functioning of the system. Subsequently, the average monthly cost of a household's energy bill was estimated from the consumption data of the inhabitants of the state. Table 6.3 shows the monthly value of

Table 6.2 Materials considered in the investment

Material	Quantity	Unit value	Total value
Panel—Eco delta, model 260w monocrystalline. A certification by INMETRO	20	R$ 625.00	R$ 12,500.00
Inverter	7	R$ 630.00	R$ 4410.00
Fixing bracket	20	R$ 120.00	R$ 2400.00
Protection panel and distrib.	1	R$ 9200.00	R$ 9200.00
Project	1	R$ 2500.00	R$ 2500.00
Installations	1	R$ 2000.00	R$ 2000.00
Total investment			R$ 33,010.00

Table 6.3 Consumption pattern in Amazonas

	Consumption	Value KWH	Cost		Consumption	Value KWH	Cost
Jan/18	491.15	0.65	317.43	Jul/17	490.54	0.61	299.28
Feb/18	494.8	0.65	319.69	Aug/17	513.14	0.59	302.34
Mar/18	504.01	0.79	397.97	Sep/17	520	0.6	312.78
Apr/18	504.88	0.84	421.98	Oct/17	509.49	0.6	306.1
May/18	499.49	0.87	434.56	Nov/17	504.62	0.61	307.87
Jun/17	481.94	0.61	292.92	Dec/17	497.49	0.6	297.55

the energy bill in the first year, so, at the end of each year, a rate of 7.875% was added to this value, which refers to the annual energy tariff inflation, according to the information made available by ANEEL.

According to Groth [10], the photovoltaic plates are able to function without presenting faults for 10–12 years. Subsequently, it is estimated that the annual maintenance would be 5% per year on the initial value of the investment with the equipment, plus the annual inflation of the sector, which is around 2.4% per year. With this, the cash flow diagram was developed considering average energy inflation of 7.875% per year, as previously mentioned. The TMA of the investment was stipulated at 15% per year (Fig. 6.4).

Once the cash flow was determined, a NPV of R$ 3584.19, IRR of 16.49% and discounted payback of 16 years and 6 months were calculated. Thus, the investment provides positive returns (NPV > 0), presents an IRR greater than the TMA and recovers before the deadline of 20 years.

6.5 Conclusion

In this study, we analyzed how efficient the Brazilian states are in using the area available for the effective generation of electrical energy through the solar source. The results obtained provide a fundamental apparatus for decision making. We noted

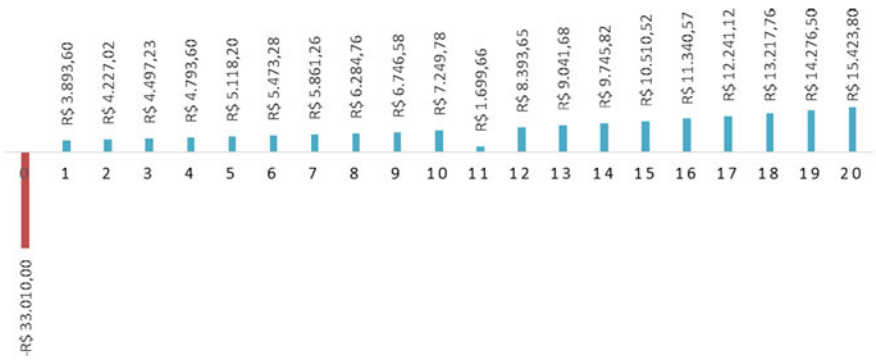

Fig. 6.4 Cash flow

that some states with good conditions for the implementation of a photovoltaic system are underutilized due to lack of investments. In the case of Amazonas, we verified that the investment is feasible, under the proposed conditions, since all the tools used indicated the financial viability throughout the development of the project.

For future studies, we suggest the expansion of the investment analysis, considering the analysis of scenarios and sensitivity, with the variation of the TMA. In addition, considering the growth of the solar energy market, different inputs and outputs can be included in the model.

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Part II
Defense, Tourism and Other Emerging OM Issues

Chapter 7
Transfer of Technology Through Offset Agreements in Brazil: The Case of AEL Sistemas S.A.

Antonio Rodrigues da Silva, Newton Hirata and Rodrigo Antônio Silveira dos Santos

Abstract This chapter highlights how a Brazilian company took advantage of offset agreements to receive intensive technology from an Israeli company. A qualitative research was conducted to study how AEL Sistemas S.A. has changed its core competencies and to understand its path to become a strategic company inside the Brazilian defense sector.

Keywords Offset · Defense · Transfer of technology

7.1 Introduction

Technological innovations have changed industries all over the world. Its possession in the contemporary world has been of great importance, since it influences all the aspects of the societies by its functional amplitude, weather in the area of communications and information technology, food and drugs, products of defense or mechanical engineering.

Following developed countries, emerging nations are economically constrained to adopt these techniques through business relationships that somehow enable the structural and organizational absorption of proven systems with global success.

One of the links used around the world that allows the creation of this environment, capable of transforming the economic branches and evolving capacities to the level of developing own competences, is the practice of compensations (offsets) in commercial contracts. They are practices carried out with the approval of regulators such as the World Trade Organization (WTO). Although there are considerations about the effects and distortions that they may cause in the 'developed market,' they

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are accepted by the dynamic that maintains the relation between these and the emerging nations, agreements naturally governed by specific laws that protect intellectual property [8].

Respecting the legal framework, Brazil makes use of this type of contract when it imports materials or services, mainly in the defense industrial base (BID). Acting with increasing attention in this segment, the Brazilian Armed Forces (AF) maintain structures to foster the implementation of offset projects, counting on the transfer of technology to national companies. This practice normally involves technical knowledge to maintain defense equipments.

In order to understand the transfer of technology process of the Israeli transnational company Elbit Systems Ltd. to the Brazilian firm AEL Sistemas S.A., through offset agreements to meet Brazilian market demands, this paper is based on the concepts of Porter [12], which lead to an understanding of how countries and their companies build skills and exploit different elements that enable economic growth.

The literature review also includes Freeman and Soete [7], Mowery and Rosemberg [10] and others authors who discuss the importance of technological innovation for the development of countries. The analysis and studies of Brazilian institutions were also consulted and monitored by indicators and promotion by national plans to understand the Brazilian reality related to the fields of innovation, transfer of technology and national companies.

7.2 The Importance of Offsets for the Defense Industry

In Brazil, the AFs were the first organizations to implement offset agreements. Since the 1950s, they use it as a form of trade compensation characterized by product exchange and countertrade [13]. From the 1960s until now, the agreements have evolved their degree of complexity to enable not only transfer of technology (ToT) processes, but also enabling the creation of technical education centers and maintenance hubs for aircraft, ships and tanks that military commands operate.

According to experts such as Mazzucato [9] and Tigre [14], these offset agreements, associated with procurement or service contracts, are not a guarantee of technological gain for the country, because 'learning how to do internally what is already known does not represent technical innovation.' But, nevertheless, such partnerships mean the insertion of a range of transnational firms into the national innovation environment in order to (i) contaminate it with the best productive practices, (ii) promote basic and technological scientific research with modernization and expansion of physical and human infrastructure and (iii) allow the absorption of new technologies for the country with multiplication of knowledge [12].

Those policies and procedures raise the importance of Science, Technology and Innovation (CT&I) as a homogeneous national power that offers credibility and confidence to foreign partners, candidates to make the offset agreements in the technological development projects offered to the Brazilian government.

The reflection of some offset initiatives, such as the development of the Brazilian communications systems (1998), the national digital television transmission system (2003), the development of military equipment for the operation of the armed forces (AF) in their constitutional missions (2012), as well as satellites for communications and defense (2014), is already perceived in the Brazilian manufacturing industry.

In particular, the Brazilian defense industrial base has grown since the beginning of the twenty-first century, supported by companies such as EMBRAER DEFESA and SEGURANÇA S.A., AVIBRAS INDÚSTRIA AEROESPACIAL and AEL Sistemas S.A. Those companies develop military aircrafts, special vehicles and avionics systems, encouraging the emergence of related companies in the supply chain to support the manufacturing industry as a whole. In 2015, the Brazilian defense sector reached a level of exports of US$1,042 billion due to the efforts made by the federal government in the promotion of the national industry by public policies, such as the Plano Brasil Maior (PBM) and the Defense Offset Policy, which sustain the initiatives undertaken in the agreements of retribution. Those numbers are important, even with the political and economic crisis that the country faces since 2013, and disregarding domestic consumption [2, 3, 4, 5].

7.3 The Defense Industrial Base (BID) and the Technological Innovation

What differentiates the BID in the broader industrial transformation segment is its high specialization and the great technological intensity that its products have. It is the result of a national defense policy focused on technical innovation. At the same time, it empowers military commands with products of technological intensity and it allows economical gains, with repercussions for the social and cultural behavior, bringing needs of different natures to the world, such as environmental ones.

With each new technological trend that may lead countries to '…origins and causes of wealth…' [14, p. 25], new plans and investments with prospects for future economic leadership are made by a few countries that have effective national innovation systems, capable of planning goals and pursuing technological results, pointed out by their research and development (R&D) system, which normally bring innovative products as a result.

And it is this disruptive characteristic as a concept linked to the advance of knowledge that attracts the attentions of nations in an increasingly forceful way, since some researchers, such as Christensen and Raynor [6] and Tigre [14], have considered that innovation should be 'the engine of the countries' for an economic development. However, more than a factor to produce wealth, innovation means investments, organizational planning, globalization, trade and scientific sharing. Innovation is related to the concepts that optimize the production on different industrial bases.

Regarding this institutional reinforcement, Porter [11] indicated that technological transfers that happen between companies of the same corporation ceased to have the exclusive character of imprisonment and channel of flow of standardized products to meet a demand 'pushed.' They are disseminated in companies with the intention of causing the strengthening of all the parts that compose them. They serve to unite the segments of the productive chain around a mission and make them proactive to the developmental challenges that the business segment proposes.

And, once this organizational state is achieved, the 'globalization' and 'diffusion' phenomena bring the challenge of maintaining standards and continually improving them, in keeping with the challenges that the new markets are presenting. The achievement of this level of self-regulatory action is only possible when the sectors that make the company have certain values in their production chains or acquire them and are able to incorporate operational concepts into their business plans that strengthen them [12].

7.4 Expected Effects of Transfer of Technology

The technological and business standards internalized by offset processes must be able to cause structural, conceptual and behavioral modifications on the beneficiary company that should adapt to the new reality and allow the emergence of a different technical institution in a market of products with high added value.

In addition, the transforming firm that emerges must become prodigal in the proliferation of incremental or radical products incorporated into military or civilian projects that, when inserted in the markets and functionally compared to their correlates, express the technical status reached in R&D conducted in its own technological center, preferably promoting partnerships for the multiplication of knowledge among the actors of the national innovation system (SNI), firms and partner academic institutions.

The other standards shown in the literature mention the possibility of changing the level of technological intensity of firms worldwide relate to (a) technological development, in the medium to long term, with continuous financial investments and obtaining conditions of factors to absorb scientific knowledge and productive techniques, in order to form a training technological base and (b) a reduction in technological dependence, with innovations that serve diverse projects in the domestic market, a greater degree of knowledge for technicians and engineers, and future transfers or compensations in national or foreign institutions, to the conceptual understanding that ToT for the productive sector does not transfer, but develops from complex technical–economic relations that target the company.

Few companies in the country have developed with this process in order to demonstrate the difference that characterizes the achievement of competitive advantages by companies in the defense material market.

7.5 AEL Sistemas: A National Strategic Defense Company

This whole set of phenomena is perceived in the Brazilian company AEL Sistemas S.A., whose business mission, corporate vision and institutional values have a strong relationship with the high-technology processes and products that it delivers in its numerous projects, developed for AFs and agencies related to the Brazilian Ministry of Science, Technology, Innovation and Communications (MCTIC) [1].

It has developed its technological, business and commercial skills acquired and multiplied internally from technological transfers that occurred in offset agreements, from 2002 to 2015, which allowed its transformation, as well as the elevation of the firm to a high technical level. Because of its development, AEL attracted national and transnational partners to take part in new projects, such as the military cargo plane KC-390 (2009), with EMBRAER DEFESA and SEGURANÇA S.A., and the Gripen NG fighter (2014), started with SAAB DEFENSE AND SAFETY at the request of Brazilian government.

The changes made in its organizational structure, in accordance with the offset plan which prioritize the production line, improving (i) factors related to infrastructure, (ii) human development, (iii) R&D and (iv) supply chain, have strengthened the technological structure of 'Marketing and Sales,' 'Operations,' 'Internal and External Logistics' and 'Service' that aimed to serve its customers within the agreed time frame and with functional quality and market excellence, exactly as indicated in the signed agreements [11].

The multiplication of standards and concepts that came into practice after the ToT processes for all stages of the production chain confirmed the technical–organizational modification provided by the offset projects that were implemented.

The technological transformation of the firm was confirmed by the range of products developed from 2004 to 2015, which accompanied the company's spin-off for the civil software segment, followed by the delivery of new technologies that resulted on dual-use products, either to partners and customers, as follows:

(a) In 2004, it was made a partnership with the National Institute of Space Research (INPE) and received ToT in energy subsystems for satellites.
(b) In 2012, it was created the company CREARE Sistemas LTDA, in order to monitor fleets and logistics services.
(c) In 2014, some products developed for MCTIC were delivered and incorporated into CBERS 3 and 4 satellites, which were then launched to space.
(d) In 2015, it was received ToT for developing embedded software (avionics) to the English company Ferranti Technologies Ltd.
(e) Since 2015, products for flight and environment monitoring are being developed for the Gripen NG and KC-390 projects, both to the COMAER.
(f) The Multimission Military Microsatellite (MMM) is being developed for the Strategic Space Systems Program (PESE) of the Ministry of Defense (MD).

The contributions made to the SNI, such as transferring expertise, creating new companies and sharing B2B environment for BID companies and national power, mainly through investments in aerospace products, among others offset transactions, have been factors that highlighted AEL Sistemas S.A. as a national high-tech pole.

7.6 Final Considerations

The defense offsets, strengthened by national legislation, have become, since the 1990s, an important way of technological transfers, based on the creation of technical education centers, maintenance centers and the implementation of business partnerships, necessary for their institutional performance. At the same time, defense offsets have contributed to develop national science and technology, mainly in the aerospace segment.

Aligned with these processes, AEL Sistemas S.A. grew technologically throughout the period from 2002 to 2015, among an SNI that strengthened the industrial segment of defense material. It added value to its production chains, improved workshops and laboratories, internalized standards and concepts and began to research and develop innovative products, both to meet the national defense policy and to develop dual technologies, also used for the civil sector.

The ToT process from the Israeli company Elbit Systems Ltd. to the national firm AEL Sistemas S.A., mainly with offset practices to meet the demands of the Brazilian market, is a success and guarantees a specialized technological actor for the Brazilian BID, which also strengthens air and space power.

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Chapter 8
Defense Industry: Ezute's Cases of Knowledge and Technology Absorption

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Abstract The aim of this article is to present Ezute's knowledge and technology absorption cases and to describe their use throughout the life-cycle phases of each Brazilian defense program, such as Brazilian Air Traffic Control System, Amazon Surveillance System, and Submarine Development Program.

Keywords Knowledge absorption · Technology absorption · Ezute Foundation

8.1 Introduction

The use of the country's purchasing power in the search for compensatory import requirements (Offset), especially in the defense sector, is a privileged mechanism to abbreviate access to technologies of interest, inaccessible by the usual trade operations. These technologies would require several years of research and high financial investments for the contracting country to reach a certain degree of maturity.

The Brazilian offset policy was formally implemented by resolution nº 764 [1], established by the Ministry of Defense (MD); however, the practice has been used since 1950, according to Modesti [2]. This current policy requires offsets whenever the purchases are above US$5 million per year.

Based on MD policy, Brazilian's Air Force, Navy, and Army have separate specific offset guidelines to apply in their strategic programs. Usually, the total offset request is about 100% of the purchased value. Although, in defense trade, offsets can include activities such as co-production, credit assistance, licensed production, subcontractor production, technology transfer, purchases, training, and foreign investment, the Brazilian offset policies objectives prioritize technological development of its defense industry.

Zuazua and Willen [3] observed the following conflict of interests between stakeholders when applying for offset's activities:

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- Contractor's Government (exporter): retain jobs and investment; secure strategic technology; boost export revenues; and sustain the nation's industrial base.
- Purchasing Government (importer): attract investment and create jobs; acquire strategic technologies; minimize procurement costs; and build national industrial capabilities.
- Contractor (exporter): maximize profits; ensure long-term business prospects; expand into attractive markets; and protect intellectual property.
- Armed Forces (Importer): minimize life-cycle costs and delivery risks; insource mission-critical capabilities; maximize capabilities; and sustain operational readiness.

Emphasizing the importer's interests, the aim of this chapter is to present Ezute's Foundation knowledge and technology absorption cases and to describe their use throughout the life-cycle phases of each Brazilian defense program, such as Brazilian Air Traffic Control System, Amazon Surveillance System, and Submarine Development Program.

8.2 Technology Transfer and Absorption at Ezute Foundation

Ezute Foundation is a private, nonprofit organization that provides innovative solutions in technology and management for the challenges and problems faced by Brazilian institutions, especially public entities. In doing so, Ezute contributes to the transformation of these organizations, to increase their productivity and effectiveness.

Ezute's technical staff was initially formed by engineers, who worked on the development of the Integrated Center for Air Defense and Air Traffic Control (CINDACTAs) 1, 2, and 3. Those professionals developed specialized knowledge due to the Brazilian effort in the process of technology transfer in the area of air traffic management, that begun in the mid-1970s.

The turning point for a truly fruitful approach in the technology absorption process at the Ezute Foundation happened, when the federal government decided to expand the coverage of national air traffic control systems, including 65% of the territory, constituted by the Brazilian Legal Amazon (the country's north and a significant part of the Midwest). This territory was uncovered by aerial surveillance radars as a consequence of the civilian and military flights control in that area was limited to radio contacts with stations on the ground.

Ezute started its operations with an extremely important mission: to be the great integrator organization of Amazon Surveillance System and the Amazon Protection System (SIVAM/SIPAM programs) and, in addition, to be responsible to absorb the technology of the winner company of the bid for what would be later the CINDACTA 4. The system's requirements were based on the Brazilian's security and sovereignty issues, defined by the Brazilian Air Force, which stated that those tasks should be done by a national organization. The organization created by the Brazilian Air Force in 1997 was the ATECH Foundation.

The SIVAM program, due to its characteristics, extrapolated its original conception and expanded its scope to include other state agents operating in the Amazon region, transforming it into a system of systems. With this, Ezute Foundation absorbed the knowledge to deal with large and complex systems, which brought the expertise to work in several other relevant projects in the defense area and in the civil field.

8.3 A Technology Transfer Receiver Agent

The transfer of technology for the purpose of complete mastery and autonomy involves not only a process to domain and provision of specific solutions by the industry but also an integration process, characterized by mastering the global solution and its interfaces by an "Integrating Organization."

The typical model for on-the-job technology transfer involves the domain of the application life cycle (as defined in system engineering methodology), which comprises the following activities: concept development, requirements engineering, system architecture, development, integration and tests, assisted operation, operation and maintenance, and disposal. During this cycle, an Integrating Organization (Integrator) carries out activities that include the coordination of the industry suppliers in their individual projects of sensors, telecommunication systems, specific systems, and other items that will take part of the final solution. Figure 8.1 illustrates the Integrator's role.

In the sequence, some examples of programs and projects that included technology transfer activities where Ezute had a relevant role are presented.

8.3.1 Integrated Centers for Air Defense and Air Traffic Control—CINDACTA

CINDACTA is the national air traffic surveillance, management, and control system for the entire area under Brazilian legal responsibility. It provides safety and economy in air navigation, as well as supports the scope of Brazilian international responsibility for search and rescue operations, and guarantees the integrity and the sovereignty of national airspace.

The technology absorption and transfer process developed in this program were so successful that it resulted in a national capability to implement the full development cycle of Brazilian airspace and air defense systems. Nowadays, Brazil has a complete domain over the application's development to manage and control the national airspace.

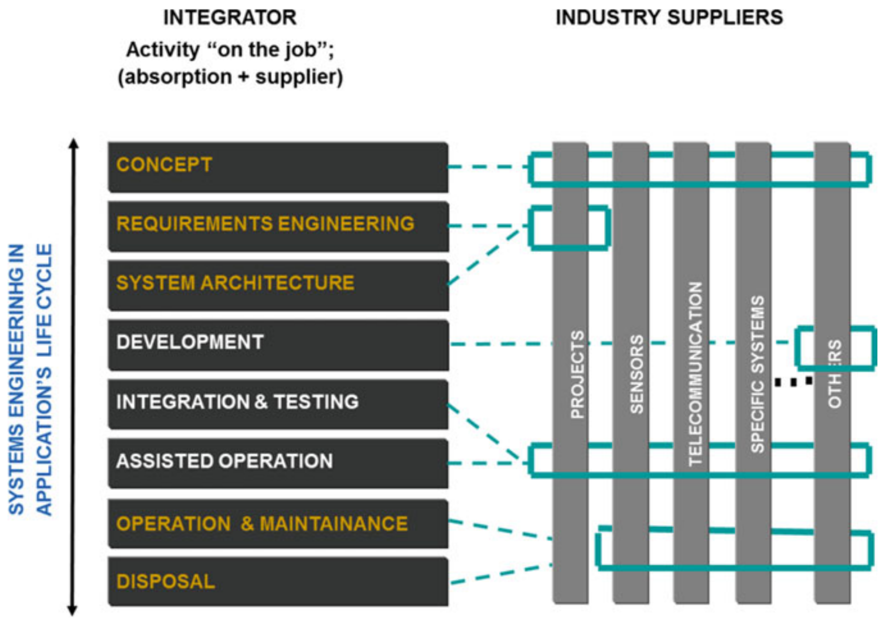

Fig. 8.1 Integrator's role

In 1980, the Brazilian government contracted a French company named Thomson-CSF to supply Automated Air Traffic Control and Air Defense Systems to equip the control centers located in Brasilia, Curitiba, and Recife. The contract included a technology transfer program for a joint system development, during the contract execution period, which ended in 1988.

In this project, the Brazilian government, through Airspace Control System Implantation Commission (CISCEA), contracted a Brazilian company and demanded it with the same level of responsibility of the French company Thomson-CSF (actual Thales). By doing this, there was an active participation of the Brazilian engineers in all stages of the application cycle, from design up to the assisted operation and configuration management, as shown in Fig. 8.2. Those engineers later were put together in the Ezute Foundation.

This project provided an evolutionary process of the Brazilian air traffic control that began with the use of "black box" systems before 1980, until the complete technological mastering at the end of 1988.

The main results of this project were:

- World-class technology and products;
- Value-added exportation once these products are now exported;
- Capability to meet any demand from the Brazilian government;
- Competence to develop air defense demands.

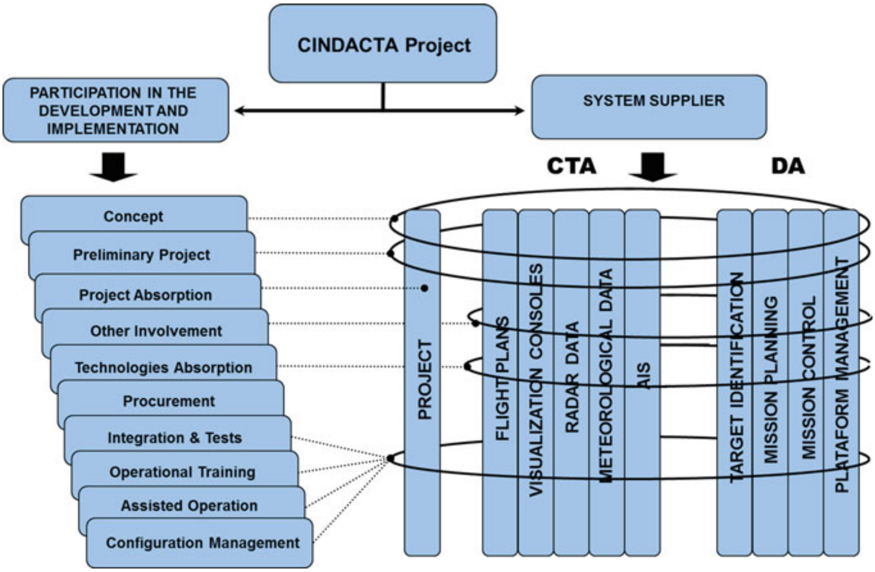

Fig. 8.2 CINDACTA project

Due to the successful results of the technology transfer of this project, Brazil is one of the few countries in the world to master completely the life cycle of air traffic management systems. As a strategic decision of the Brazilian Air Force, the Ezute Foundation retained this knowledge. In 2009, this knowledge was transferred to a private Brazilian company named "ATECH Negócios em Tecnologia S.A.," a spin-off from the Ezute Foundation, which actually is in charge to maintain and evolve the systems and export these products abroad.

It is important to note that over the years, even with the various changes in the team originally involved in the process of technology transfer, the knowledge has been maintained and multiplied. This was possible due to Brazilian Air Force constant demand for services related to the operation, maintenance, and evolution of the air traffic system. Therefore, this constant application of the knowledge acquired, ensured its perpetuation, provided the team to be permanently and actively involved in the day-to-day operation and evolution of the system. This fact is a key element for the success of technology transfer and absorption processes in the defense sector, as the knowledge acquired will be lost if not applied.

8.3.2 Amazon Surveillance and Protection System—SIVAM/SIPAM

The SIVAM was the first challenge involving technology transfer and absorption of the Ezute Foundation. The Brazilian government, represented by the SIVAM Coordination Commission, contracted Ezute in 1997 to carry out the integration of this great program. As a result, Ezute became the unique Brazilian organization capable and authorized to perform directly or indirectly related services, related to SIVAM integration activities due to its technological competence obtained in the process of technology transfer and absorption.

The SIVAM and its civil counterpart SIPAM (Amazon Protection System) made possible the integration of actions to control and defend the Amazon territory, the airspace, and the environment, by providing knowledge and intelligence, offering relevant resources to support its sustainable development. These systems also enabled the reconnaissance and early warning of aircraft flying over the Amazon region and allowed the Brazilian Air Force to modernize its operational plans and doctrines as well as to Brazil, in order to have a strategic instrument in geopolitics.

The SIVAM project included several modules and parts supplied by companies of various nationalities including Brazilian ones, but the American company Raytheon provided its core. The contract with this company included an extensive on-the-job technology transfer program, involving the participation of dozens of Brazilian technicians during the whole process of development, integration, and operationalization of the systems to be delivered.

In this project, the Ezute Foundation was contracted directly by the Brazilian government, as well as Raytheon and Embraer, the main companies in this project. Ezute developed the Information Systems that were considered strategic and absorbed the technology provided by Raytheon. In order to do this, Ezute sent engineering teams to Raytheon's premises, at the USA, to work in an Integrated Production Team (IPT) model.

As in the previous case, there was active participation of the Ezute Foundation in all stages of the application development cycle since its design up to the assisted operation and configuration management, as shown in Fig. 8.3.

The main results of this project were:

- Implementation and operation of the SIVAM/SIPAM;
- Capability to perform technological evolution of the system;
- Capability to specify and develop C4I systems;
- Capability to offer similar solutions to the world market; and
- Capability to absorb system engineering methodologies used by US Department of Defense (DoD).

In this project, the Ezute Foundation played a role not only as a receiving agent in technology transfer activities, but also as a transferring agent of technology to CCSIVAM. Under this latest role, Ezute was in charge of operation, maintenance, system evolution, and also for training the Brazilian government operation and maintenance

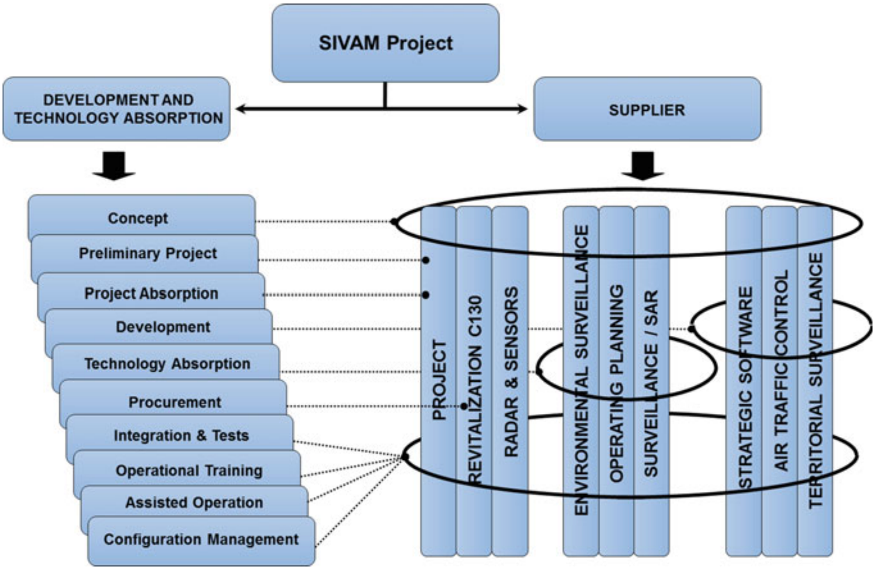

Fig. 8.3 SIVAM project

staff. This experience gave to Ezute Foundation an even more complete vision of the technology transfer and absorption process, once it developed the receiver and supplier roles.

8.3.3 Combat System of Submarines in PROSUB

To protect the Brazilian waters and to assure Brazilian sovereignty at the Atlantic Ocean, the Brazilian Navy (BN) invests in the expansion of its naval force, and the Submarine Development Program (PROSUB) is an essential part of this investment. Created in 2008 as part of a cooperation agreement in defense industry between Brazil and France, PROSUB will enable the production of four conventional submarines (diesel–electric propulsion, identified as SBR), the production of the first Brazilian submarine with nuclear propulsion (SNBR), and the construction of a naval complex in Itaguaí (RJ).

PROSUB can be considered one of the largest industrial and technological training programs of the Brazilian defense industry. As well as the transfer of French technology to Brazil, the program also advocated the nationalization of products and systems, encompassing more than 100 projects that represent around €400 million in offset. PROSUB's transfer of technology (TOT) and transfer of knowledge (TOK) projects, together with the development of local content, aim to meet Brazil's goal of national sovereignty and self-sufficiency in the production of submarines.

According to the contract between BN and the French company Naval Group (formerly DCNS—Directions de Construction Navales et Services), Naval Group is to supply 05 combat systems (CS): 04 for the SBR and 01 for the SNBR. The agreement also established TOT/TOK for BN engineers and to a Brazilian Industry Company (BIC), with Ezute Foundation being the organization selected as the CS BIC by Naval Group, with BN approval.

As a result of the contract signed between Naval Group and Ezute Foundation, the TOT/TOK of the combat system foresees progressive implementation, based on "on-the-job training" (OJT), aiming at Brazil achieving great autonomy in engineering and integration of submarine combat systems, in order to be able to:

- SBR CS: long-term maintenance support (LTMS); and
- SNBR CS: design, development, integration, and maintenance.

The training of Ezute Foundation in TOT/TOK SBR CS considers:

- Combat System (CS): training in SBR CS in Systems Engineering and Integration, up to Factory Acceptance Tests (SIFAT) in the Shore Integration Facility (SIF) in France, and OJT complementary activities in Brazil, during the commissioning of the submarines.
- Combat Management System (CMS): training and/or production in the design, coding, use of development tools, testing, debugging, and validation of the SBR CMS.

The expected main results of this project are:

- Capability to perform the integration tests for the commissioning of the SBR CS (STW—setting to work, HAT—harbor acceptance tests, SAT—sea acceptance tests), in Brazil, and to perform evolutive and adaptive maintenance, in the long-term support, under the BN responsibility, after the commissioning of the fourth SBR.
- Capability to provide CMS maintenance in SBR LTMS or support MB in the future SBR CMS evolutions and customizations.

As in the previous cases, Fig. 8.4 illustrates the expected participation of the Ezute Foundation in the stages of SBR and SNBR's life cycle.

Since 2011, engineers from Ezute Foundation have performed courses, training, and productions, guided by Naval Group in France and Brazil, as part of the transfer of technology contract. Currently, some of these professionals replicate to other members of the Foundation the knowledge acquired, while, at the same time, support the Brazilian Navy CDS (Submarine Development Center) in the preliminary design of the SNBR CS, through a contract with Amazul (Amazônia Azul Tecnologias de Defesa S.A.).

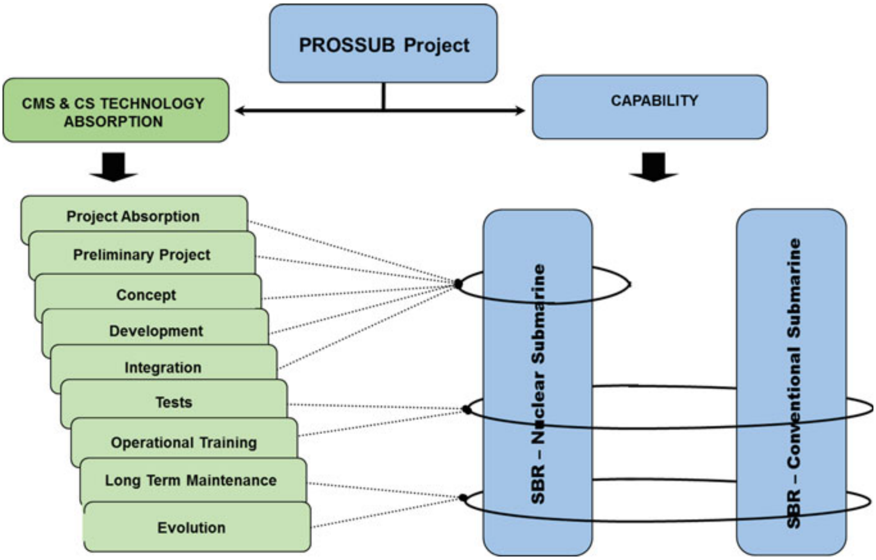

Fig. 8.4 PROSUB project

8.4 Final Considerations

Based on Ezute Foundation's experience, the following key elements are responsible for the success of technology transfer and absorption processes in the defense sector:

- Participate in the complete life cycle of the system being transferred;
- Have the teams working in an IPT model (companies who are transferring and receiving knowledge);
- Be part of the productive team whenever is possible;
- Have a strong knowledge management policy in place, since the beginning, with knowledge's maintenance and multiplication.

The last key element can only be fully achieved with a constant demand for services and/or products related to the operation, maintenance, and evolution of the technology. This constant application of the knowledge acquired, ensures its perpetuation, provides the team to be permanently and actively involved in the day-to-day operation and evolution of the system. Ways to have a sustainable demand may include a regular Brazilian governmental demand for the service/product; based on the maturity of the technology absorbed and on contractual agreements with the original company, service, and products exportation, as a Brazilian product or being part of a global supply chain of the original company.

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Chapter 9
The Importance of Architectural Design in Disaster Mitigation Involving Crowds

João Carlos Souza, Anne Wetzstein Schumann and Manuela Lalane Nappi

Abstract To assist in the rescue and protection of victims in fatality events, consideration should be given to collective behavior in large public gathering venues in order to bring to architecture project solutions that ensure the safe escape of people from these environments in situations of emergency.

Keywords Disaster · Collective behavior · Architecture

9.1 Introduction

With increasing population concentration in large urban centers, society has been suffering from the most diverse types of disasters, which may be derived from natural causes or from anthropogenic actions, which are the result of human action. These events cause great suffering and emotional, moral, physical, and material damage to the population, affecting the normal functioning of a community.

This research acquires importance in the frequent occurrence of disasters in places that congregate crowds, aiming to study their behavior in places destined to the meeting of the great public. We describe the relevance in the planning process of actions prior to the occurrence of fatalities and how the built environment can affect the safety and evacuation of buildings in emergency situations. It is also important to develop studies that address the topic of humanitarian logistics, which proposes to employ logistic concepts adapting them to the characteristics of the chain of humanitarian assistance.

At a time when people come together in groups, collective behavior interferes with individual behavior under the influence of a common and collective impulse, resulting in social interaction. Collective behavior is very interesting and complex and can become dangerous because it can take on a variety of forms, such as disturbances, mass hysteria, and panic. Thus, it is necessary not only the study of the behavior of this new organism, but also the understanding of this collective mind.

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Studies regarding the design of spaces demonstrate that architectural design must be based on the relationship between the user, his activities, and the environment, since these factors form a system and influence each other. Thus, places that congregate large concentrations of people should be designed to be safe and comfortable to the user, in their daily use or in emergency or panic situations.

The aim of this work is therefore to demonstrate to architects the importance of understanding collective behavior and its relationship with the built environment, taking into account the principles of humanitarian logistics and crowd management, with the aim of reducing or the risks to human life in buildings.

9.2 Disasters Involving Crowds

The intensity and occurrence of natural disasters in the world have been increasing in the last decades and tend to continue to increase as a consequence of factors such as population increase, undue land occupation associated with the urbanization process and industrialization [1]. It is noteworthy that not only natural disasters are growing in numbers, but also man-made disasters, especially those of a religious nature such as terrorist attacks, which are increasingly evident.

The IFRC [2] describes that disasters can be the result of naturally occurring physical phenomena, such as the succession of earthquakes, floods, landslides, tsunamis, storms, and so on. They can also be man-made, such as conflicts, wars, emergencies, famines, and accidents, occurring in or near human settlements.

In recent years, numerous countries have been hit by natural disasters of intense proportions. In December 2004, a tsunami in the Indian Ocean, triggered by a 9.1 magnitude earthquake off the Indonesian coast of Banda Aceh, killed 226,000 people [3]. In Brazil, in January 2011, a storm that hit the Serrana Region of Rio de Janeiro was considered the greatest climatic tragedy in the country's history. Billions of cubic meters of water and mud descended the slopes of the region at an average speed of 150 km/h [4]. In that disaster, 400,000 people had to leave their homes and more than 900 people died. Specialists point to the fact that this type of tragedy occurs, the lack of control and planning in the growth of cities [5].

In turn, disasters derived from human action can occur anywhere, especially those with large concentrations of people, increasingly frequent in modern society. These sites hardly meet the minimum safety standards, do not have emergency prevention systems, and have deficiencies in personnel management, resulting in people being injured and killed [6]. In this way, crowded places must have a differentiated attention, through planning and preparation, to improve the security of the population, increasing the chances of survival in any critical or emergency situation.

Numerous disasters involving crowds have been recorded in history. In 1990, during the annual pilgrimage of 2 million people in Mecca, Saudi Arabia, a riot led to the death, by crushing and suffocating, 1426 people. The event took place in a tunnel that connects Mecca with the city of Mina. It is speculated that someone has fallen into the crowd, blocking movement within the tunnel and initiating the tumult

[6]. In September 2015, the tragedy was repeated on the pilgrimage to Mecca, leading to death 1958 people [7].

In Brazil, one of the biggest disasters involving crowds in places of great concentration of people was the fire at the Kiss Nightclub in January 2013 in the city of Santa Maria, Rio Grande do Sul. Considered the greatest tragedy of the last 50 years in the country, the fire originated with the use of a flag, inside the nightclub, during a musical presentation. The fire spread rapidly through the roof of the nightclub, which was coated with a highly flammable material. After a visit to the site and analysis of documentation related to space, a report was presented that pointed out a number of factors that would have contributed to the severity of the fire. These include: failure of fire extinguishers, poor emergency exits and lighting, difficulty in evacuation, lack of smoke removal mechanisms, and inadequate use of materials [8]. In addition to these elements, the nightclub had a maximum capacity of 691 people, but there were more than a thousand people at the time of the tragedy. The accident caused the death of 242 people [9].

It is seen that, regardless of the disaster, from the lowest intensity to the highest intensity, a form of prevention is essential to ensure the least possible material damage, preserving, mainly, the integrity of human lives.

9.3 Humanitarian Logistics

As described earlier, humankind has been experiencing major disasters throughout its existence, which may come from natural phenomena or human action, making it a challenge to effectively meet the affected population.

The term "logistics" emerged and was widely disseminated in military organizations during World War II through the acquisition and supply of materials and has since evolved [10]. According to the authors, following the terrorist attacks of September 11, 2001, in the USA; July 21, 2005, in London; and the natural tragedies such as the Indian Ocean tsunami in 2004, a new perspective on logistics, the humanitarian perspective, was observed. Zary et al. [11] argue that humanitarian logistics have been the object of academic studies in more depth since 2004 and, in order to better understand this definition, one must understand the conception of business logistics and the main one's differences between these two branches.

For Ballou [12], business logistics aims to provide the best level of profitability in distribution services to customers and consumers, through the process of planning, organizing, and controlling the activities of movement and storage that aims to facilitate the flow of products. Humanitarian logistics, in turn, consists of the processes involved in mobilizing resources, people and knowledge to assist communities affected by disasters and assist as many individuals as possible [13].

According to Nappi [14], humanitarian logistics proposes to use logistic concepts adapting them to the peculiarities of the chain of humanitarian assistance. For Gralla et al. [15], profit maximization has little relevance to nonprofit relief agencies. But the basic principles of managing commodity flows, information, and finance, which are present in business logistics, remain valid in humanitarian logistics [16].

Humanitarian logistics is a key tool that can help save lives and protect victims of disasters. According to Wassenhove [17], it is “the part [of any aid in disasters] that can mean the difference between a successful operation or not.” Complements Nascimento [18] states that “the humanitarian logistics is to promote actions aimed at ensuring the necessary conditions for a population hit by a disaster.”

Despite the improvement of the concept of humanitarian logistics, it is evident that there is still a need to evolve and expand the studies in this area so that logistics processes become more and more efficient. The aim is to reduce the impact on the population affected by disasters, as well as to disseminate this concept more clearly to the population in general.

Considering what has been explained previously, it is also of great importance to understand the behavior and dynamics of crowds, as well as these factors can influence the safety of individuals in an emergency or panic situation. Next, the principles of collective behavior and the relationship between the built environment and the user will be described.

9.4 Collective Behavior

In order to better understand human behavior in society, the scientific study called sociology, defined by Lakatos [19] as a way of study and objective knowledge of social reality, of forms of association emerged in the nineteenth century, highlighting the characteristics general and common to all social classes.

Simultaneously with sociology, the study of collective behavior emerged, evidencing the behavior of the crowds and what their impacts on social life. Park and Burgess [20] define collective behavior as something that overlaps the behavior of individuals under the influence of a common and collective impulse, the result of social interaction [21].

In the field of study for the behavior of crowds, Le Bon [22] instituted a new concept in relation to the multitude, describing the word as a gathering of individuals of any nationality, sex, or profession, whichever factor brought them together. In the psychological view, the word assumes another meaning, portraying that, under certain situations, an agglomeration of people presents new characteristics, very different from those of the individuals that compose it. There would thus arise a collective mind, forming a unique being, subject to the law of the mental unity of the multitudes.

With regard to crowd safety, it is of fundamental importance to initially understand the dynamics of crowds [23]. Remembering that the behavior of a crowd is not the same as that of a person on a street, square, or mall, because individuals have individual interests and goals, which differ from those around them. In this way, studies related to the dynamics of the crowds are models different from those used to plan the pedestrian flow [24].

In order to understand the crowds, Le Bon [22] classified them into four types: casual crowd (a momentary crowd to watch a street artist), a conventional crowd (which can be represented by a group of spectators watching a football match), active crowd (objective or even aggressive crowd), and expressive or dancing crowd (crowd of harmless character). It is important to emphasize here what concerns the active crowd.

For Blumer [25], the formation of an active crowd begins with a circular behavior. Initially, there is an episode of social unrest that draws the attention of the individual and leads him to act, directing the focus of the group to the event [21]. Then there is the milling process which, according to Park and Reuter [20], can be explained as a collective attitude that reflects fear and discomfort, increasing according to the sensation of the individual or social unrest. In a third moment, the crowd finds a common object of attention, so that the feelings, the imagination, and the mood of the individuals are focused on this object. Already in the fourth stage, the understanding of the situation, acquired through focus, manifests a collective excitement. At the fifth moment, collective excitement leads to social contagion, which is the irrational and accelerated propagation of impulses, moods or forms of conduct that occur, for example, in collective outbreaks [26].

One of the most adverse conditions of collective behavior is the fleeing crowd caused by panic. Such a situation can lead to trampling and/or crushing of people, leading to death and serious injury to these individuals. The theory of panic mainly addresses the aspects that can lead the individual to this behavior during emergencies. The principle of panic theory is that, in normal situations, individuals act naturally and have their behavior influenced by factors in the environment in which they are inserted. In panic situations, there would be a transformation in the habitual conscious personality of individuals, causing a shift to an unconscious personality that would lead to irrational attitudes, such as moving faster than usual, becoming impatient, and pushing others.

Alves [26] concludes that panic in crowds can be triggered by innumerable reasons and is a form of collective behavior on which certain aspects must be weighed. In general, individuals in these situations deduce that their survival is the result of immediate decisions and attitudes. There are changes in values and a decrease in responsibility, which leads to the imitative behavior present in the groups. By focusing on escape, individuals manifest a high degree of irrationality and disregard the consequences of their actions.

Schadschneider et al. [27] describe that in many emergency situations, many collective phenomena related to panic behavior are reported. However, there is evidence to the contrary, that panic occurs in situations where individuals compete for safe areas or access to an emergency exit, leading to selfish, irrational and antisocial behavior that influences large groups. In this context, the term panic should be avoided. Taking into account that behavior in emergencies is assessed as irrational only by those outside the event, it would best be described as non-adaptive behavior.

Studies of collective behavior by Quarantelli [28] report that, in general, people do not panic in a dangerous situation. There must be more specific conditions for the development of panic, in addition to a general crisis setting occurring in the environment. Often individuals may feel extremely threatened and afraid for their physical safety and yet react with direct actions against danger while maintaining control over their activities.

Knowing the dynamics of pedestrians and how the collective behavior influences it becomes a great challenge in the architectural field. As it has been seen, it is something that is constantly changing and always has a "distinct formation," making it a challenge for architecture not only to design an environment to receive a crowd, but also to create mechanisms so that, if this large body gets out of control, there is as little impact as possible to its components. In this way, studies related to collective behavior can help the development of the architectural design of environments, in order to cancel or reduce to the maximum any type of risk to the population that attends them.

9.5 Architecture and the User

In architecture, constructive fundamentals determine the physical environment and impact human behavior. Studies related to the built environment and human behavior contribute to the project development process, mainly considering the user's psychological factors, their interests and how he understands the building [29].

In order to be able to design efficient spaces that aim at aspects such as comfort, safety, functionality, salubrity, aesthetics, and quality of life of its users, architects must realize the need to understand the relationship between environment, user, and activity, considering the importance of each one of these components, the direct influence that exists between them, their characteristics, needs, and constraints [30]. From this perspective, Moore [29] states that the architect has the responsibility, before the public, to configure the needs of the user and their relationship with the environment. Their competence should be to design buildings that fit their users, their needs and particularities, rather than users having to adapt to the built environment.

For Goulart [31], designers should consider the perceptual structure of the people who are involved in the project, since this structure is essential for achieving the objectives of creating a project that integrates the interests of users. What makes a place a source of emotional security and a basis for its self-identification is the creation of a more appropriate environment for the user to help him develop his perception and cognition of the environment that surrounds him.

It is possible to perceive that faults in buildings are frequent on the aspects related to the junction of function to form. In this sense, architecture challenges the systematic introduction of knowledge about the characteristics of human behavior in the creative process, contributing to the conceptual enrichment, establishing rules with human and scientific questions within a project methodology [32].

The dynamics of pedestrians, for example, presents a great variety of phenomena of self-organization and of collective effects that can be analyzed. Schadschneider et al. [27] describe some of these phenomena:

(a) Agglomerations and clogging: They occur generally in places with high density, where the flow exceeds the capacity. These locations with reduced capacity are called bottlenecks.
(b) Density waves: Pedestrians' clusters can be characterized as almost periodic density variations in space and time.
(c) Band formation: In the movement of coming in the opposite direction, for example, there is the formation of bands, where people move in only one direction. Thus, interactions with other individuals are reduced, which is more comfortable and allows for a higher walking speed.
(d) Oscillations: One can observe bottlenecks in the opposite direction of the flow by oscillating changes in the direction of the movement.
(e) Patterns at the intersections: At the intersections, several collective patterns of movement can be formed, such as short-term deviations that make movement more efficient.
(f) Emergency situations: Numerous collective phenomena attributed to panic behavior have been reported, but there is evidence that this is not the case. Typically, panic behavior occurs in situations where people compete for safe areas or access to an emergency exit.

Regarding the project design, Sagun et al. [33] explain that an improper layout of a building and failures in crowd management can lead to loss of life and injury in public spaces. Human behavior, which includes panic, ignorance of orientation or variations in route and exit preferences, based on the level of familiarity with construction, is a challenge when designing a guidance system for safe evacuation of buildings.

In emergency situations, the way the building plan is organized, the users' familiarity with the enclosures, exits and signs can affect the response time of the individuals. Thus, the choice of the route of escape by the user is defined by the degree of architectural differentiation, spatial knowledge, presence of safety signaling, among other aspects [34]. It is also important to carry out abandonment training because the occupants are looking for exits that are familiar, rather than escape routes not known.

It is considered, therefore, that the architectural project should offer an easy understanding of the space constructed by its users, in normal situations as well as in emergencies or panic situations. This enables people to quickly identify and interpret the safest and most efficient escape routes that direct them to the nearest exit, depending on their location in the environment.

9.6 Final Considerations

Understanding the collective mind under normality is complex. In emergency situations, the complexity increases, since the human behavior in these situations cannot be predicted with precision and becomes variable, being able to influence other individuals and to hinder the evacuation process of the place.

The relevance of research related to pedestrian dynamics is justified by the wide variety of phenomena of self-organization and collective effects that can be analyzed, as seen previously. On the other hand, the research related to the behavior of individuals in emergency situations collaborates with the planning of places that gather large concentrations of people providing means to analyze and evaluate the systems of prevention and emergency of these environments, increasing the levels of security for the occupants of these buildings.

This study intends to expand knowledge about the topics covered in the research, such as humanitarian logistics, crowd behavior, and the influence of architecture on the user and, from this knowledge, identify possible flaws and help in the elaboration of measures that can contribute to the design of new building projects and to the adaptation of existing buildings.

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Part III
Healthcare Operations Management

Chapter 10
Public Purchase Governance in Brazilian Local Healthcare Systems: A Pattern Analysis by Text Mining

Maria Clara Lippi, Diego Carvalho and Rafael Garcia Barbastefano

Abstract Brazilian cities are establishing consortia to advance public healthcare procurement and purchasing systems. Although these alliances yield recognized benefits, their governance structure is an intricate issue, involving opposing stakeholders' interests. This research analyzes governance patterns emerged from 50 public consortia by hierarchical clustering through a data mining technique.

Keywords Purchasing · Procurement · Governance · Public management · Public health

10.1 Introduction

The Brazilian institutional framework builds upon Federal, State, and Municipal tiers and decentralization policies aiming at the public system transferred most of the delivery and managerial responsibilities from the state and federal level to municipalities [30]. In this context, Brazilian local healthcare systems face challenges related to public purchasing issues which constrain services and goods provision regarding volume, costs, quality, and time.

Since the public duty to provide healthcare services and goods increased, the cities have organizational, logistics, and financial disadvantages, such as scale and scope inefficiencies and low bargaining power with suppliers. This scenario is even harder for small and remote cities with small population density rates [13, 20, 22, 33, 40, 45].

On the other hand, purchasing literature on health sector suggests that managerial initiatives focusing on reducing supply costs and resources utilization improve system's efficiency and service quality [5, 25, 42]. Furthermore, input's availability and regular supply are critical impact factors to a health program effectiveness [18, 32, 44].

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There are also some barriers derived from the Brazilian purchasing law that rules the Public Administration, for instance, higher lead times and delays on purchasing processes, lower service level (mainly quality and delivery time) and excessive variabilities on inventory management [4, 23, 24, 27].

Therefore, healthcare managers and politicians must develop and implement solutions for coordination and integration between systems [29]. Public consortia implementing Group Purchasing Organizations (GPO) shall be among the solution palette [15, 30, 46].

The main advantages of these GPO are: economies of scale, lower stockout risks, processes and cost structure efficiency, viability of collaborative projects which would not be possible if were developed individually, service portfolio expansion (increasing organization capabilities on providing more specialized and technological services), flexibility in workforce payment methods, bargaining power over suppliers, and political empowerment/strengthening for the region [11, 3, 14, 21].

The decision-making processes and governance structure of public GPO are an intricate issue because it involves opposing stakeholders' interests (politicians from different cities, suppliers, local managers, consortia administrators, and other actors) [34] and the relationship between members should be based on equality and autonomy [6].

There are approximately 216 health consortia in Brazil [31] and related studies usually proceed local and isolated diagnosis through qualitative research methods [14, 16, 17, 19, 28, 34, 35, 38, 43].

For those reasons, this paper analyzes governance patterns emerged from 50 public consortia by hierarchical clustering through a data mining technique. Applied researches in text mining in health [7, 8, 9, 26, 37] and in public management [1, 39] are promising and just have started to be developed.

10.2 Methods

The research is an exploratory and applied study of 50 Brazilian public consortia, which uses hierarchical clustering to identify governance patterns. Hierarchical clustering technique, as a distance-based clustering algorithms, is useful for finding groups of similar objects since its similarity function measures how close text objects are from each other. This technique "successively merges groups based on the best pairwise similarity between these groups of documents" [2: 90].

Public consortia's institutional and governance structure are ruled by some mandatory public documents: the by-law and/or the memorandum understanding (free translation from "Protocolo de Intenções" in Portuguese. This document is a legal requirement to create any consortia). Documents were collected and treated (just 1 document per consortia) in order to be processed by the software Orange (https://orange.biolab.si/), a tool for data mining. Figure 10.1 details the research process.

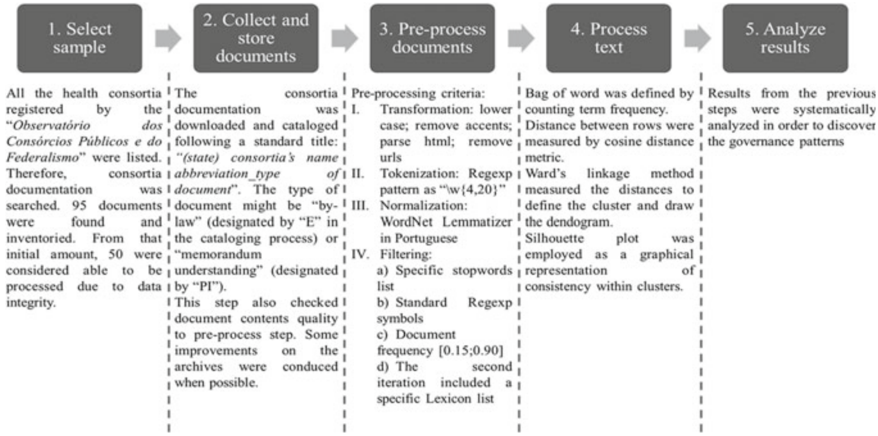

Fig. 10.1 Research methods. Adapted from Refs. [2, 12]

Research method considered two clustering activities. The main difference between them is the set of filtering criteria on the pre-process phase. The first one is the so-called General Clustering (GC) analyses which considered no Lexicon restriction. The second one, the "Governance-Oriented Clustering" (GOC), kept GC criteria and added a specific Lexicon list (selection of words that represents governance elements, such as board, director, president, general assembly, vote, decision, to deliberate).

10.3 Results and Discussion

Consortia sample is a set of consortia from eight different states, four regions and two types of documents. Both GC and GOC resulted in five different clusters, as presented in Fig. 10.2. Each cluster was labeled as "Cx" subsequently, as represented by black shapes in Fig. 10.2.

Clusters C7 and C8 are outliers because both are composed by only one consortium (CODESP is within C7 and CIMVI in C8). It means that their governance elements are distant from other clusters and from each other and possibly are specific. However, when considering the entire corpus (no lexicon restriction), CODESP and CIMVI stay closer to other consortia, indicating they share similarities with them from an entire corpora perspective. For example, in GC, CODESP and all the other consortia from Rio de Janeiro State are clustered in C3 together. Additionally, C3 contains just understanding of memorandum documents.

Silhouette plot is a graphical tool to interpret clustering consistency. Whenever the Silhouette value comes near to 1, the document is close to its cluster center and when it is zero, the document is on the border of two clusters. Negative scores could

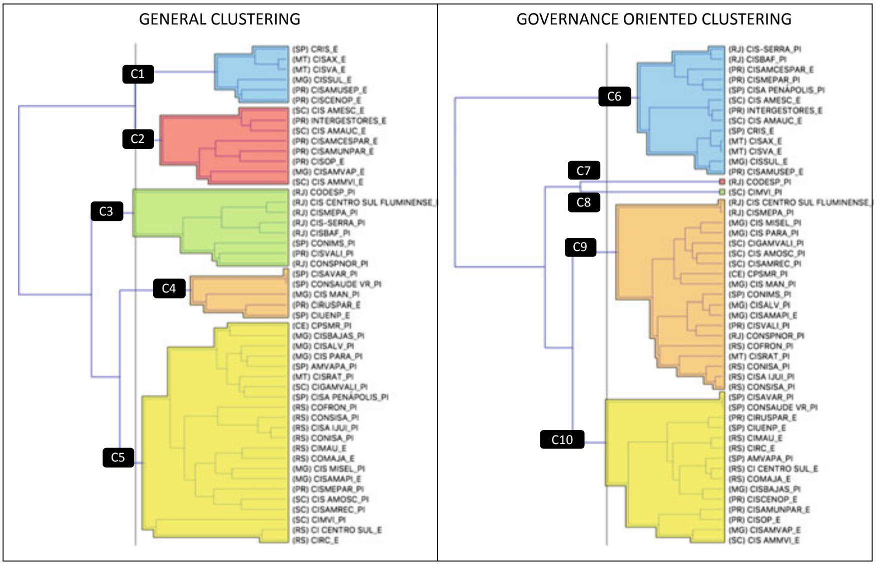

Fig. 10.2 Hierarchical clustering results

indicate "misclassification," in a way that the object should probably be classified in the other cluster [36].

Figure 10.3 presents the Silhouette plots of GC and GOC, which indicates GOC clusters have more "internal similarities" (objects within a cluster are closer to it center). C5 objects are mostly away from the C5 center, and its narrow shape suggests that the elements are not very similar between each other.

Table 10.1 also supports interpreting hierarchical clustering results. It represents, for example, how many documents from the same cluster in GC were clustered together in GOC. C1 has six elements and they were classified in two different clusters in GOC (5 of them in C6 and 1 in C10). For instance, it is reasonable to claim that these five documents share similarities (it is possible to confirm it by tracking these five documents in silhouette plot). In general, there is no correspondence between the clustering results.

Brazil is composed of five geographical regions that encompass economic and social similarities. Figure 10.4 is a regional and a document-type analysis. From the regional perspective, GC's clusters tend to present one predominant region, while GOC does not follow this trend. On the other hand, document-type criterion seems to influence both GC and GOC's results.

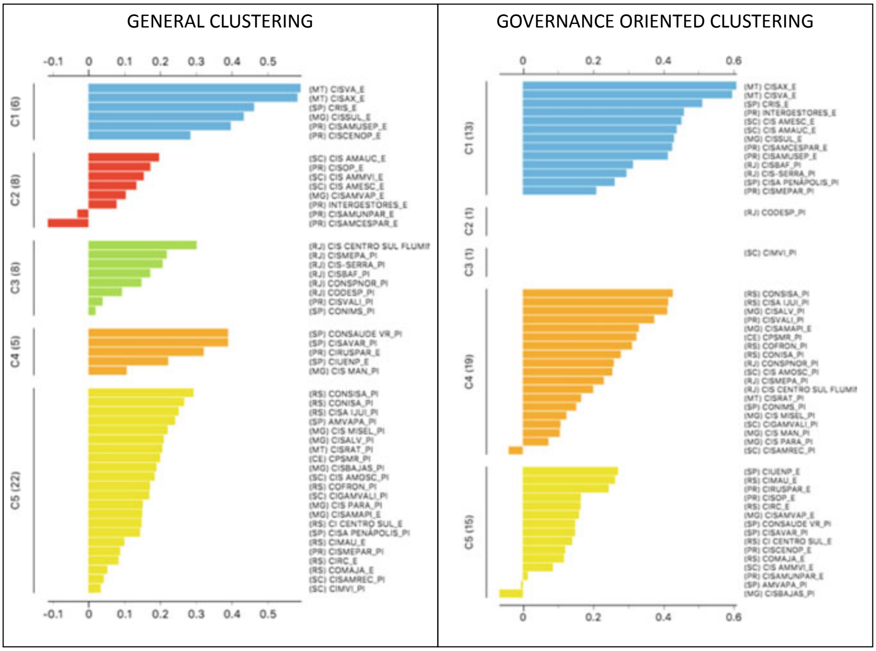

Fig. 10.3 Silhouette plot of GC and GOC

Table 10.1 GC and GOC correspondence

	C6	C7	C8	C9	C10
C1	5	–	–	–	1
C2	4	–	–	–	4
C3	2	1	–	5	–
C4	–	–	–	1	4
C5	2	–	1	13	6

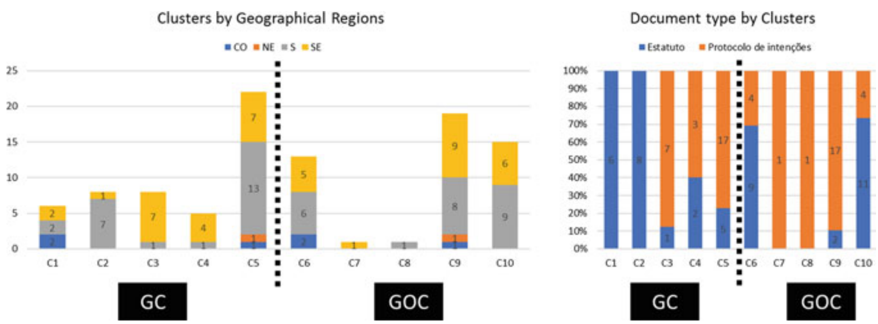

Fig. 10.4 Regional and document-type comparison

10.4 Conclusion

The paper text mined institutional documents from 50 different Brazilian public consortia in healthcare and identified governance patterns through hierarchical clustering analysis. Geographical region and document type are relevant patterns to analyze public consortia. For future research, it should be relevant to deeper analyze these patterns individually checking documents contents, because writing style and format might also have influenced clustering results.

Public management research on local government is still insulated on bureaucratic perspective, discussing governance and social participation/relationship with society by less representative cases or methods [41]. Public consortia in healthcare is a potential and unexplored solution to deal with health systems decentralization and public purchasing [10]. There are multidisciplinary gaps to be bridged on consortia governance, such as to diagnose and to analyze their organizational structure development, decision-making processes and criteria, relations between operations and performed outcomes.

The promising results achieved by this exploratory research start to build a bridge to reduce the gap on public policies for empowering intergovernmental relationships to improve public health outcomes. This is a reasonable research strategy to advance on comparative, predictive, and propositive studies in consortia governance as, for example, an impact analysis of different governance structures.

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Chapter 11
A Two-Step Optimization Process for Medical Center Location and Capacity Allocation

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Abstract This study aims at locating and sizing medical centers and allocating equipment to meet the community secondary care needs, since the specialized care on public Brazilian national health system is critical and chronically underfunded. Therefore, we develop a two-step optimization system and Web-based interface to provide scientific-based results to health system managers.

Keywords Public healthcare planning · Facility location · Mixed integer linear programming

11.1 Introduction

The distance to healthcare facilities is critical to establish the population accessibility to health services; consequently, the location and size of hospitals, medical centers, or emergency units have been an issue of growing technical and political importance. In Brazil, public healthcare planning has been challenged by decreasing economic growth and fast aging communities which raises service demand and increases the health system's costs. As a result, leaders face difficulties in setting priorities in allocating resources. This study identifies and solves a location-allocation problem on second-level health care by a two-step optimization procedure using mathematical programming models. The problem arose in a study requested by the Secretary of

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State for Health of Minas Gerais, Brazil. Financial and cultural barriers are not on the scope of this work.

Since 1989, all Brazilian have been entitled to free health care at the primary, secondary, and tertiary levels through a national health system (Sistema Único de Saúde—SUS) established by 1988 constitution. The system is funded by taxes and social security payments [25]. Over the past 28 years, SUS has increased access to primary and tertiary care. The primary care, which comprises prevention and low-cost procedures, reached about 98 million people in 85% (4737) of municipalities in 2010. The tertiary care, which includes high-cost procedures, is executed by county, public teaching hospitals, and contracted private sector providers, paid by the SUS at about market value. The provision of secondary care, however, is problematic. At the second level, health care has little regulation and SUS is highly reliant on the private sector; therefore, medium complexity procedures are often limited to individuals with private health plans. Only 24.1% of computed tomography scanners and 13.4% of magnetic resonance imaging scanners in Brazil are public [16]. Furthermore, the medical centers, qualified for the health care on the second level, are not geographically dispersed, which motivates this study of medical center location and equipment allocation for health care.

Healthcare location problems have been an active research area [18]. The models are an extension of the classic p-median, p-centers [9], set-covering [22] and the max-covering model [3], and the *location-allocation* model [19]. For a historical perspective, we refer the interested readers to a comprehensive review [10], successful case studies [2], and a recent survey [1]. Applications include modeling a three-level location system of perinatal facilities [6]; the use of genetic algorithm for a maximal covering location problem for healthcare planning [20]; a facility location model for primary care system approaching physicians' preferences with integer programming [8]; the integration of community-based organizations with healthcare providers to address a hierarchical location model by a multi-objective framework [12]; the development of a decision support system to optimize the equipment allocation [23]; a mathematical programming model to support planning tactical workforce capacity allocation minimizing salary costs considering vacation and subcontracting opportunities [24]; and a performance evaluation of 87 primary care health units to identify disparities in resource use among private and public facilities [15]. On healthcare location-allocation problem, examples include: a two-phase solution procedure to set the location and size of medical departments by a multi-objective approach [21]; the optimal location of preventive healthcare facility locations [7]; and a two-step optimization process for improving spatial accessibility [13].

Despite the rich literature, most studies address primary care on the municipality level. A limited number of researches explore location-allocation healthcare problems on the second level, so there are potential gaps and open issues yet to investigate; besides, the literature presents few studies that address realistic problems [1, 8]. Our models: (i) address the facility location and capacity allocation for secondary care on the state level; (ii) adopt the available equipment idle capacity on a hierarchical healthcare system; and (iii) recognize multiple preferences. When planning on the state level, we must consider the physicians' inclination for working on metropolis which is the opposite of the patients' choice on moving the least from their cities.

The remainder of this paper is organized as follows: The next section outlines the healthcare problem and the suggested location-allocation MILP models. Next, we evaluate scenarios of a case study on a Brazilian state. We finish the paper by providing a conclusion and recommendations for future investigation.

11.2 Problem Description and Model's Formulation

We study the healthcare planning at the state level, in which the planner must select secondary care facility locations and designate equipment to them. The planner must combine patients–physicians' preferences, and adequately size workload and assure service quality to justify the public infrastructure financing. Although medical procedures are often realized on equipment, databases demonstrate that there is no direct relationship of equipment per specialty. Several medical specialties use equipment in proportions that change over time, which leads us to conclude that we should set the number of equipment required per inhabitants, as presented on official standards. Finally, the planner must consider, simultaneously, (i) patients' multiple medical service needs, (ii) the available idle capacity of equipment on servers, and (iii) the rational use of infrastructure in the context of a hierarchical healthcare system with limited resource availability.

The purpose is twofold: (i) minimizing the weighted sum of distances between patients' demand, clustered on districts, and physicians' service supply, located on municipalities, and (ii) minimizing equipment acquisition cost to secondary care centers to meet official criteria of equipment per inhabitants. Official parameters set specialists and medical equipment per inhabitants. The number of professionals is given in terms of specialists' available hours per healthcare region. Physicians can ponder municipality infrastructure and move between them. Remark that there are numerous primary cares and tertiary care specialists and equipment in a hierarchical system, so we decrease the available capacity, estimated from equipment registries and prior medical appointments of the national registry of health departments, from official demand and supply parameters. Further, the model should provide the additional hiring hours of specialties if the number of professionals per medical center is not capable of satisfying the local demand.

To address this problem, we introduce the development of a two-step optimization process. On the first step, we analyze physicians' preferences for selecting several candidate municipalities; following, we develop a MILP model to elect medical center facilities which minimize the weighted sum of demand and distances between patients and physicians of all specialties. For the second step, we propose a MILP model to meet patients' need for examinations on equipment. The demand is partly met by the available idle capacity of equipment, like medical centers and hospitals; then, new types of devices are allocated to the elected medical centers on the first step. The model minimizes the weighted sum of demand for examinations and distances between patients and medical centers. The equipment allocation depends on demand parameters and distance from patients, so they do not share the same resources. This circumstance allows the use of the equipment allocation model for any type of equipment. The past flow of patients affects the proposed solutions. It is explicitly formulated.

We denote a state with I districts and J municipalities. $K \subset I \times J$ are the available paths between I and J. Pacitents move from local districts to municipalities to be served by E medical specialties. These specialties are distributed over M medical healthcare regions. The notation is presented in Table 11.1, while the MILP model of center location is presented in the following.

$$\text{minimize} \sum_{ij \in K | D_{ij} \leq D\text{max}} \sum_{e \in E} D_{ij} H_{ie} x_{eij} + \sum_{m \in M} \sum_{e \in E} w_{me} \tag{11.1}$$

The objective function (11.1) minimizes the distances, limited by $D\text{max}$, between patients, on districts, and physician, on medical centers, and the additional hiring hours of medical specialties. Distance is weighted by patients' demand to provide incentives for selecting districts close to each medical center. This function is subjected to the following constraints:

$$\sum_{j \in J | (ij) \in K} x_{eij} = 1 \quad \forall e \in E, i \in I \tag{11.2}$$

$$\sum_{j \in J} y_j = P \tag{11.3}$$

$$x_{eij} \leq y_j \quad \forall e \in E, \ i \in I, \ j \in J \tag{11.4}$$

Table 11.1 Input parameters and variables of the facility location model

Parameters	Description	Unit
D_{ij}	Distance between district i and facility j	Km
$D\text{max}$	Maximum distance between a district and a facility	Km
H_{ie}	Demand of patients of district i by medical specialties e	h
P	Maximum number of secondary healthcare facilities	Facilities
A_{me}	Availability of medical specialties e on region m	h
R_{jm}	Indicate if municipality j is located on region m	Binary
T_j	Indicate if municipality j has infrastructure	Binary
Variables	**Description**	**Unit**
x_{eij}	If demand of district i is met by specialty e on municipality j	Binary
y_j	If a healthcare facility is located at municipality j	Binary
w_{me}	Additional hours of specialties e to be hired for region m	h

$$\sum_{(ij)\in K|R_{jm}=1} H_{ie}x_{eij} \leq A_{me} + w_{me} \quad \forall e \in E,\ m \in M \tag{11.5}$$

$$y_j \in \{0, 1\} \quad \forall j \in J \tag{11.6}$$

$$x_{eij} \in \{0, 1\} \quad \forall e \in E,\ i \in I,\ j \in J \tag{11.7}$$

$$w_{me} \geq 0 \quad \forall e \in E,\ m \in M \tag{11.8}$$

In Eq. (11.2), the demand for medical services of each district must be attended by only one medical center. In Eq. (11.3), the number of medical centers is set according to the planner financial condition. Constraint (11.4) sets the conditions for allocating specialties of districts to medical centers, which occurs only if a municipality is selected to receive a medical center. Constraint (11.5) establishes that the demand for each medical service of municipalities that belongs to a healthcare region is limited by the available workforce of each medical specialties for each healthcare region. If demand exceeds the available capacity, additional hours of specialists must be hired. Constraints (11.6–11.8) set the domain of the decision variables. The equipment allocation model used in the second step of the two-step optimization process presents the notation described in Table 11.2. The MILP model is presented in the following.

Table 11.2 Input parameters and variables of equipment allocation model

Parameters	Description	Unit
B_i	Inhabitants on municipality i	Inhabitants
H_i	Demand of equipment for district i	Examinations
K_i	Available equipment capacity on municipality i	Examinations
D_{ij}	Distance between municipality i and municipality j	Km
P	Maximum number of additional equipment	Equipment
E_i	Observed overall efficiency of facility of municipality i	Percent
C_i	Municipality i that received a medical center	Binary
F_{ij}	Historical flow of patients from municipality i to municipality j	Patient
$D\max$	Maximum distance between patients on municipalities and a facility	Km
T	Penalty for moving over maximum distance	Scalar
W	Equipment nominal capacity	Examinations
Variables	**Description**	**Unit**
x_{ij}	If the demand of municipality i is met by equipment of municipality j	Binary
y_j	Number of equipment to be acquired for municipality j	Equipment
r_i	Patients move over the maximum distance from a municipality	Km

$$\text{minimize} \sum_{(ij)\in I} D_{ij} H_i \frac{x_{ij}}{1+F_{ij}} + \sum_{i\in I}\sum_{j\in I} D_{ij} H_i r_i T \tag{11.9}$$

The objective function, in Eq. (11.9), minimizes the distances between patients and equipment, in medical centers. The flow of patients is influenced by the historical flow. In case of moving beyond the maximum distance, a penalty is applied. This function is subject to constraints (11.10–11.19):

$$\sum_{j\in I} x_{ij} = 1 \quad \forall i \in I \tag{11.10}$$

$$\sum_{i\in I} H_i x_{ij} \leq K_j E_j + y_j C_j W \quad \forall j \in I \tag{11.11}$$

$$\sum_{j\in I} \left(K_j E_j + y_j C_j W\right) \geq \sum_{i\in I} H_j \tag{11.12}$$

$$\sum_{j\in I} y_j \leq P \tag{11.13}$$

$$\sum_{i\in I} x_{ij} \geq 1 \quad \forall j \in I | K_j > 0 \wedge C_j > 0 \tag{11.14}$$

$$B_j x_{ij} \geq B_i x_{ij} \quad \forall j \in I,\ j \in I | D_{ij} < D\text{max} \tag{11.15}$$

$$D_{ij} x_{ij} - r_i \leq D\text{max} \quad \forall j \in I,\ j \in I \tag{11.16}$$

$$y_j \in \mathbb{Z}^+ \quad \forall j \in I \tag{11.17}$$

$$x_{ij} \in \{0, 1\} \quad \forall i \in I,\ j \in I \tag{11.18}$$

$$r_i \in \mathbb{Z}^+ \quad \forall i \in I \tag{11.19}$$

In Eq. (11.10), the demand for examinations of each municipality must be attended by only one medical center of a municipality or attended at the same municipality i. In constraint (11.11), the demand for examinations is met by available idle capacity or by the allocation of new equipment on the medical centers selected on the first step of the optimization process. Constraint (11.12) guarantees that the overall capacity, provided by available capacity and new equipment, is greater than the demand for examinations of all municipalities. Constraint (11.13) limits the amount of equipment acquisition according to financial conditions. In constraint (11.14), the demand for examinations is met preferably to the municipality with idle equipment capacity by a new medical center. Constraint (11.15) represents a historical move of patients to municipalities with a bigger population. Although this is not a mandatory rule, it was suggested by decision-makers to avoid unusual policies and facilitate an initial discussion. Constraint (11.16) relaxes the condition of maximum distance and penalizes this situation on the objective function. Constraints (11.17–11.19) set the domain of the decision variables. The results of the proposed two-step optimization method are presented in Sect. 11.4.

11.3 Results and Discussion

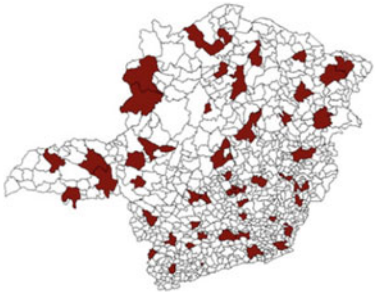
Minas Gerais is the Brazilian state with the largest number of municipalities and districts, 853 and 1633, the second most populous, with more than 20 million inhabitants, and fourth biggest, with 586.528 km^2. Recent advances in health care include a decentralization process in the second level to increase the population access to specialized centers. The first medical center, in the proposed new arrangement, was established in 2016 [5]. In the study, 51 medical centers should be installed providing 9 medical specialties. The selection of candidate municipalities should take into account physicians' preference as municipalities with at least 30 thousand inhabitants and more than three medical specialty services. The selection of 116 candidates resulted from the contribution of experts in medicine, engineering, demography, and the government, representing patients. Table 11.3 lists the selected municipalities. Then, medical equipment should be allocated to each unit. Data presented on parameters were sourced from IBGE, DATASUS, and Ministerial Decree [4, 11, 14].

Analysis revealed that each medical center serves an average of 32 districts and a patient travels on average of 59 km from their district to the nearest medical center, but there will be patients who will travel up to 247 km to the nearest medical center. The shortest distance between two medical centers is 19 km, while the longest distance between two medical centers is 230 km. It provides only 25 h of mastologist in the municipality of Frutal, while the highest number of hours of medical specialty is in the capital, Belo Horizonte, with 11,792 h of pediatric service. The model also sets the minimum number of additional hours to be hired to meet the parameters of the decree for each medical specialty. Results are resumed in Fig. 11.1.

We evaluate scenarios by changing input parameters of patients, physicians, and government. For *patients*, we change the number of new medical centers in case the user migrates at most 100–200 km, for example. For *physicians*, we modify criteria of minimum infrastructure, varying the candidate municipalities' population from 30 to 60 thousand inhabitants. On the *government* plane, we alter the number of medical centers, from 10 to 80, in accordance with the budget. Figure 11.2 presents the results.

The second step of the optimization concerns in allocating equipment to medical centers. The model does not limit the type of equipment. For the principle of didacticism, we evaluate one type of equipment, the MRI scanners. Analyses revealed that MRI scanners' idle capacity could fulfill 73% of the demand. The purchase of an additional 20 MRI scanners for new medical centers would cover nearly 98% of examinations' demand for a maximum displacement of 200 km. Such results are acceptable since the state presents large areas with low demographic density. Patients

Table 11.3 Municipalities selected to receive a medical center

	#	Municipality	#	Municipality	#	Municipality	#	Municipality
	1	Alfenas	14	Curvelo	27	Lavras	40	Sabará
	2	Almenara	15	Diamantina	28	Leopoldina	41	S. A. Monte
	3	Araçuaí	16	Divinopolis	29	Manhuaçu	42	S. J. del Rei
	4	Araxá	17	Frutal	30	M. Claros	43	S. Lourenço
	5	Barbacena	18	G. Valadares	31	Muriaé	44	S. Lagoas
	6	B. Horizonte	19	Ipatinga	32	Paracatu	45	Taiobeiras
	7	Betim	20	Itabira	33	Passos	46	T. Otoni
	8	B. Minas	21	Itabirito	34	P. Minas	47	Uberaba
	9	Campo Belo	22	Ituiutaba	35	Patrocínio	48	Uberlandia
	10	Capelinha	23	Janauba	36	Pirapora	49	Unai
	11	Caratinga	24	Januaria	37	P. Caldas	50	Varginha
	12	C. Lafaiete	25	Jequiti	38	P. Alegre	51	Viçosa
	13	Contagem	26	J. de Fora	39	R. Neves	52	

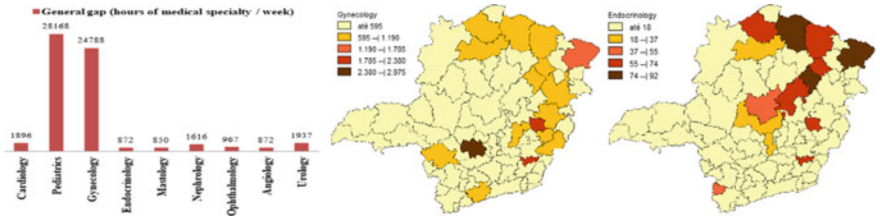


Fig. 11.1 General gap of medical specialty hours in MG and the gap distribution for two medical specialties, for example out of 9, over MG state health regions

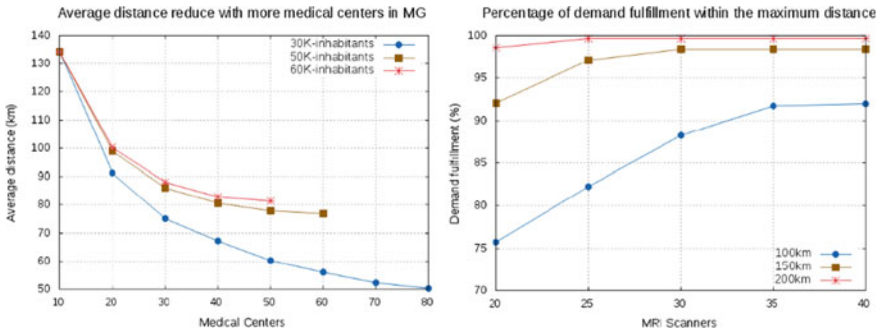


Fig. 11.2 The average distance decreases considerably with the investment on at least 40 CEM. The percentage demand fulfillment for MRI scanner changes with at distances of 100, 150, and 200 km

would move at most 100 km. Figure 11.2 shows the percentage of demand satisfaction by changing the maximum distance and the number of new MRI scanners.

11.4 Conclusion

This study set out the location of medical centers and the allocation of equipment to meet the population's secondary care needs on a state level by a two-step optimization process. The proposed method was developed for dealing with the problem faced by a project [17]. It was recognized that the setting was of a generic character, representing an unstudied component of real healthcare location-allocation problems. The first model finds 51 medical centers' optimal location considering the demand for medical specialty services. It provides the expected additional hours for specialists. The centers are homogeneously dispersed over the state area and located in municipalities with a minimum infrastructure. A second model establishes the allocation of equipment to the medical centers.

In general, the findings suggest that the proposed optimization process is a potential method to promote the interaction and integration of public health, medicine, and engineering teams, strengthening the decision-making process. The results, of course, need to be scrutinized by managers, who are required to have a deeper understanding of the system and the desire to provide scientific support for their management decisions. The findings also contribute to recent debates about the use of analytic tools for healthcare system integration in the legal and regulatory landscape.

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Chapter 12
Scaling Hospital Laboratory Queues via Discrete Event Simulation Using Simpy

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Abstract We propose new activities set to a hospital laboratory in Belo Horizonte and queues of patients with different profiles. We developed a simulation model using the Simpy module of the Python programming language. The study establishes the minimum number of employees to attend patients at the contracted service level.

Keywords Health care · Simulation · Simpy

12.1 Introduction

In 1988, health became a right of every citizen and a State's duty (Brazilian Const. art 196). The Unified Health System (SUS—Sistema Único de Saúde) was settled since then to ensure equal access to health services. The system has a decentralized governance and civic participation in the administration. Currently, the public domain health system provides primary care to citizens on 96% of municipalities by health units. SUS also enables access to expensive treatments and drugs, as to HIV and cancer without costs to the patients [12].

The development of SUS improved the health coverage; however, the poor funding of the program is a problem. The public sector in comparison with total health expenditure in Brazil was 41% in 2007, while in the UK and Mexico were 82 and 47%, respectively. Additional problems include high staff turnover, dependency on foreign technology, and low coverage to specialized and intermediate treatments. Only 6% of diagnosis and therapy centers, 11% of specialized clinics, and 32% of hospitals are public [13].

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The occurrence of queues is a major problem in treatments and health care in the public health system. 57.6% of the population in five municipalities from the most populated state complained about the sizes of the queues [10]. Citizens have waited hours to days in queues for a treatment, worsening of the patient's health condition [11, 3], and wasting human, financial and medical resources. Therefore, the improvement of resource distribution over the time enables the correct sizing of queues resulting in a better treatment and service quality while being able to reduce management costs when seeming fit.

This paper aims at developing a discrete event simulation model to study a public hospital's sector responsible for laboratory analysis, which consists of blood sampling and material collecting. With the available data, we analyze the resource management and propose a new capacity to attend the patients within a time limit. Section 12.2 presents the relevant literature and contributions. In Sect. 12.3, we evaluate the case study and analyze the simulation model results based on data acquired on site. Finally, in Sect. 12.4, we present the conclusion and future developments.

12.2 Literature Review

Discrete event simulation is a method used for developing solutions to queue-like problems. The approach is vastly used to analyze and enhance healthcare systems, mostly for units or facilities. Also, health systems are characterized by their high variability due to the human involvement at resource and entity levels [4]. The application of discrete event simulation in the analysis of health systems has become increasingly accepted by health decision makers as a viable tool to improve operations and reduce costs [7].

In addition, "efficient patients' flow is shown by high patient throughput, low patient waiting times, a short length of stay at the clinic, and low clinic overtime, while maintaining adequate staff utilization rates and low physician idle times" [7]. Also, it is said that patient routing and scheduling and availability of resources impact this flow, what may be evaluated by event discrete simulation.

Similar case studies show that the simulation models, results' implementation could improve the healthcare system by means of scenarios evaluation. In a screening sector of a Brazilian hospital, a study demonstrated that increasing the medic crew in day shift reallocating nurses and attendants could keep up with the patients' demand without compromising the patients' care [2]. The results were reached using queuing theory and theory of constraints; however, a simulation model was needed to prove the solution [8]. The use of discrete events simulation can also be used with Petri nets modeling [1] to determine solutions to the similar system.

Several tools facilitate the discrete event simulation modeling; however, these graphical user interface simulation programs are usually costly or impose a limitation to the model variables. Therefore, we develop a simulation model with an open-source programming language—Python and Simpy framework [9]—which can achieve inventory sizing for logistics' operations and maintenance [6] and inventory optimization modeling [5].

12.3 Case Study

We study a SUS's Hospital, of Belo Horizonte, Brazil, which faced a demand reduction on laboratory analysis sector and a demand increase in complementary sectors, as a result of a healthcare legislation adjustment. The hospital clearly presents a deficient capacity's utilization, generating queuing in some departments, and idleness in others. This study aims at analyzing the system in order to improve personnel utilization.

The system consists of 11 areas: one of them is exclusively for patient screening and is being referred to 2.1 in Fig. 12.1. Patients receive passwords for their activities within the system. In 2.2, professionals are responsible for attending patients or issuing their results or registering the requested tests, although, only two of them are used. Furthermore, there are 16 fully equipped collection sites and three infant care sites, used just on special occasions, and three semi-equipped service locations that are not being used. Despite, only four nurses attend at this department, doing the blood sampling. To summarize, each professional uses one of the fully equipped sites for the service, so 12 of them are not operated. There are four possible paths for patients in the system: blood sampling and material delivery; blood sampling; material delivery and results' emission, depicted in Fig. 12.1.

Activity diagram cycle (ADC) in Fig. 12.2 represents patients' flow in the laboratory and activities' statistical distribution time. This information was obtained from the hospital's data between March and June 2018, incorporating the time for patient registration, material delivery, and blood sampling duration. The laboratory had no information about patients' arrival rate and, consequently, we applied a queuing theory Eq. (12.1) to estimate this value. The estimate is based on the mean number of patients in the triage class and the meantime of the screening with one attendant. The arrival rate, λ, is estimated at 0.4 patients/min based on attendance rate, μ, and queuing average size.

$$\frac{\lambda^2}{\mu\,(\mu - \lambda)} \tag{12.1}$$

The screening process is responsible for classifying the patients by analyses of their form and characteristics. The system attends four classes of patients, presented in order of priority for attendance: special, emergency, preferential, and normal. From data collected, it was observed that 17.4% of patients are usually emergency, 3.5% are special, 68.5% preferential, and 8.6% normal. The laboratory's operation hour is from 07:00 to 12:00, for the blood sampling. Material's delivery operates from 07:00 to 16:00, and the results issue runs from 07:00 to 18:00.

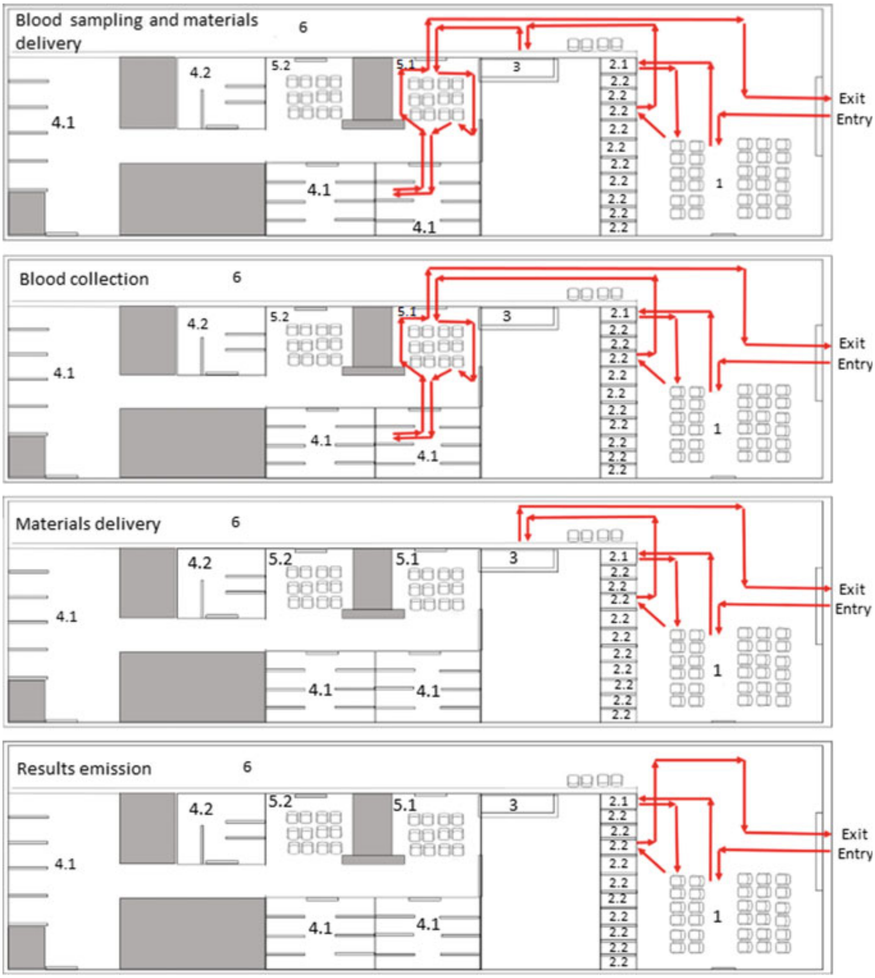

Fig. 12.1 Laboratory's analysis layout. 1: sector's reception, 2.1: screening area, 2.2: patient registration and delivery of reports. 3: materials delivery, 4.1: blood sampling, 4.2: blood sampling for children, 5.1: waiting area for sampling, 5.2: location for a snack after sampling

We implemented the computational model using the Simpy, a python framework for discrete event simulation. The program reflects ADC to represent 5 h, simulating one day of the system, and the sector is open for all activities in this period of time. The algorithm, presented in Fig. 12.3, calculates the statistics such as average time in queue and number of patients in a queue.

The computational implementation simulates the laboratory's current scenario with the same number of employees in each of the jobs which are briefly shown in Table 12.1. The number of runs was stipulated with a confidence interval of 95%

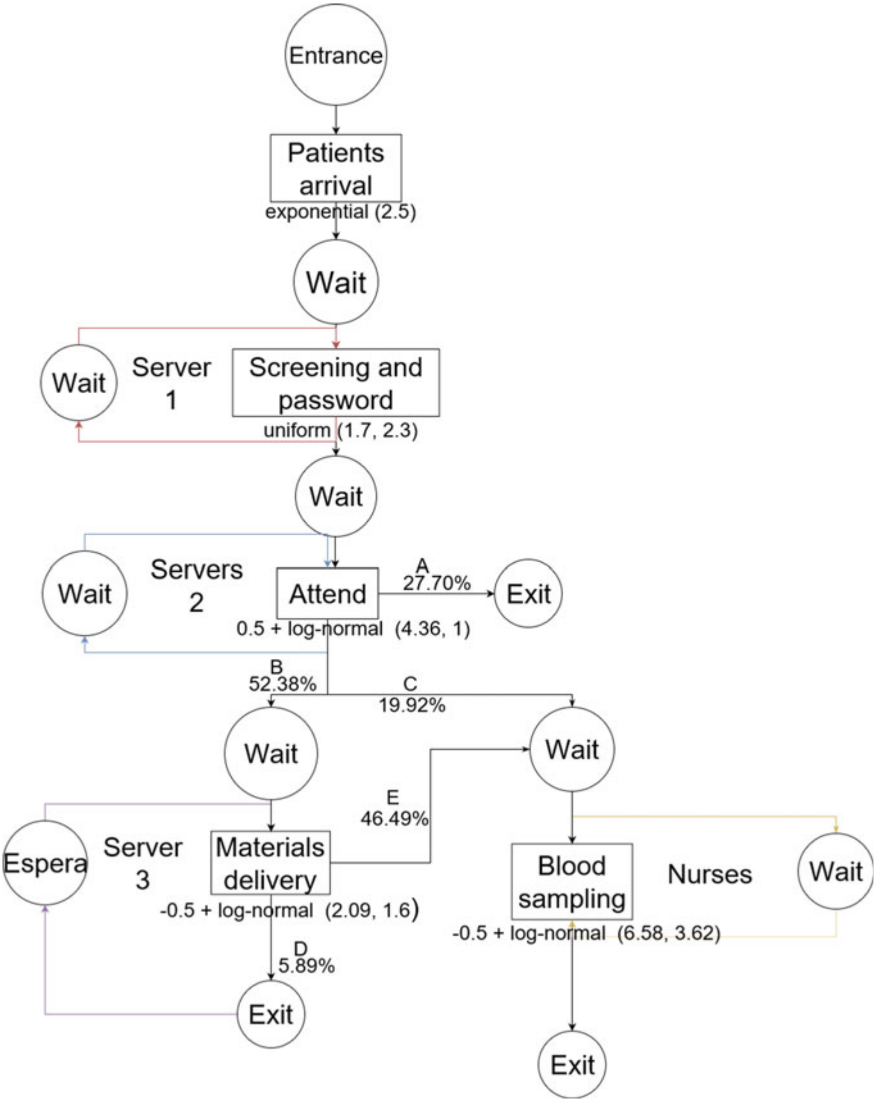

Fig. 12.2 Laboratory's activity diagram cycle

```
        For each run:
    Set predefined data for capacity's resources
            Set queue's statistics variables = 0
    Set patients' statistics variables= 0
    Process patient arrival (during 300 minutes)
    Screening
    Registration
    Blood Sampling
    Material deliver
    Result Request
    Calculates final statistics for each variable

    Patient arrival: Set input of frequency for each
type of patient (priority and services)
        Set an initial number of patients
            Call function Screening
            Until 300 minutes
                New patient
                Draw frequency for each patient
                Call function Screening for patients
    Screening:   Patient waits in queue
        Hold resource
        Calculates statistics
        Do screening (process)
          Call function Registration
```

```
Registration:  Patient waits in queue
    Hold resource
    Calculates statistics
    Do registration (process)
    If (delivery is in patient services)
        Call function delivery Material
    Elif (blood-samp is in patient services)
        Call function Blood Sampling
    Elif (result is in patient services)
        Call function Result Request

Blood Sampling:  Patient waits in queue
    Hold resource
    Calculates statistics
    Do Blood Sampling (process)
    Patient exits system
Material deliver:  Patient waits in queue
    Hold resource
    Calculates statistics
    Do Material Deliver (process)
    If (blood-samp is in patient services)
        Call function blood sampling
    Patient exits system
Result Request:     Do result emission
            Patient exit system
```

```python
def patientRegistration(environment, resources, statistics, patient):
    #
    # @note: wait in queue
    #
    queueSize = statistics["queue-size-records"]["registration"][-1];
    statistics["queue-size-records"]["registration"].append(queueSize + 1);
    enterQueueDate = environment.now
    request = resources["registration-worker"].request(priority=patient["priority"])
    yield request

    patient["time-in-queue"] += environment.now - enterQueueDate
    queueSize = statistics["queue-size-records"]["registration"][-1];
    statistics["queue-size-records"]["registration"].append(queueSize - 1);
    statistics["patients-in-queue"]["registration"] += 1
    statistics["avg-time-in-queue"]["registration"] += environment.now - enterQueueDate
    statistics["time-in-queue-records"]["registration"].append(environment.now - enterQueueDate)
    #
    # @note: do registration
    #
    processDuration = max(0.5 + 27 * beta(3.58, 18.2), 0.0)
    yield environment.timeout(processDuration)
    yield resources["registration-worker"].release(request)
    #
    # @note: go to next process -- blood sampling or material delivery
    #
    # According to the profile, a percentage of patients is deviated to Material Delivery
    if   "delivery" in patient["services"]:
        environment.process(materialDelivery(environment, resources, statistics, patient))
    # According to the profile, a percentage of patients is deviated to Blood Sampling
    elif "blood-samp" in patient["services"]:
        environment.process(bloodSampling(environment, resources, statistics, patient))
    # According to the profile, a percentage of patients is deviated to Result Request
    elif "result" in patient["services"]:
        environment.process(resultRequest(environment, resources, statistics, patient))
```

Fig. 12.3 Model pseudocode and the Simpy implementation of function registration

Table 12.1 Worker numbers of new scenarios

Activity	Base scenario (1)	Scenario 2	Scenario 3	Scenario 4
Screening	1	1	1	1
Registration	2	2	2	3
Blood sampling	4	2	1	4
Materials delivery	1	1	1	1

and a precision of 0.1 min for the meantime in the queue. The results are presented in Table 12.2.

The resulting statistics were compared to the data from the hospital. The screening average size, for example, is aligned with the manager's estimate (3 min). Also, the patients' meantime in the system, according to the spreadsheets with the data collected in recent months by the hospital, varies from 25 min to 35 min. With the model's validation, we used it for complementary scenarios' simulation. The scenarios 2 and 3 represent nurses' reduction. The assignment of four nurses in this sector is unnecessary.

Tables 12.2 and 12.3 results suggest that at least one nurse, in the actual scenario, is idle, since the reduction for three nurses did not change the simulation's statistics. Reducing to two nurses in the blood sampling increases the average time in the system only 6.6% compared with the actual scenario, not affecting the queue size nor the average time in a queue.

The nurses' reallocation to more critical areas could be advantageous. In the third scenario, when the laboratory operates with only one nurse, the average waiting time in the blood sampling goes from almost zero to more than 40 min. This is relevant. If at any time there is a need for the reallocation of nurses, the laboratory will generate queues when the number of nurses is below two.

Another scenario is hiring another employee to perform the customer registration. The impact on the quality of service grows considerably with this supplement. The mean waiting time in the queue shows a reduction of 62%. It decreases from 17.67 min in the current scenario to 6.79 min in scenario 4. Currently, the registra-

Table 12.2 Results of base scenario and scenario 2

	Base scenario (1)				Scenario 2			
	Waiting (min)		Queue size		Waiting (min)		Queue size	
Queue	Avg.	Std.	Avg.	Std.	Avg	Std.	Avg	Std.
Screening	6.1	9.8	3.2	2.7	6.3	10.3	3.3	2.8
Register	11.6	15.7	6.4	3.6	11.6	15.1	6.3	3.7
B. Sampling	0.04	0.2	0.5	0.5	3.9	5.8	1.4	1.2
M. Delivery	0.3	0.8	0.5	0.5	0.3	0.8	0.5	0.5
Avg. time in system (min)	29.7				31.70			
Avg. time in queue (min)	17.06				19.53			

Table 12.3 Results of scenarios 3 and 4

	Scenario 3				Scenario 4			
	Waiting time (min)		Queue size		Waiting time (min)		Queue size	
Queue	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.
Screening	6.1	9.7	3.2	2.7	6.4	10.2	3.3	3.3
Register	11.5	15.4	6.3	3.6	0.2	0.6	0.5	0.5
B. Sampling	40.4	44.0	14.8	8.8	0.1	0.4	0.5	0.5
M. Delivery	0.3	0.8	0.5	0.5	0.5	1.0	0.6	0.6
Avg. time in system (min)	45.46				19.23			
Avg. time in queue (min)	34.03				7.00			

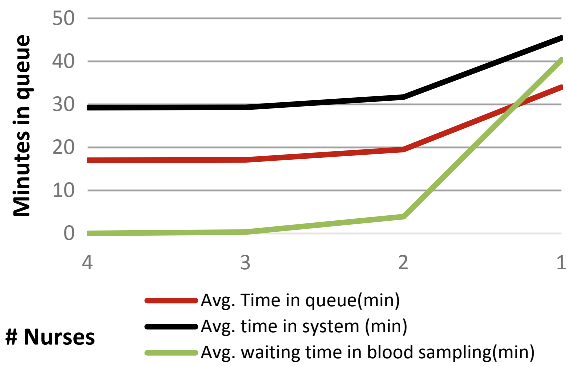

Fig. 12.4 Statistics of time in queue and time in system considering different number of nurses

tion of patients is the bottleneck of the system. With an increase of the number of professionals to register customers, the patients would spend a shorter time in the queue (see Fig. 12.4).

12.4 Conclusion

This study proposed a rearrangement of resources to balance activities in a hospital laboratory in Belo Horizonte evaluating queues composed of patients with four different profiles. They developed a simulation model implemented in Simpy proved to be efficient for modeling the particular healthcare problem. The study proposes the reduction of workforce in the laboratory establishing the minimum of two nurses to perform the blood sampling activity. Results also suggest an increasing in customer register capacity to reduce patients waiting time in queue by approximately half, improving the service level. We highlight that capacity increase does not mean inevitably hiring obligation. The capacity expansion can be also obtained by training, activity redesign, or by the adoption of better information technology systems.

Analyzing the scenarios, we conclude that implementing the suggested rearrangement could be advantageous to the hospital; however, further research about the nurse's activities is needed to complete this evaluation. Moreover, we plan to set the number of runs based on a confidence interval of 95% and precision of 0.1 min for the meantime in queue. These results show that using discrete event simulation in the context of healthcare system improve the user's knowledge about the system, enabling improvement actions such as reallocating resources. Finally, the proposed model can be adapted to similar healthcare systems. Further activities include the development of open-source generic healthcare operation's modules to enable a wider utilization.

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Chapter 13
An Integrated Model of Healthcare Facility Location and Equipment Allocation

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Abstract This study aims at locating Medical Specialties Centers' (MSCs) and allocates medical equipment to meet maximal demand for secondary public healthcare. Therefore, we propose an integrated model addressing both problems simultaneously, optimizing resource usage. As a result, we expect to contribute to the long-term healthcare planning.

Keywords Public healthcare planning · Facility location · Equipment allocation · Mixed-integer linear programming

13.1 Introduction

One of the biggest problems faced by vulnerable and less developed regions around the world is the difficulty of access to well-equipped public hospitals [1]. The health system regionalization process is complex; among other reasons, the social inequality, cultural, economic, and geographic heterogeneity affect the appeal to specialized workforce in these vulnerable places. Therefore, decisions regarding the best location of a new hospital and a medical equipment are essential to improve the access and attendance quality.

The facility location problem consists in determining the best place to assign facilities in a geographical space that satisfies demand, given an objective function, technical constraints and limited resources availability. Recently, equity in location problems has received increased attention mainly in the public sector, although the main challenge remains in fitting the best equity measure to each type of problem [2]. In this paper, we apply equity as the guarantee of minimum access [3] for the

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most vulnerable municipalities according to the social vulnerability indicator (SVI). We adopted the SVI to investigate real contexts as urban mobility and health access [4].

A recent survey on healthcare facility location problem shows the need to develop new models with more than one critical decision together to provide results that are closer to reality [5]. Aligned to recent trends, this research is a different approach of the maximal covering location problem (MCLP) introduced by Church and Revelle [6] and proposes an integrated model that settles MSCs locations and allocates equipment simultaneously to maximize demand coverage for medical specialties and exams in a Brazilian state.

The facility location–allocation problems are NP-hard. Major computational advances in integrated modeling have occurred since the 2000s [7]. Table 13.1 presents some papers that relate the elements presented in this study: maximum patient travel distance, limited resource, eligible municipalities, social equity, trade-off analysis, and case study.

A recent study presents the long-term healthcare planning with the objective function of minimizing the total cost, considering access, usage, socioeconomic, and geographical equity [3]. Although the paper addresses equity, it does not approach vulnerable regions and candidate municipalities' characteristics to select eligible places. These characteristics include minimum infrastructure to install and manage a hospital or a medical center. The selection of a candidate's location is also important to attract healthcare professionals, given that one of the major challenges is the lack

Table 13.1 Papers approaching integrated facility location–allocation problems

Reference	Max. travel distance	Resource limitation	Available resources	Eligible sites	Social equity	Trade-off analysis	Case study
Branas et al. [8]	x	x	x				x
Mak et al. [9]	x	x					
Cho et al. [10]	x	x					x
Delmelle et al. [11]	x	x	x			x	x
Cardoso et al. [3]	x	x	x				x
Mestre et al. [12]	x	x	x	x		x	x
Qi et al. [13]		x	x	x			x

of a skilled workforce in developing regions. The present paper contributes to the recent studies approaching vulnerable regions and maximizing demand coverage to provide quality healthcare to all residents.

The challenges addressed in this paper are manifold. It investigates mathematically the interdependence between medical specialties demand and exams. An exam is performed exclusively after a medical specialty attendance. Besides, equipment can be acquired only if a municipality is chosen to be a location for a new MSC. Moreover, from a practical viewpoint, it is mandatory to recognize potential locations to maintain a medical center running. The study insights can contribute to long-term healthcare planning by proposing an integrated model that maximizes demand coverage and optimizes resource use, concerning equity by social indicators. In the following section, we describe the problem and the data adopted for the case study. Next, Sect. 13.3 presents the results and a discussion across scenarios. We finish by providing a conclusion and suggestions for future work in Sect. 13.4.

13.2 Problem Description

The problem consists in locating new MSCs to meet population demand for specialized medical care and exams. Each MSC will attend nine medical specialties that express the main patients' health services demand in the state; according to the demographic synopsis, epidemiological profile, aging, and economic growth: cardiology, pediatrics, mastology, gynecology, endocrinology, ophthalmology, nephrology, urology, and angiology. Then, the regular equipment used by these medical specialties will be allocated to satisfy the demand for exams: tomography, mammography, magnetic resonance, Doppler and conventional ultrasound.

The demand for medical specialties and exams on a municipality level considers the number of inhabitants and the Ministry of Health ordinance 1631, of October 1, 2015, [14] that estimates the desired number of physicians and exams for each specialty and equipment. The municipalities' population were estimated by 2015 based on the last Brazilian Institute for Geography and Statistics census, in 2010. The demand is from the secondary public healthcare system [15]. The distance between municipalities was obtained from Google API [16] and the number of physicians and equipment by municipality, from DATASUS [17]. The number of physicians determines the health region capacity by specialty and the quantity of equipment per municipality sets exams execution capacity.

The model should consider the demand for medical assistance and exams to set MSCs location and equipment allocation simultaneously. In that way, it is essential to establish a link between specialties and equipment by analyzing exams, and the model should be flexible in setting both the number of specialists and equipment.

13.2.1 Mathematical Model

This section presents the mathematical formulation. The notation used for sets, parameters, and variables is presented in Table 13.2.

The proposed mixed-integer linear programming (MILP) model is presented as follows:

$$\text{Max} \sum_{i \in I} \sum_{j \in J} \sum_{e \in E} \text{DM}_{ie} x_{ije} - \sum_{m \in M} \sum_{e \in E} h_{me} + \sum_{i \in I} \sum_{j \in J} \sum_{q \in Q} \text{DE}_{iq} v_{ijq} - \sum_{j \in J} \sum_{q \in Q} w_{jq} \tag{13.1}$$

The objective function, on Eq. (13.1), aims at satisfying the demand for specialists and medical exams and avoids the need for extra specialists and new equipment. The demand and extra hours are on the same units (hours/week). Although the demand and extra hours for specialist have less weight in terms of data representativity, a demand for equipment is only met if first there is a patient attended on a related specialty, Eqs. (13.20–13.23). Therefore, the patient attendance is prioritized before having extra hours of equipment. The extra hour of equipment and physicians will only be required if necessary according to the available capacity on the state, constraints (13.10–13.12), and the number of equipment and MSCs available for purchase, limited by the state budget, constraints (13.7–13.9). Equations (13.2–13.6) refer to demand allocation for medical services of each municipality for an open MSC.

$$\sum_{j \in J} x_{ije} \leq 1 \quad \forall i \in I,\ e \in E \tag{13.2}$$

$$x_{ije} - y_j \leq 0 \quad \forall i \in I,\ j \in J,\ e \in E \tag{13.3}$$

$$x_{jje} - y_j = 0 \quad \forall j \in J,\ e \in E \tag{13.4}$$

$$\sum_{j \in J} v_{ijq} \leq 1 \quad \forall i \in I,\ q \in Q \tag{13.5}$$

$$v_{ijq} \leq y_j \quad \forall i \in I,\ j \in J,\ q \in Q : K_{jq} = 0 \tag{13.6}$$

$$\sum_{j \in J} y_j \leq \text{NC} \tag{13.7}$$

$$\sum_{j \in J} w_{jq} \leq \text{NE}_q C_q \quad \forall q \in Q \tag{13.8}$$

$$w_{jq} \leq \text{NE}_q C_q y_j \quad \forall j \in J,\ q \in Q \tag{13.9}$$

Table 13.2 Data and variables of the healthcare facility location–allocation model

Sets	Description	
I_1	Subset of less vulnerable municipalities	
I_2	Subset of more vulnerable municipalities	
$I = I_1\ u\ I_2$	Origin municipalities (demand). Represented by the 853 municipalities of MG	
J	Destination municipalities	
M	Healthcare regions	
Q	Equipment	
E	Medical specialties	
Parameters	Description	Unit
DM_{ie}	Demand of patients from municipality i by medical specialties e	Hours/week
DE_{iq}	Demand of patients from municipality i by medical equipment q	Hours/week
D_{ij}	Distance between district i and facility j	Km
PE_j	Indicate if registered production in at least 3 specialties per municipality j	Binary
NC	Maximum number of secondary healthcare facilities	Facilities
NE_q	Number of available equipment q to be acquired	Equipment
P_i	Inhabitants per municipality i	People
$P_{\min}$	Minimum population per candidate municipality	People
$D_{\max}$	Maximum distance between a municipality and a facility	Km
R_{jm}	Indicate if municipality j is located in region m	Binary
O_{me}	Availability of medical specialties e in region m	Hours/week
SV Ii	Indicator of social vulnerability per municipality i	Scalar
ES	Level of demand attendance for subset $I2$	Percentage
K_{jq}	Exams availability per municipality j and equipment q	Hours/week
C_q	Nominal equipment capacity q	Hours/week
MX_{eq}	Indicate if specialty e uses equipment q	Binary
Variables	Description	Unit
x_{ije}	If demand of municipality i is met by specialty e in municipality j	Binary
y_j	If a healthcare facility is located in municipality j	Binary
h_{me}	Additional hours of specialties e to be hired for region m	Hours/week
l_{ej}	Total allocated demand for municipality j and specialty e	Hours/week
v_{ijq}	If demand of municipality i by exam q is met in municipality j	Binary
w_{jq}	Additional hours of exam used by equipment q from municipality j	Hours/week

$$\sum_{i \in I} \mathrm{DM}_{ie} x_{ije} = l_{ej} \tag{13.10}$$

$$\sum_{j \in J : R_{jm}=1} l_{ej} \leq O_{me} + h_{me} \quad \forall m \in M,\ e \in E \tag{13.11}$$

$$\sum_{i \in I} \mathrm{DE}_{iq} v_{ijq} \leq K_{jq} + w_{jq} \quad \forall j \in J,\ q \in Q \tag{13.12}$$

Equations (13.13) and (13.14) respect the patient historical flow to be attended, with a travel limit of a maximal distance, Eqs. (13.17) and (13.18). Equations (13.15) and (13.16) select the eligible places to open a MSC-based on specialty patient history of attendance and municipality population size, respectively. On Eq. (13.19), the attendance level of most vulnerable municipalities should be satisfied. Equations (13.20–13.23) link medical specialist appointments to exams conducted on equipment. Constraints (13.24–13.29) present the variables domain.

$$P_i x_{ije} \leq P_j x_{ije} \quad \forall e \in E,\ i \in I,\ j \in J \tag{13.13}$$

$$P_i v_{ijq} \leq P_j v_{ijq} \quad \forall q \in Q,\ i \in I,\ j \in J \tag{13.14}$$

$$PE_j \geq y_j \quad \forall j \in J \tag{13.15}$$

$$P_j \geq P_{\mathrm{min}} y_j \quad \forall j \in J \tag{13.16}$$

$$D_{ij} x_{ije} \leq D_{\mathrm{max}} \quad \forall i \in I,\ j \in J,\ e \in E \tag{13.17}$$

$$D_{ij} v_{ijq} \leq D_{\mathrm{max}} \quad \forall i \in I,\ j \in J,\ q \in Q \tag{13.18}$$

$$\sum_{i \in I_2, j \in J} \mathrm{DM}_{ie} x_{ije} / \sum_{i \in I_2,} \mathrm{DM}_{ie} \geq \mathrm{ES} \quad \forall e \in E \tag{13.19}$$

$$\sum_{j \in J, q \in Q} v_{ijq} \leq \sum_{e \in E, j \in J} x_{ije} \quad \forall i \in I \tag{13.20}$$

$$\sum_{j \in J} v_{ijq} \leq \sum_{e \in E, j \in J} x_{ije} \mathrm{MX}_{eq} \quad \forall i \in I,\ q \in Q \tag{13.21}$$

$$v_{ijq} \mathrm{MX}_{eq} \leq x_{ije} \mathrm{MX}_{eq} \quad \forall i \in I,\ j \in J,\ e \in E,\ q \in Q : K_{iq} = 0 \tag{13.22}$$

$$v_{ijq} \leq 0 \quad \forall i \in I,\ j \in J,\ q \in Q : i \neq j K_{iq} \geq 0 \tag{13.23}$$

$$x_{ije} \in \{0, 1\} \quad \forall i \in I,\ j \in J,\ e \in E \tag{13.24}$$

$$y_j \in \{0, 1\} \quad \forall j \in J \tag{13.25}$$

$$l_{je} \geq 0 \quad \forall j \in J,\ e \in E \tag{13.26}$$

$$h_{me} \geq 0 \quad \forall m \in M,\ e \in E \tag{13.27}$$

$$v_{ijq} \in \{0, 1\} \quad \forall i \in I,\ j \in J,\ q \in Q \tag{13.28}$$

$$w_{jq} \geq 0 \quad \forall j \in J,\ q \in Q \tag{13.29}$$

13.3 Case Study

We apply the proposed method in Minas Gerais, a state located in the southeast, which has the second largest population in Brazil estimated in 2017 [18]. The state has 853 municipalities and 77 health regions [17]. Among the 853 municipalities, 26.1% (223) have up to 5000 inhabitants, 86% (734) have up to 30,000 inhabitants, and only 3.1% (13.27) have more than 100,000 inhabitants.

The socioeconomic and demographic inequality between regions is a major problem. The Jequitinhonha/Mucuri and Rio Doce are the most vulnerable regions reflecting the communities' difficulties and the challenge of healthcare managers in operations planning. Furthermore, the developed municipalities of the central and south regions concentrate on hospitals, equipment, and medical specialists, highlighting the residents' unequal access to healthcare.

The secondary care requires equipment of high technology, which is mostly in urban centers. For instance, the public mammography of the state is located mainly in the central and southeast region, and its total capacity can cover only about 38% of residents' demand. There is a high dependence on the use of the private sector equipment, as the government funds the complementary demand for exams to private health units at market price [19].

We suggest a strategic solution to these problems, which is to locate MSC to provide medical care and to allocate equipment to these units considering the available network.

13.3.1 Results

This section presents the study results and sets the optimal number, and MSC location, and equipment. Finally, we analyze the trade-off concerning the location and allocation decisions.

13.3.1.1 Maximal Demand Attendance

The minimum number of MSC, with the optimal number of specialists and equipment to meet the maximal demand attendance for specialty and examinations, was determined by using an extreme scenario: maximum number of MSC (NC) is equal to the 116 candidate municipalities, thousand pieces of equipment available for acquisition (NE_q) for each type of equipment, a coverage range agreed by medical and engineering experts in 200 km and a SVI limit value of 0.301. The objective function results with the demand met in physicians and examinations, and the additional hours of specialists and examination are presented in Table 13.3.

The model met 99.1% of the demand for medical specialty with 19,630 additional hours of specialists' services. However, it obtained low attendance in demand for exams, 32.4%, being necessary 44,110 additional hours, which represents to increase the number of physicians by 4.1%, while for new equipment it is necessary to acquire around 1.5%. The covered demand from the most vulnerable group was 97.9%. The low-level fulfillment in exams demand is explained by the quantity of available hours for conventional ultrasound and mammography that is below the necessary to cover all demand.

Eighty MSCs were selected to meet the demand for specialists (Fig. 13.1a). The municipalities chosen to attend examinations include those already with available capacity in any of the five types of equipment, which is equivalent to 182 municipalities highlighted in gray on the map in Fig. 13.1b, and Almenara, in red, stands out as

Table 13.3 Results of the objective function

Demand for medical specialty attendance	290,613 (99.1%)
Additional hours	19,630
Demand for medical examination attendance	823,041 (32.4%)
Additional exams	44,110
Total	1,049,914

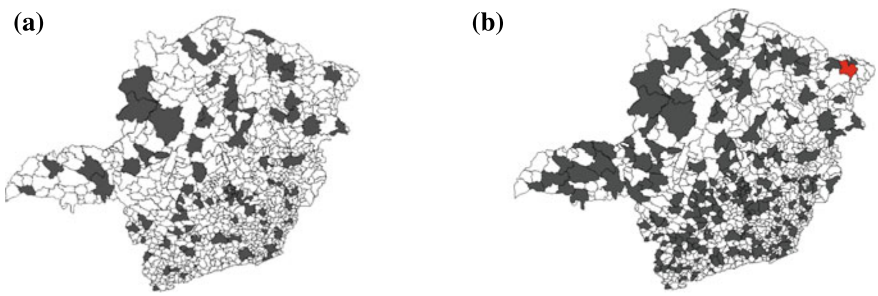

Fig. 13.1 Selected municipalities to receive service, **a**—Municipalities to receive an MSC in grey, **b**—Municipalities to attend a demand for examination in grey, and Almenara, in red

the only municipality to receive an exam care that does not have available capacity in any of the five-piece equipment considered.

From the 77 health regions, 55 require complementary hours in at least one specialty, except ophthalmology. The most deficient regions in specialists are concentrated in the north and northeast of the state, which can be explained by the uneven physicians' distribution along the state. For this, one solution would be the labor hiring or the redistribution of physicians among the poorest regions. In terms of exams, conventional ultrasound is the equipment with the major extra need. The analysis for additional exams can be solved by evaluating the best cost–benefit, whether to purchase exams at market price through contracts with the private sector or to purchase new equipment. Thus, the managers should evaluate the feasibility of purchasing, maintaining, and operating this new equipment in relation to the cost to execute in the private network.

Thirty-six different scenarios were also analyzed, with instances altering in number of MSC and equipment, maximum coverage distance and the SVI value. From these scenarios, the results show that increasing the number of MSC, after a determined amount, may not bring significant gains in total demand coverage. For example, with an increase of 50% on the number of MSC, the total demand coverage raises in 22.6%. After that point, following the growth of MSC in 25%, the total coverage raises only 1.29%. The same occurs by varying the number of new equipment. By increasing this number in ten times, there is a gain of only 0.09% in exams coverage. These remarks indicate that after determined growth, installing new centers or procuring new equipment does not imply on-demand coverage at the same rate, which indicates that it is necessary to adjust the maximal travel distance and the characteristics to eligible places, allowing the installation of new equipment in less developed municipalities.

13.3.1.2 Trade-Off Analyses

In some circumstances, meeting the demand in medical specialty may have greater noticed value than the attendance in exams or the opposite. Thus, this section analyses the integrated model when assigning different weights to the two choices as demonstrated in Eqs. (13.30–13.32).

$$\text{Max } \alpha f_1 + (1-\alpha) f_2 \tag{13.30}$$

$$f_1 = \sum_{i\in I}\sum_{j\in J}\sum_{e\in E} \text{DM}_{ie} x_{ije} - \sum_{m\in M}\sum_{e\in E} h_{me} \tag{13.31}$$

$$f_2 = \sum_{i\in I}\sum_{j\in J}\sum_{q\in Q} \text{DE}_{iq} v_{ijq} - \sum_{j\in J}\sum_{q\in Q} w_{jq} \tag{13.32}$$

The objective function results for each weight show that when prioritizing medical examination attendance, all the effort allocated to this service is also converted to attendance in specialized service; therefore, the highest final service coverage is obtained. The greater attendance of the demand for specialists and exams requires greater additional hours for physicians, examinations, and the number of new specialized centers.

For alpha is equal to zero, there is the highest need for new MSC (115), as a consequence of the greatest total attendance: 99.95% medical and 36.47% for exam. However, it is interesting to emphasize that for the second most coverage, 98.80% for specialty and 31.59% for exam, represented by alpha is equal to 0.1, the number of new MSCs decreases to 76, while the need for extra medical hours reduces 78% and for extra hours in equipment in 84%, approximately. This indicates that the extreme scenario cannot represent the best cost–benefit. When analyzing the other extreme, alpha is equal to 1, there is the worst scenario: 98.43% of specialty demand coverage, with 0.00% of exam. There is no coverage in exams because the medical attendance decision does not depend on the exam attendance, but rather the opposite.

This result reinforces the trade-off between service and resource needs. The higher the final patients' coverage, the greater the costs of the installation, maintenance, and operation of the new center and the necessity of equipment to reach this coverage. Therefore, with this analysis, an ideal result can be obtained to attend users demand and respecting the budget limit.

13.4 Conclusions and Discussion

This paper set out the simultaneous facilities location and resource allocation problem in the public health sector. The purpose was to set the location to install MSCs and assign medical equipment in order to satisfy residents' demand and avoid the use of supplementary resources. The relationship linking the two decisions imposes a challenge on the problem, which incites the investigation of an integrated approach to solve this problem.

When applying to a real data context, the findings suggest that an increase in the budget for new MSC and new equipment may not determine direct gain in population demand coverage. This indicates that it is crucial to improve the available equipment use and specialists' administration, considering the population supply and demand. In addition, the trade-off investigation has the purpose of supporting decision makers considering priorities.

This study presents some limitations. First, since data collection was made from the public health system, it may contain omissions or incorrect values. The second is the available resources, such as the number of MSC, physicians, and equipment, that may vary according to each context. Moreover, this work simplifies the relation of one examination to one attendance. In future works, it can investigate the relation of more than one examination to one medical appointment.

Finally, despite the proposed application is in a state of Brazil, the integrated approach can contribute to future works with a similar problem in other healthcare divisions. The present study described how operational research can contribute to the decision-making process through the effective use of public resources influencing the population's better-living conditions.

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Chapter 14
Improving Operation Rooms and Planning to Reduce Surgery Cancelations and Inpatient Length of Stay

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Abstract We apply process modeling and simulation to improve surgery planning, through the coordination of operation rooms and intensive care unit (ICU). A case study was carried out in a Brazilian hospital. With the proposed changes, we obtained a 39% reduction in surgery cancelations and a 61% decrease in preoperative length of stay.

Keywords Operation room · Intensive care unit (ICU) · Simulation

14.1 Introduction

The surgical center (SC) is often the highest cost and revenue department in a hospital and therefore exerts a major impact on the performance of the hospital as a whole [3]. The flow followed by a patient scheduled for an operation involves a number of stages. Each stage requires specific resources, as personnel (such as surgeons, anesthetists and nurses), and specialized equipment and facilities (preoperative facilities, operation rooms, post-anesthesia care units, etc.), which must be synchronized [5]. Blake and Carter [2] note that in addition to resources directly related to the SC, external resources (e.g., the intensive care unit (ICU) and ward beds) must also be scheduled.

Knowing that surgery planning is affected by various factors and involves coordination of resources and activities in uncertain environments, we sought to investigate a planning problem at the operational level involving coordination of the SC with external resources (the ICU) in a Brazilian public hospital. Of note, a surgical center

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(SC) is composed by a set of operation rooms (OR, also referred in the literature as operating theater); in this article, we use SC and OR as interchangeable terms.

In the literature on OR planning and scheduling, discrete event simulation (DES) is used for many different purposes. At an operational level, it is frequently used to evaluate different ways of allocating and sequencing surgical procedures in ORs [4, 7, 9, 10, 15, 16]. There are also studies on rescheduling, in which the schedule is adjusted on the day of surgery when the schedule is subjected to disruptions. An example is the paper of Allen et al. [1]. Many papers evaluating the utilization of the SC and associated resources can also be found in the literature [6, 17].

Monte Carlo simulation (MCS) is used in, for example, by Lebowitz [8], in which various combinations of short and long surgical procedures are scheduled, and by Paoletti and Marty [13], in which the objective is to calculate the likelihood of an anesthetist being needed simultaneously in two ORs.

While computer simulation has been widely used to analyze various metrics in SC performance, there are few articles that integrate the surgery booking and scheduling process with resources outside the SC. However, the number of papers that integrate booking and scheduling decisions with factors related to ICU resources is very small.

In Brazilian hospitals, most decisions related to bed and SC management are based on tacit knowledge and limited empirical observation, leading to long waiting lists and low service levels. In this article, we use Monte Carlo simulation and discrete event simulation (DES) to identify opportunities for improving the surgery planning process. The aim of the study was to analyze the activities involved in surgical procedures in the hospital, where the main problem is the high surgery cancelation rate.

To this end, we utilize Monte Carlo simulation to identify how better use could be made of beds in the ICU so that bookings would be more in line with the available ICU capacity. Then, we evaluate the proposed changes to the booking process for surgical procedures requiring postoperative admission to the ICU and investigate the impact of the suggested changes on length of stay (LOS) and surgery cancelation rate using DES.

This article is divided into five sections including this one. Section 14.2 describes the problem. Section 14.3 presents the solution framework. Section 14.4 presents the results and discussion, and the conclusions are given in Sect. 14.5.

14.2 Problem Statement

The case studied is a Brazilian public hospital that was set up to carry out medium- and high-complexity neurologic, vascular and orthopedic surgery. It has a mean capacity of 350 admissions per month. The hospital has wards for each specialty with a total of 145 beds as well as an ICU with 18 beds. There are five ORs. All have different characteristics and are assigned to each specialty according to these.

The main problems mentioned by senior management at the hospital were the high surgery cancelation rate and excessive LOS. Many visits were made to the hospital in order to identify the root cause of the problem mentioned. In these visits, we interview the SC nursing coordinator, the nursing manager and the ICU coordinator; we observe the activities related to the surgery planning process in the hospital; we perform the modeling using BPMN 2.0 (Business Process Model and Notation)—(Object Management Group [11]); and we collect data about patient admissions, operations and internal transfers over one year, data on surgery scheduling, including details of bookings and information about each patient scheduled between April and December 2014, as well as data on the reasons for surgery cancelations between July and December 2014. The data were taken from the hospital electronic medical records (EMRs). The interviews and visits were carried out in the same year of data collection. The situation continues to reflect the reality lived in the hospital because, according to recent contact with senior management, the hospital processes have not yet been changed and the case mix of patients also remains the same.

By the process modeling and data analysis, the main reason for cancelations is a shortage of beds in the ICU, about 57% of the cancelations. Under the hospital's current policy, surgical procedures requiring postoperative admission to the ICU are scheduled without information about expected patient discharges from the ICU. Consequently, there is a tendency for more bookings for procedures requiring post-operative admission to the ICU to be made than there is capacity for, resulting in a high cancelation rate. To address this issue, we proposed a framework based on MCS and DES that is detailed in the following sections.

14.3 Solution Framework

Since the major cause of surgery cancelations is the shortage of beds in the ICU, the senior management at the hospital want to know: How many surgical procedures requiring postoperative admission to the ICU should be scheduled per day in order to reduce the number of cancelations?

For this, we used MCS to establish the ideal number of bookings/day requiring postoperative admission to the ICU and we used DES to test the proposed changes to the booking process at the hospital and to evaluate whether it would provide the expected benefits in terms of a reduction in the number of cancelations and a shorter LOS. Figure 14.1 shows how the techniques are used to solve the problem.

Fig. 14.1 Solution framework proposed

It should be stressed that only regular elective cases were considered, as emergency and outpatient cases are rare and have little influence on hospital planning.

14.3.1 Monte Carlo Simulation

An average of 12 surgical procedures is carried out every day in the hospital studied, but an average of 14 is scheduled. Approximately 50% of the surgical procedures require postoperative admission to the ICU. However, the number of beds available each day at the ICU is not sufficient to meet this demand. This is the main reason why procedures are canceled.

In practice, not all patients for whom the ICU has been recommended will actually need to be admitted to the unit due to other reasons for cancelation, as shown in Table 14.1. There are also some patients for whom the ICU was recommended who do not actually use a bed there because their clinical condition was reassessed during surgery. The data for the ICU are given in Table 14.1.

As said previously, surgical procedures requiring postoperative admission to the ICU are scheduled without information about expected patient discharges from the ICU. Therefore, we carried out an MCS to identify a better surgery booking policy for the hospital and support decision-making regarding the number of bookings requiring postoperative admission to the ICU that should be made each day.

A trade-off was sought between the number of surgery cancelations and the number of empty beds in the ICU, as a large number of surgical procedures requiring postoperative admission to the ICU each day imply a large number of surgery cancelations. However, if there are fewer bookings, there may be empty beds in the ICU and a longer LOS.

Using the historical data, the distributions of the three data series in Table 14.1 were determined. The series correspond to the percentage of patients scheduled for surgery with postoperative admission to the ICU who did not performed the surgery (NR), the percentage of patients who underwent surgery but did not use an ICU bed (R_{S_ICU}) and the number of discharges from the ICU each day (A_{ICU}). The chi-square test was used to identify the best-fit distribution for each series, as it can be used for

Table 14.1 Appointments for surgery requiring admission to the ICU

	Scheduled procedures requiring ICU	Not performed for different reasons	Performed but ICU not used	ICU beds needed	ICU beds available	Canceled because of lack of ICU beds
Total	829	122	188	519	426	161
Daily average	7.5	1.3	2.2	6.2	3.9	2.5
Max	18	4	6	10	8	8

Fig. 14.2 Logic of the experiments in the Monte Carlo simulation

Procedure for Monte Carlo Simulation

Let $\mathbf{X_{ICU}}$ be the number of scheduled surgical procedures requiring postoperative admission to the ICU and j the number of iterations for each X_{ICU}. Let $\mathbf{X_{ICU}}$ range from 3 to 12;

Let **NR** be the number of surgical procedures requiring postoperative admission to the ICU that were not performed for different reasons;

Let $\mathbf{Rs\_{ICU}}$ be the number of surgical procedures requiring postoperative admission to the ICU for which an ICU bed was not actually required;

Let **QV** be the number of ICU beds actually needed each day, $\mathbf{A_{ICU}}$ the number of discharges from the ICU, **S** the number of cancelled procedures and **VO** the number of empty beds in the ICU;

Let **min** and **max** be the minimum and maximum number of procedures requiring postoperative admission to the ICU;

```
For XICU = min : max
   For j = 1:10000
      NR = Exponential (λ);
      Rs_ICU = Triangular (a,b,c);
      QV = XICU − NR − Rs_ICU;
      AICU = Binomial (n,p);
         If AICU < QV
            S = QV − AICU
         Else
         If AICU > QV
            VO = AICU − QV
         End If
   End
End
```

continuous and discrete data [12]. The results indicate that NR has an exponential distribution (0.1), R_{S_ICU} a triangular distribution (0; 0; 0.7) and A_{ICU} a binomial distribution (9; 0.4).

Ten experiments were run, each of which corresponded to analysis of a number/day of scheduled surgical procedures requiring postoperative admission to the ICU. For each experiment, 10,000 iterations were performed to guarantee convergence to the expected values. Figure 14.2 shows the logic of the experiments.

14.3.2 Discrete Event Simulation

The DES model was developed (in Arena Simulation [14]) to identify whether the limit on surgery bookings defined with MCS could reduce the preoperative LOS, measured from the time the patient was admitted to hospital to the time when the operation had been performed. The length of the postoperative stay depends exclusively on clinical aspects and thus is out of scope of our study.

Figure 14.3 shows the flowchart of the simulated surgery planning and scheduling process at the hospital studied in BPMN 2.0. The model has three main parts: (A) arrival of patients for admission and subsequent surgery in the SC, (B) booking surgery and clearing patients for surgery and (C) release of beds in the ICU.

We carried out the initial tests to ensure that the model accurately reflected the situation in the hospital. Based on a number of experiments, it was determined that a 30-day warm-up period and 10 replications would be used to ensure that ward occupancy corresponded to the real starting conditions. Each replication simulated 270 days of operations, similar to the period the real observations were made. The model was validated by comparing the real hospital data with the values of the output variables that had the greatest influence in the study. The simulated data accurately reflect the real data, as the percentage variation is less than 10%. To confirm that the simulated and real data can be considered equivalent, a t-test was used to compare them at a significance level of 95% ($\alpha = 0.05$). For all the control variables tested, the hypothesis of equivalent means could not be rejected.

14.4 Numerical Results and Discussion

The results of the MCS experiments are shown in Fig. 14.4. As mentioned previously, there is a trade-off between canceled procedures and empty ICU beds.

Each point on the graph represents the mean number of cancelations/empty beds in the experiments for a given number of simulated bookings per day. For example, for four bookings per day requiring postoperative admission to the ICU, there are 0.7 empty beds and 0.5 cancelations.

If it is more important for the hospital to avoid cancelations, five operations requiring postoperative admission to the ICU should be scheduled, but if avoiding empty beds in the ICU and reducing LOS have greater priority, then six bookings should be made.

Once the DES model had been verified and validated (as discussed in Sect. 14.3.2), the idea of imposing a daily limit on the number of surgical procedures requiring postoperative admission to the ICU could be evaluated. The limit of six surgery bookings per day determined in the Monte Carlo simulation was used in the tests with the DES model and yielded a 61% reduction in the LOS. The results are shown in Table 14.2.

Significant reductions in surgery cancelations were achieved. The most significant reduction (53%) was in cancelations due to a shortage of ICU beds. There was a 14% reduction in cancelations for other reasons and an overall improvement of 39% in surgery cancelations.

As there was a substantial reduction in the number of cancelations and the LOS, more patients can be treated in the hospital. A simulation was therefore run using the proposed policy (a fixed number of six bookings requiring postoperative admission

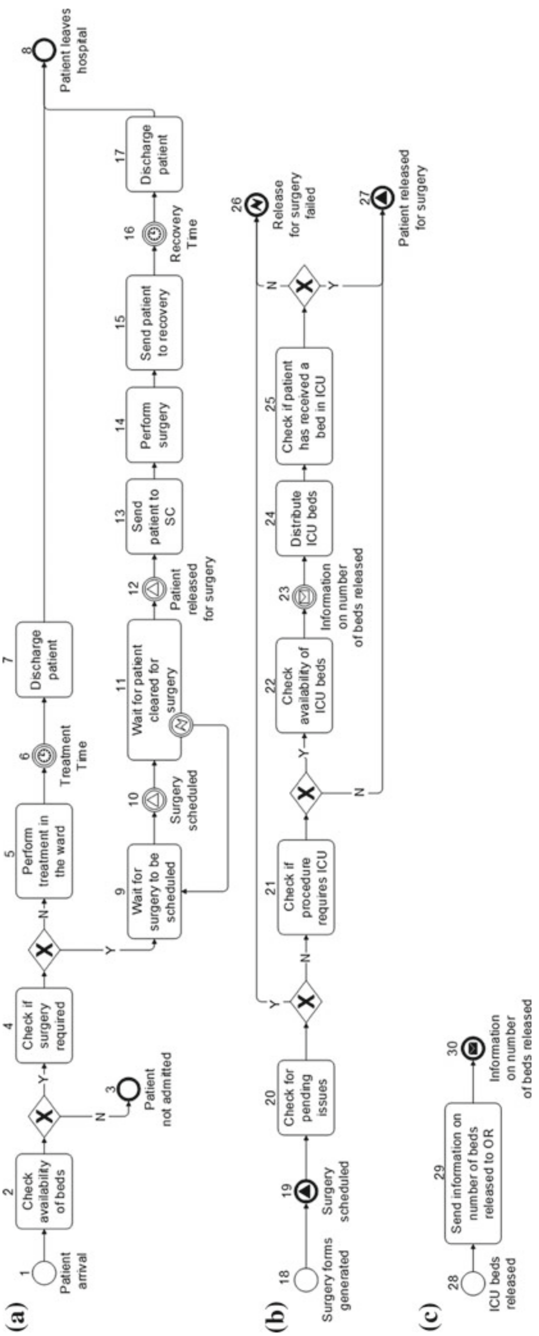

Fig. 14.3 Flowchart of the conceptual model

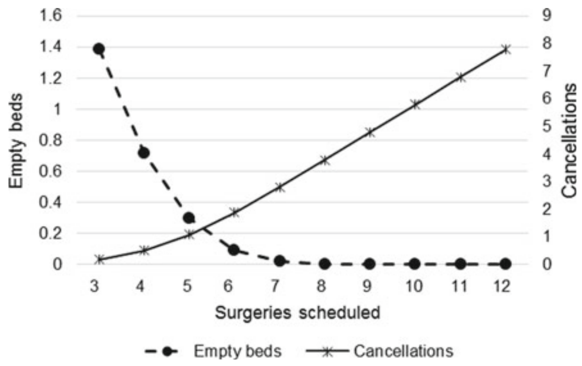

Fig. 14.4 ICU empty beds and number of canceled surgeries

Table 14.2 Reduction in the LOS

Variable analyzed	Actual (days)	Simulated six scheduled procedures requiring ICU (days)	Percentage reduced (%)
Overall LOS	7.0	2.7	61
LOS for neurologic procedures	10.6	2.0	81
LOS for orthopedic procedures	5.1	2.8	44
LOS for vascular procedures	6.5	3.1	53

to the ICU) and a higher patient arrival rate. With this policy, the number of scheduled neurologic and orthopedic procedures can be increased by 30% and the number of vascular procedures by 10% while keeping mean surgery waiting time below the actual waiting time observed in the hospital. This corresponds to a potential increase of 19% in the overall number of procedures.

In practice, the solutions identified help solve an important, real problem and can improve quality of service by reducing the LOS and increasing the number of patients treated in the hospital. The results of this study hold promise for healthcare provision in Brazil as users of the public healthcare system face long queues and low service levels because of insufficient use of advanced techniques for decision-making in bed and SC management. The results can therefore be expected to contribute to a general improvement in the Brazilian public health system, as the proposals described here allow hospitals to treat more patients because of the reduced LOS and greater turnover of beds.

14.5 Conclusions

The study showed that OR planning and scheduling are affected by various factors and involve coordinating a range of resources and performing different activities in an uncertain environment. When coordination of OR planning and scheduling takes into account resources outside the SC, better overall hospital performance can be achieved. Using the solution framework proposed in this study, which is based in Monte Carlo Simulation and Discrete Event Simulation, to establish the number of surgeries requiring postoperative admission to the ICU should be scheduled per day, the hospital expect to achieve 39% of reduction in number of surgery cancellations and 61% of reduction in overall LOS. The use of MSC is important to establish the number of surgeries requiring postoperative admission to the ICU should be scheduled per day DES as it is important to evaluate the impact of this on hospital operation.

Further studies could include an analysis of bed occupancy in the wards, as once the number of patients treated in the hospital increases, beds tend to become a critical resource. Thus, it is possible to evaluate the redistribution of beds in each specialty or identify opportunities to improve the number of wards or ICU beds. In addition, an optimization study to define which patients should be scheduled each day and for each room could also be undertaken to increase OR utilization.

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Chapter 15
Application of Layout Analysis in the Pediatric Emergency of a Teaching Hospital

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Abstract The HUAP is a teaching hospital affiliated with the Fluminense Federal University. This study aimed to improve patient flow and reduce departmental crowding in the pediatric emergency room. A layout analysis with its tools was performed. Findings may reduce time in the triage area by providing better patient accommodation.

Keywords Health care · Process improvement · Layout

15.1 Introduction

The layout analysis arises from the need to make a strategic planning that meets the client's expectations and also calculate appropriate physical space to the activities and machines. According to Perretti [1], the study of layout has several advantages, such as minimizing the staff, materials, and information flow. According to Moreira [2], decisions about layout have great relevance, since they may affect the installation capacity and the productivity of the operations. If facilities are poorly designed and managed, they may imply financial losses and higher costs.

In terms of procedures, a great analysis is important to identify bottlenecks and present improvements. The processes can be improved in two ways: One is refining the product, and another is updating the manufacturing methods, by Shingo [3]. Process improvement method applications can reduce costs, increase productivity, reduce number of failures and rework, increase product reliability, and improve customer satisfaction [4].

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The chosen organization was the Antônio Pedro Teaching Hospital (HUAP), a federal institution affiliated with the Federal Fluminense University. The HUAP provides health services to the population and teaches the medicine and nursing students.

The article is organized as follows: After introduction, the literature review is developed briefly in item 2. The methodology is defined in item 3, and then, in item 4, the study case is presented. Item 5 finalizes the work, by discussing the conclusions. Finally, the references used are presented.

15.2 Literature Review

15.2.1 Layout Study

With the intent of increasing productivity, in a specific work environment, and causing a better experience for the worker, in ergonomic terms, the need to study the layout arises. According to Slack [5], the layout studies is one of the most evident characteristics of a productive operation, due to its shape and appearance.

For the health area, the benefits are clear; according to Souza et al. [6], the study of the facilities can result in many benefits for hospitals such as wider space for employees and trolleys to move around, better use of storage space, and minimizing the effort and delivery time of drugs.

In order to analyze the layout, there are some tools, among them the relationship diagram. According to Slack [5], it is a qualitative method of indicating the importance of the relationships between the areas, indicating how desirable it is to keep the center pairs together. Another tool that is widely used is the mapofluxogram, which represents the movements of an item through the processing centers arranged in the layout, following a fixed sequence or routine [7]. According to Milhomem et al. [8], the main characteristic of this tool is the studies about the physical space where the productive processes are being carried out, obtaining a broad view of the whole process, demonstrating movements of different pavements.

15.3 Methodology

Information was collected during the visits to the hospital and through a semi-structured interview with the employees and with the director of nursing. They were questioned about the procedures of care, the routine of hospitalized patients, and the difficulties of their work.

In the analysis process, the need to come up with a mapofluxogram and a relationship diagram was raised. From these, two proposals of layout were conceived for the pediatric emergency department of the hospital.

15.4 Case Study

15.4.1 Process Analysis

Among the several problems listed by the head of nursing, the main ones are faulty double doors, the nursing station is in a higher ground, difficulty in moving beds and cribs around, wet counter too close to the dry counter, nurses cannot constantly observe the patients due to misplaced walls, tight spot for parents/guardians to be around their children, inconvenient location of the water filter and bottle warmer, and the small size of the play area.

Due to the crowded space, it is very difficult to move the beds in order to meet the patient's needs. The pediatric emergency services admit newborns to teenagers under the age of 16; therefore, it is important to be able to switch places between beds and cribs. In addition, patients must be close to switch plugs and oxygen points.

At the nursing station, the dry and the wet counter are connected and at different height levels. So when the tap is on, the water goes all the way to the dry counter where the medicines are stocked. Besides that, the disposal of the nursing station does not allow visualization of all patients, which makes it difficult for nurses to take a fast response toward the patients.

The spot where the water filter and bottle warmer are placed must change. Since both objects are in the children reach, accidents may occur.

In Brazil, it is demanded that hospitals have a play area with books and toys for the children. At HUAP, the play area concerns a small table and a bookshelf with few books. Children usually stay at the hospital for a week, so it is important that they have play time due to the fact that they cannot leave the ICU area.

Considering all of the problems already listed, the most significant ones are the disposal and location of the nursing station, the play area, moving beds, and cribs around. Since it is important to be always monitoring the children, the nurse station needed to be elevated by a foot tall. In addition, we aim to easy up the beds switching and by that reduce the nurse's physical exhaustion and streamline the process. Finally, we consider adding a runway at the nursing station to avoid the wear of the nurse's knees by going up and down all day long. Besides, it also may reduce the number of accidents at work, such as falls.

We interviewed the head of nursing and a few nurses, so we were able to identify the main problems faced daily. From that, we studied the admittance process to understand the people and materials flow. Then, we discussed possible improvements and developed a new flowchart (Figs. 15.1 and 15.2).

The admittance process can be improved by preventing the patient from leaving the pediatric emergency area to fill in forms. We suggest that the patient profile forms are available within the pediatric emergency and are filled in by the nurses present on site. Therefore, the admittance process is decreased; this benefits both the patients and the hospital.

With the improvements, we made a new optimized mapofluxogram. Due to the reallocation of tasks, the process is leaner (Fig. 15.3).

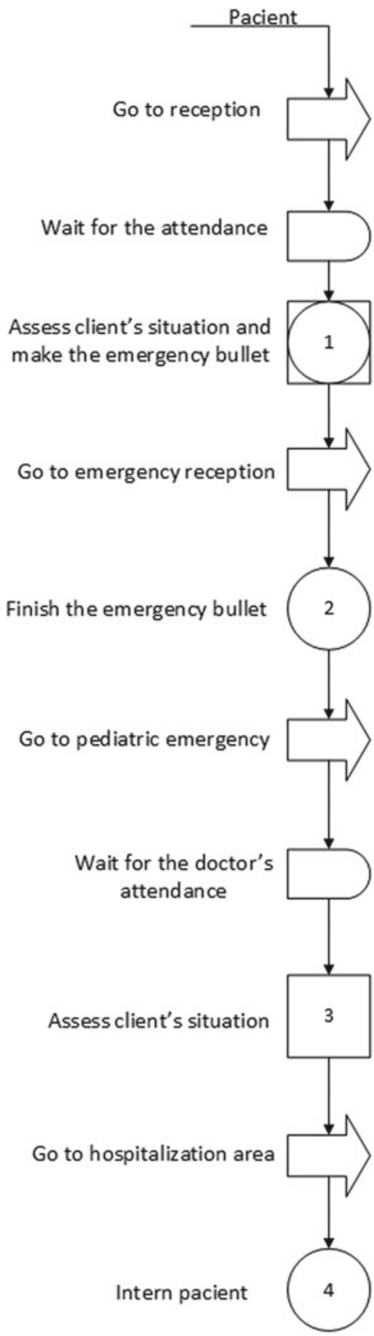

Fig. 15.1 Care process and patient flowchart

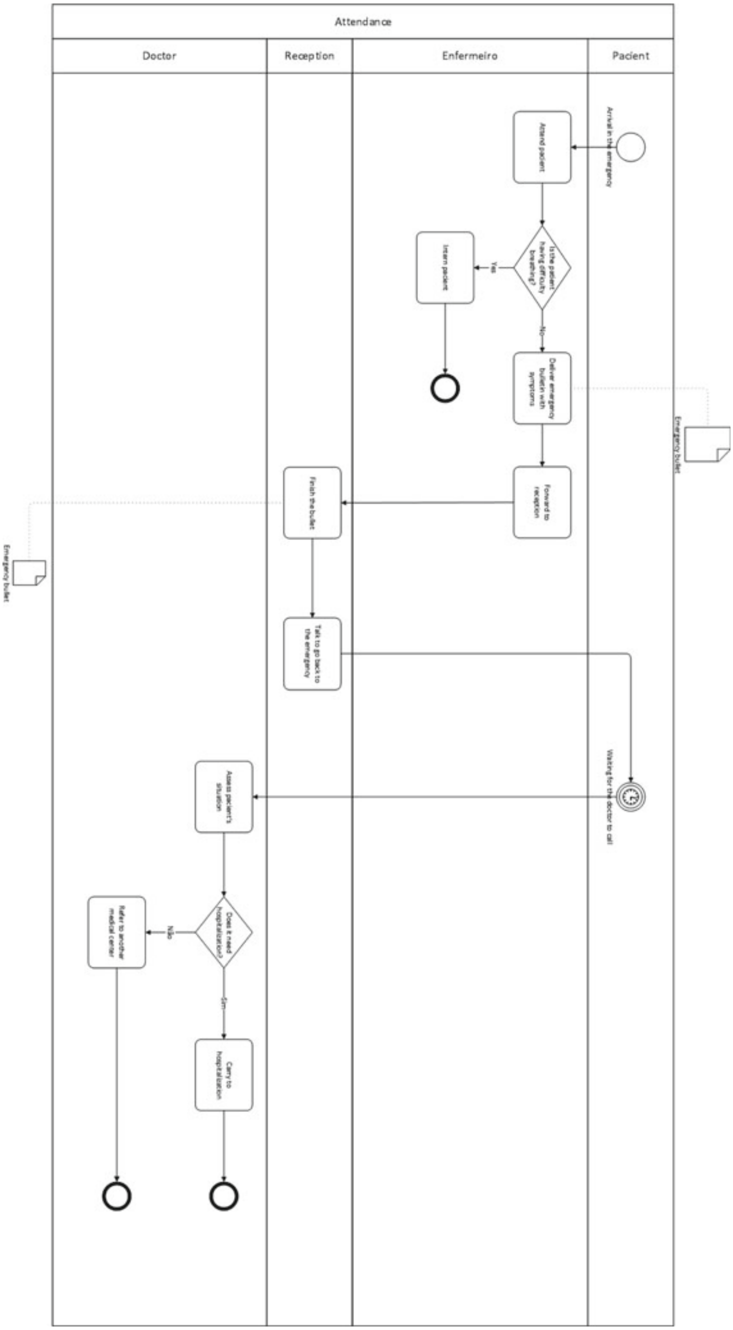

Fig. 15.1 (continued)

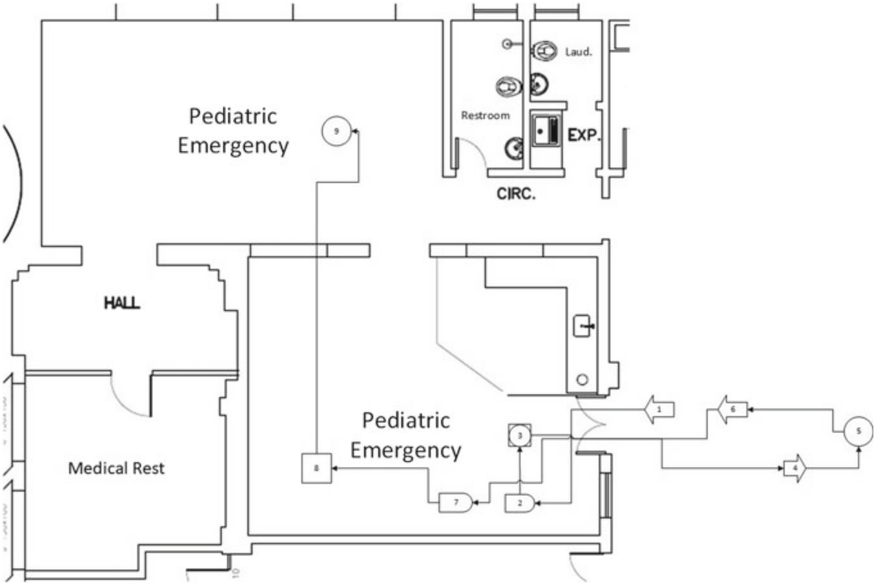

Fig. 15.2 Mapofluxogram

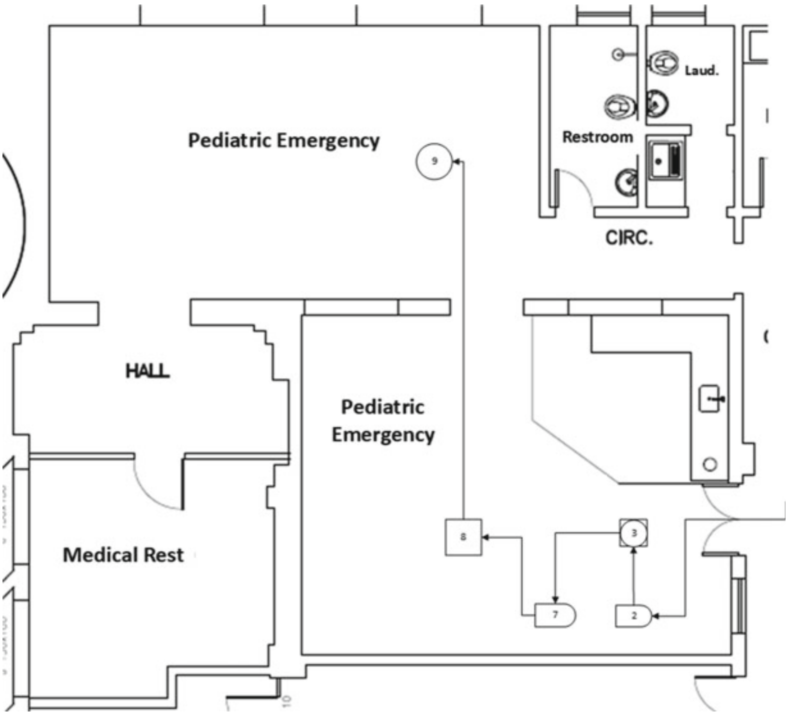

Fig. 15.3 Optimized mapofluxogram

15.4.2 Layout Analysis and Improvement

Using all the information already acquired, it was possible to build a relationship diagram. With that, we thought about possible improvements considering the proximity of the departments (Figs. 15.4, 15.5 and 15.6).

From the relationship diagram, two possible changes in the current layout are: The first one, which almost does not involve costs, consists of moving a crib to the space where old equipment and no longer used tools are stored. According to the diagram, it is very important that the ICU is nearby the nursing area; besides that, the inventory area has no requirements; two beds will stand side by side at the smaller wall; the playroom will take the bed spot below the window; lastly, at the play area would be installed the bottle warmer and a chair for breastfeeding. With this new layout, all of the beds would have access to the oxygen and switch plugs, minimizing the beds and cribs switches, besides having a wider space to the play area and relocating the bottle warmer to a more reserved area (safer for the children). Since the inventory area, according to the relationship diagram, does not have to be close by any other area, it would be moved to another place, the main material storage room. This layout does not include building an access ramp in nurse area (Figs. 15.7 and 15.8).

The second one involves refurbish, budget, and shutting down the operations during the construction period. The changes would be made as follows: the current nursing area would be turned into a meeting room, with drywall walls and a small

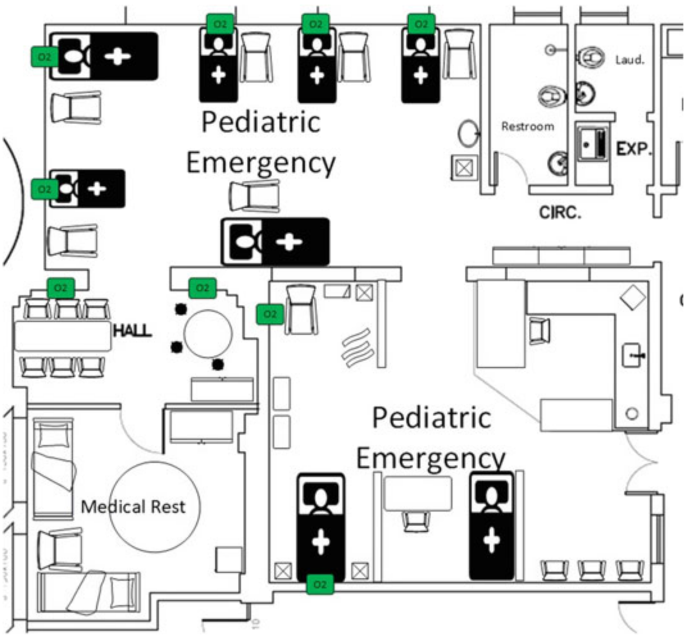

Fig. 15.4 Actual layout

Fig. 15.5 Actual layout by department

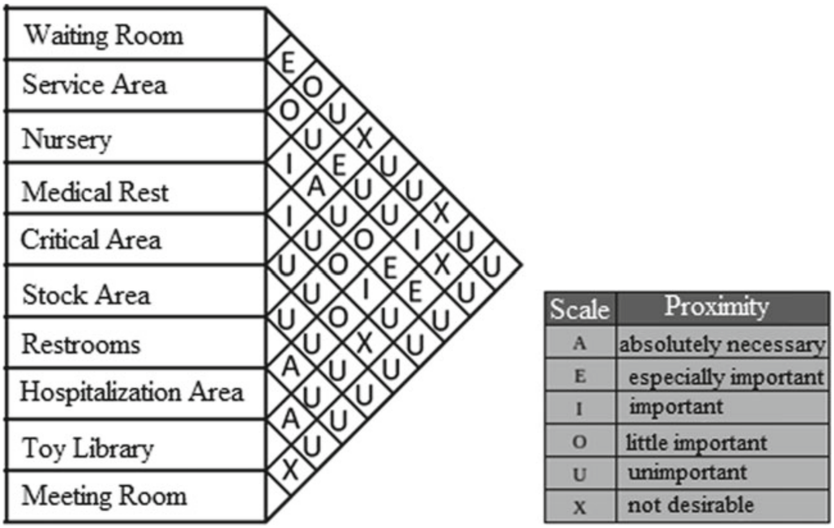

Fig. 15.6 Relationship diagram

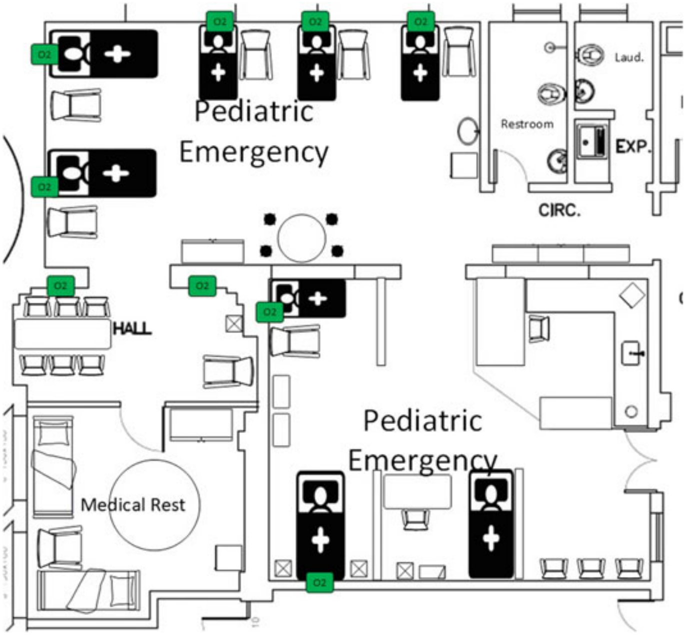

Fig. 15.7 Layout of proposal 1

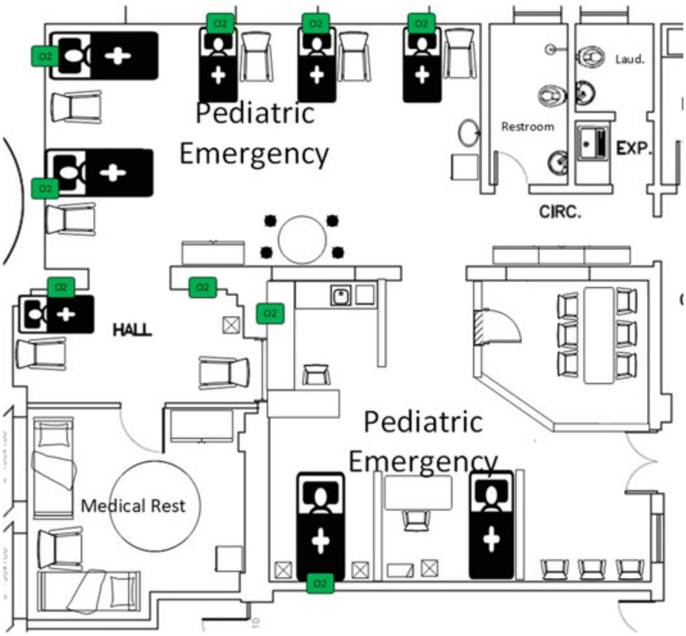

Fig. 15.8 Layout of proposal 2

ramp under the door. Since the only restriction of the meeting room is the play area, according to the relationship diagram, and with the ramp, frequent accidents would be avoid. In the old meeting area, the table and the chairs would be replaced by a crib; the nursing station would move to the storage room, with the benches, sink, cabinets, and necessary equipment. In addition to the aforementioned changes, a new glass window would be added to the hall where the crib was moved to, by that the nurses to be closer to the children, as alerted in the relationship diagram; just like the first option, the play area would pass into the main ICU area and the bottle warmer would take its place. Considered all changes described before, we would be able to solve the ergonomic problem of the step, the nurses would have a direct vision of almost all the beds and cribs, all the beds would have access to oxygen and switch plugs, ending the need of moving beds and cribs, besides a wider play area and a better bottle warmer setted up.

15.5 Conclusion

The study has two alternatives, one of low cost and one of a higher cost; it is expected that by any one, the impact on the hospital will be considerable, improving the patient's experience and also improving the nurse's routine work. In addition that, there is a legal impact; according to the RDC-50 norm, the nursing station must have a complete view of the patients and does not have to be in higher level (which was a requirement of the old norm); then, this proposal helps the institution adjust to the law. The negative impact of this change may be due to the lack of engagement by employees; for example, there is a chance that the proposal will not be put in practice; then, the beds and cribs would get all mixed up again. To avoid that, we advise the hospital to paint stripes on the floor signaling where each type of bed should be, so that the standardization is visible.

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Chapter 16
Vascular Elective Surgeries Planning and Scheduling: A Case Study at a Teaching Hospital

Daniel Bouzon Nagem Assad, Silvio Hamacher and Thaís Spiegel

Abstract Teaching hospitals must comply with current legislation, which recommends a minimum number of surgeries for the resident's approval in the training program. Thus, we propose a mathematical-based methodology to find efficient solutions for planning and scheduling elective surgeries that comply with the legislation.

Keywords Master surgical scheduling · Mathematical programming · Hospital

16.1 Introduction

Vascular diseases are serious illnesses, and their treatment is complex, and need specialized surgical procedures performed in tertiary health centers. As the increase in life expectancy causes a higher prevalence of this type of disease, teaching hospitals deal with a challenge: how to increase resource planning efficiency while subjected to several rules from various regulatory bodies. Therefore, to achieve an efficient allocative resident planning we propose a mathematical approach, a technique that proposes optimal resource use and its allocation. For resident, we consider doctors under specialized training.

Some studies use mixed integer linear programming to address surgical operations management ([7, 1–3, 5, 6, 8–11]). We did not find any research in which quantitative legislation criteria were considered. Hence, we present an approach that associates operation room planning and the annual minimum number of surgeries that must be performed by each resident.

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Springer Proceedings in Business and Economics,
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16.2 Problem Description

Teaching hospitals are subjected to several rules from various regulatory bodies. For the specialty of vascular surgery, for example, resolutions request that each resident performs at least 150 surgeries per year. Among that, at least 50 must be arterial surgeries, 30% of them small surgeries, 40% medium surgeries, and the last 30% of major ones, all within the deadline of a year.

Despite the specification effectiveness as a normative instrument, teaching hospital's vascular surgery department categorizes surgeries as: varicose veins (1), aortic (2*), fistula (3*), femoral (4*), carotid (5*), amputation (6), and endovascular (7). Those marked with * can be considered arterial surgeries, so each resident must perform at least 50 of them, which should be further divided into 15 small, 20 medium, and 15 large surgeries (Table 16.1). The operating hours of the operating room, to meet the demand for elective surgeries, are from 7 am to 7 pm, on weekdays only. However, working hours were considered to be from 8 am to 5 pm (540 minutes) in order to ensure 25% of slack time (the current literature assumes slack time between 20 and 30 percent of total time) [4]. It is also assumed that the time horizon (one year) in working days is 250 days.

16.3 Nomenclature and Mathematical Problem Formulation

It is difficult and time-consuming to propose a surgery planning and scheduling that meets country-specific legislation and hospital internal rules. This task is currently performed manually by the chief surgeon. Given this context, this article proposes a mathematical model to increase the efficiency of surgical planning. In other words, to find the configuration that minimizes resource allocation (rooms, anesthetists, and equipment) meeting the minimum amount of the surgeries required. In addition, the proposed model considers business' rules as: minimum frequency of the residents group scheduled per week, maximum amount of room given in the week, maximum number of anesthetists given in the week, maximum amount of equipment given in the week.

The nomenclature and mathematical model formulation are presented below (Table 16.2). The model was implemented in the commercial software AIMMS 3.14 with the standard solver CPLEX 12.6 on a computer with Intel Core i5 and 16 Gb of RAM.

Objective function:

$$\text{Min} \sum_{e,r,d} Weight_1 * Room^{r,d} + Weight_2 * AnDay^{r,d} + Weight_3 * EqDay_e^{r,d} \tag{16.1}$$

Table 16.1 Classification of procedures for category and size, as defined by the teaching hospital's vascular surgery department

Resource parameterization		Surgical instruments							Equipment	Blood bank	Time (in minutes)			Human resources				Minimum number of surgeries			Resolution NCMR
Largeness	Surgeries	1	2	3	4	5	6	7	Is required?		Room preparation	Patient preparation	Surgery duration	Anesthetist	R1	R2	R3	R1	R2	R3	
1	1	X			X						20	0	45	–	X	X	X	10	0	0	45
	2*			X					X	X	20	0	–	–		X	X	0	0	0	
	3*					X					20	0	60	–	X	X	X	20	0	0	
	4*	X					X		X	X	20	0	150	X	X	X	X	5	15	0	
	5*		X						X		20	0	–	–		X	X	0	0	0	
	6							X			20	0	40	–	X	X	X	10	0	0	
	7					X	X		X		20	0	60	–		X	X	0	10	15	
2	1	X			X						20	20	75	X	X	X	X	10	5	0	60
	2*			X					X	X	20	20	–	–		X	X	0	0	0	
	3*					X					20	20	110	X	X	X	X	20	0	0	
	4*	X					X		X	X	20	20	210	X	X	X	X	10	15	15	
	5*		X						X		20	20	135	X		X	X	0	15	10	
	6							X			20	20	50	X	X	X	X	10	0	0	
	7					X	X		X		20	20	135	–		X	X	0	10	20	
3	1	X			X						20	90	105	X	X	X	X	5	5	0	45
	2*			X					X	X	20	90	240	X		X	X	0	15	5	
	3*					X					20	90	110	X	X	X	X	5	5	0	

(continued)

Table 16.1 (continued)

Resource parameterization		Surgical instruments							Equipment	Blood bank	Time (in minutes)			Human resources				Minimum number of surgeries			Resolution NCMR
Largeness	Surgeries	1	2	3	4	5	6	7	Is required?		Room preparation	Patient preparation	Surgery duration	Anesthetist	R1	R2	R3	R1	R2	R3	
	4*	X					X		X	X	20	90	210	X	X	X	X	5	10	5	
	5*		X						X		20	90	135	X		X	X	0	5	10	
	6							X			20	90	90	X	X	X	X	5	5	0	
	7					X	X		X		20	90	165	X			X	0	0	10	
Total		1	2	2	5	2	3	2	–	1	–	–	–	–	2	2	2	115	115	90	150
Frequency		Once per day									Not applicable			Depends on scenario				Not applicable			

Source the authors

Table 16.2 Statement of Master Surgical Schedule model indexes, parameters, and variables

Indexes	Meaning	Parameters	Meaning
Ar	Arterial surgery	$durSu_{s,l}$	Duration of the largeness (l) surgery (s)
s	Surgery	$\underline{fClwk}$	Minimum frequency of resident groups per week
d	Day	$quClSu_{s,r,l}$	Resident's (c) qualification to perform the largeness (l) surgery (s)
e	Equipment	M	Large number
i	Resource	$weight_i$	Weight assigned to each type of resource (i)
m	Material	$\overline{nAnwk}$	Maximum number of anesthesiologists given in the week
l	Surgery largeness (size)	$\underline{nSuYr}$	Minimum number of surgeries a year per resident
c	Class (group) of residents	$\underline{nClAr}$	Minimum number of arterial surgeries per resident
r	Room	$\underline{nClArLa_l}$	Minimum number of arterial surgeries per largeness(l) for each resident
Variables	Meaning and type	$\underline{nSuLa_l}$	Minimum number of surgeries of largeness (l) for each resident
$AcClSu_{c,s,l}$	Number of surgeries (s) of the largeness (l) performed by the residents of type (c) in the year—Integer	$\underline{nSuCl}_{c,s,p}$	Minimum number of surgeries (s) of the largeness (l) for the resident of type (c) established by the preceptor

(continued)

Table 16.2 (continued)

Indexes	Meaning	Parameters	Meaning
$AnSu_{s,l}^{r,d}$	Decision of allocating anesthetist to perform surgery (s) of largeness (l) in the room (r) on day (d)—Binary	$\overline{nEqwk_e}$	Maximum number of equipment (e) assigned in the week
$AnDay^{r,d}$	Decision of allocating anesthetist in room (r) on day (d)—Binary	$nMat_m$	Number of surgical materials (m) available at SMC
$AuxAn^{r,d}$	Auxiliary variable created to associate variables $AnSu_{s,l}^{r,d}$ and $AnDay^{s,d}$—Integer	nCl_c	Number of residents per type (c)
$AuxEq_e^{r,d}$	Auxiliary variable created to associate variables $EqSu_{e,s,l}^{r,d}$ and $EqDay_e^{r,d}$—Integer	$\overline{nroomwk}$	Maximum amount of room assigned in the week
$AuxCl_r^d$	Auxiliary variable created to associate variables $ClSu_{c,s,l}^{r,d}$ and $ClDay_r^d$—Integer	$nblood$	Number of patients attended by hemotherapy service (blood) per day
$EqSu_{e,s,l}^{r,d}$	Decision of allocating equipment (e) in surgery (s) of largeness (l) in the room (r) on day (d)—Binary	$rSuAn_{s,l}$	Ratio anesthetist surgery (s,l)
$EqDay_e^{r,d}$	Decision of allocating equipment (e) in room (r) on day (d)—Binary	$rSuEq_{s,l,e}$	Ratio surgery equipment (s,l,e)
$MatSu_{m,s,l}^{r,d}$	Decision of allocating the surgical material (m) in surgery (s) of largeness (l) in the room (r) on day (d)—Binary	$rSuMat_{s,l,m}$	Ratio surgery material (s,l,m)
$ClSu_{c,s,l}^{r,d}$	Decision of allocating allocate a resident of type (c) to perform surgery (s) of largeness (l) in the room (r) on day (d)—Binary	$rSublood_{s,l}$	Ratio surgery blood (s,l)
$ClDay_r^d$	Decision of allocating allocate any resident of type (r) on day (d)—Binary	$tPrep_l$	Preparation time for largeness surgery (l)
$Room^{r,d}$	Decision of allocating allocate/block the room (s) on day (d) for the surgical service—Binary	$tPreroom$	Room preparation time
$BloodSu_{s,l}^{r,d}$	Decision of allocating allocate blood smear in surgery (s) largeness (l) in the room (r) on day (d)—Binary	$troom$	Room time

The objective function (16.1) minimizes the room allocation ($Room^{r,d}$), anesthetists ($AnDay^{r,d}$), and equipment ($EqDay_e^{r,d}$) throughout the year. Prioritization is defined by the weights ($Weight_i$). These weights will vary in 10 scenarios of Table 16.3 in order to show the resources availability range and their utilization.

Constraints:

$\sum_{s,l,c} ClSu_{c,s,l}^{r,d} * \left(durSu_{s,l} + tPrep_l + tPreproom\right) \leq troom \quad \forall r, d$	(16.2)
$\sum_{s,l,r} ClSu_{c,s,l}^{r,d} * \left(durSu_{s,l} + tPrep_l + tPres\right) \leq troom \quad \forall c, d$	(16.3)
$ClSu_{c,s,l}^{r,d} \leq Room^{r,d} \quad \forall c, s, l, r, d$	(16.4)
$AClSu_{c,s,l} = \sum_{r,d} ClSu_{c,s,l}^{r,d} \quad \forall c, s, l$	(16.5)
$AClSu_{c,s,l} \geq \underline{nSuCl}_{c,s,l} * nCl_c \quad \forall c, s, l$	(16.6)
$\sum_{s} AClSu_{c,s,l} \geq \underline{nSuLa}_p * nCl_c \quad \forall c, p$	(16.7)
$\sum_{ar,l} AClSu_{c,ar,l} \geq \underline{nSuAr} * nCl_c \quad \forall c$	(16.8)
$\sum_{ar} AClSu_{c,ar,l} \geq \underline{nSuArLa}_l * nCl_c \quad \forall c, l$	(16.9)
$\sum_{s,l} AClSu_{c,s,l} \geq \underline{nSuyr} * nCl_c \quad \forall c$	(16.10)

(continued)

Table 16.3 Weights and business rules by scenario

	Weight, per allocative decision, related to			Weekly allocation business rules			
Scenario	Surgery room	Anesthetist	Equipment	Minimum frequency	Maximum number of rooms	Maximum number of anesthetists	Maximum amount of equipment
1	10^6	10^3	1	0	10	10	10
2	1	10^3	10^6	0	10	10	10
3	10^3	10^6	1	0	10	10	10
4	1	10^6	10^3	0	10	10	10
5	10^3	10^3	1	0	10	10	10
6	1	10^3	10^3	0	10	10	10
7	10^3	1	10^3	0	10	10	10
8	1	1	1	0	10	10	10
9	10^6	10^3	1	3	8	8	8
10	10^6	10^3	1	3	8	7	6

(continued)

$AnSu_{s,l}^{r,d} = \sum_{c} ClSu_{c,s,l}^{r,d} \quad \forall s, l, r, d$	(16.11)
$AnDay^{r,d} + AuxAn^{r,d} = \sum_{s,l} AnSu_{s,l}^{r,d} \quad \forall r, d$	(16.12)
$AnDay^{r,d} * M \geq \sum_{s,l} AnSu_{s,l}^{r,d} \quad \forall r, d$	(16.13)
$EqDay_{e}^{r,d} + AuxEq_{e}^{r,d} = \sum_{s,l} EqCi_{e,c,p}^{r,d} \quad \forall e, r, d$	(16.14)
$EqDay_{e}^{s,d} * M \geq \sum_{s,l} EqSu_{e,s,l}^{s,d} \quad \forall e, r, d$	(16.15)
$ClDay_{c}^{d} + AuxCl_{c}^{d} = \sum_{s,l,r} ClSu_{c,s,l}^{r,d} \quad \forall c, d$	(16.16)
$ClDay_{c}^{d} * M \geq \sum_{s,l,r} ClSu_{c,s,l}^{r,d} \quad \forall c, d$	(16.17)
$MatSu_{m,s,l}^{r,d} = \sum_{c} ReCi_{r,c,p}^{s,d} \quad \forall m, s, l, r, d$	(16.18)
$\sum_{\mathrm{s,l,r}} MatSu_{m,s,l}^{r,d} \leq nMat_{m} \quad \forall m, d$	(16.19)
$BloodSu_{s,l}^{r,d} = \sum_{c} ClSu_{r,c,p}^{r,d} \quad \forall s, l, r, d$	(16.20)
$\sum_{\mathrm{s,l,r}} BloodSu_{s,l}^{r,d} \leq nBlood \quad \forall d$	(16.21)
$\sum_{d-4}^{d} ClDay_{c}^{d} \geq \underline{fClwk} \quad \forall c, d$	(16.22)
$\sum_{r,d-4}^{d} Room^{r,d} \leq \overline{nRoomwk} \quad \forall d$	(16.23)
$\sum_{r,d-4}^{d} AnSu^{r,d} \leq \overline{nAnwk} \quad \forall d$	(16.24)
$\sum_{r,d-4}^{d} EqDay_{e}^{r,d} \leq \overline{nEqwk_{e}} \quad \forall e, d$	(16.25)

Equations 16.2 and 16.3, respectively, ensure that rooms and residents can work until $troom$ hours each day (it does not allow overtime). Equation 16.4 just allows any resident can be allocated to perform some surgery if the room is available. Equation 16.5 sums the amount of performed surgeries. The variable is used in the Eqs. 16.6–16.10 to ensure the minimum quantity of the surgeries. Equations 16.11–16.21 are related with resource availability that has limits described in Table 16.1 and Eqs. 16.22–16.25 fulfill business rules presented in Table 16.3.

Although these scenarios do not have a "practical value," their response allows us to evaluate which rules cause greater impact, which ones interfere little in programming and, therefore, provide the decision-maker with guidance to which rules could be disregarded, reinforced, adopted, or negotiated with other clinics or with the head of the operating room.

In this case, taking as example scenario 1 of Table 16.3, the solver will allocate the team of surgeons from the same residence year in as few rooms as possible (highest weight assigned in scenario 1). Then, after defined the number of rooms, the solver will seek the least amount of anesthetist allocation (intermediate weight in scenario 1). And for that will be necessary to reallocate surgeries in each room and in each day. At the end, after specifying the number of rooms and anesthetics, the solver will seek the least amount of equipment to allocate (lower in scenario 1). Moreover, in this scenario, there is no obligation to schedule the resident group in every week and up to two rooms available on each of the five days of the week are considered. In other words, although it is possible, but not desirable use 10 rooms in the week with anesthetists and equipment were at all rooms.

16.4 Results

The weight given to all resources in each scenario (Table 16.3) establishes resource hierarchy. Table 16.4 summarizes the relation between model's input and answers.

In order to meet surgeries defined by the regulator and the preceptor in the first five scenarios, the amount of allocated resources vary in the intervals from 273 to 347 for rooms, from 224 to 279 for rooms with anesthetics and from 200 to 310 for rooms with equipment. In this case, the surgical service at stake currently has 8 operating rooms a week (rule defined by the direction of the surgical center) and therefore 400 rooms in the year (up to 2 surgery rooms per day up to 8 rooms per week during the 250 days). It can be stated that this restriction of rooms (Eq. 16.22) does not limit the space of viable solutions.

Yet due to the scarcity of other resources such as anesthetics and equipment, the direction of the surgical center assigns in the weekly horizon rooms with anesthetist only for 3 days and with equipment for also 3 days only. From the results of the model, it is concluded that these two rules make any solution impossible.

For these two resources in the annual horizon (250 days) would be available only in 150 days (3 days a week over 50 weeks), whereas at least 224 rooms with anesthesiologist and 262 rooms with equipment (scenario 4) or 247 rooms with anesthetist (scenario 2) would be required. Thus, the only resource that would not make sense to prioritize (assign greater weight) to the detriment of others it would be the surgery rooms.

However, scenario 1 was chosen as ideal by the chief surgeon of the vascular surgery service with the argument that other surgical services receive fewer rooms in the week and this kind of solution could, in the limit, free room spaces to be allocated according to other rules or even just to be available.

Thus, working considering the priority order proposed in scenario 1, the scenario 9 was built changing the minimum frequency parameters of scheduling the resident

Table 16.4 Model results by scenario

Scenario results	Input data	Model answers							
	Objective function	Model size		Computational resource	General solutions	Sizing model answers			
	Resource criticality order (Hierarchy)	# decision variables	# Constraints	Solution time (in seconds)	Gap (%)	Average usage (%)	# Rooms	# Anesthetists	# Equipment
1	Room; anesthetist; equipment	52250	70621	11.456.4	1,48	86,9	285	285	262
2	Equipment; anesthetist; room	52250	70621	10.026,2	0,03	73,3	339	274	200
3	Anesthetist; room; equipment	52250	70621	12.340,2	4,39	73,3	344	230	333
4	Anesthesist; equipment; room	52250	70621	10.178,3	4,39	69.1	364	230	310
5	Room and anesthetist; equipment	52250	70621	19.633,1	11,55	83,5	297	269	270
6	Anesthetist and equipment; room	52250	70621	68.774,9	12,19	70,1	354	278	200
7	Room and equipment; anesthetist	52250	70621	69.962,0	2,48	84,6	293	293	200
8	No hierarchy	52250	70621	106.748,5	10,44	84,9	290	280	200
9	Room; anesthetist; equipment	52250	70612	60.038,6	1,48	86,9	285	285	262
10	Room; anesthetist; equipment	52250	70612	60.051,3	1,83	86,6	286	286	254

group per week to 3 ($\underline{fClwk} = 3$), maximum amount of room, anesthetics, and equipment (e) assigned in the week to 8 ($\overline{nRoomwk} = \overline{nAnwk} = \overline{nAnwk} = 8$). Finally, scenario 10 was obtained changing the previous parameters, respectively, to 3, 8, 7, and 6. Therefore, in the last scenery, the aim is to bring the last two parameters closer to the current business rules and check the impact of this change in the found solution. By the preceptor's choice, the scenario 10 was admitted as the ideal one, due to the fact that it is the closest to the current set of rules.

16.5 Conclusion

The present research proposed a model of resource sizing to meet the minimum training criteria required by current legislation and by the chief surgeon of the vascular surgery service Thus, besides efficiently designing the planning and scheduling of the elective surgeries of this service (research question), it was possible to evaluate the pertinence of current business rules of the surgical center and business rules internal to the service, responding, at a tactical level (master surgical schedule), when each resident group should be allocated in which room, with which resources and how many times it should be scheduled to perform any surgery in a weekly horizon.

As a result, it was obtained different resource prioritization to each scenario. To accomplish minimum annual number of surgeries needed in the residence program, it is necessary a range that varies from 273 to 347 surgery rooms, 224–279 rooms with anesthetics, and 200–310 rooms with equipment (Table 16.4). Finally, ensuring a feasible and efficient surgical planning, in which requires to each scenario a different resource prioritization logic, implies that surgery rooms utilization range from 67.6 to 85.6%.

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Chapter 17
The Use of Big Data for Researching the Leprosy Healthcare Supply Chain

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Abstract The use of big data can help to analyze the healthcare variables and their relationships. Through the analysis of some variables, it is possible to measure characteristics related to the quality of care. The present study aims to use big data for analyzing the leprosy healthcare supply chain.

Keywords Big data · Operation management · Leprosy health care

17.1 Introduction

The big data analytics, an analysis of large databases, has been used worldwide as an important organizational management tool [6]. In Brazil, the large database of the Unified Health System is a source of public health information, and it remains open with free access. This database is found on the DATASUS Web site, Department of Informatics of the Unified Health System, and can be used as a management tool through the creation of a model that systematically helps to evaluate the efficiency of the services in order to the proper control of the resources.

Leprosy is a disabling disease which receives specific attention especially in developing countries [2]. Brazil ranks second in a number of cases worldwide. One of the main procedures to develop control is compulsory notification due to legal requirements. For this reason, it is a disease whose records have a higher fidelity pattern, which means that the flow of information about them has a lower degree of loss and

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is closer to reality. Therefore, the management of information becomes more accurate enabling improvements on the strategies to research, analysis, and implement changes in Brazil.

Efficiency: The evaluation of efficiency in this study is based on the creation of a georeferenced mapping framework. This is a regional ranking based on the quality of care, classified by SUS as high, medium, and low complexity. The presented framework was created through the systematization, an analysis of large public health databases in Brazil. The present paper considered the federal units of Brazil in the period of 2001–2016.

17.2 Problematization

17.2.1 The Big Data Analytics

The big data analytics is a methodology that uses the analysis of large databases or a large set of stored data to generate useful information in any area of knowledge [12]. In the business world, the private network, especially in multinational organizations, the methodology of the big data analytics is used as a strategic support tool within organizations, with the aim of improving the processes and to acquire information about market trends, consumer behavior, and expectations [6]. This creates the possibility of improving the decision-making process and managing to reduce costs in several points of the supply chain. Although the analysis of large databases is of great importance within organizations, including healthcare institutions, few studies have gathered efforts to design frameworks to improve the evaluation of the efficiency or healthcare quality.

The epidemiological analysis or the profile evaluation of diseases are quite common today, however, those that specifically focus on resource management and the efficiency of operations management regarding healthcare procedures need to be expanded. Raghupathi and Raghupathi [7] described the potential of analyzing large databases through the big data analytics in health care. According to them, the data can improve the results and at the same time, reduce healthcare operations costs. Wang and Hajli [11], previously, also constructed a study that explores the importance of the analysis of large databases for healthcare institutions. This study attempts to explain the importance of developing resources to analyze these data and assessing benefits to the healthcare supply chain.

The development of studies within the improvements of operations management is very important for Brazil due to the emergency to implement strategies regarding the optimization of resources. In this country, there is a large database of public health, available for free access, on the Internet that has not yet been used in order to evaluate the efficiency of health operations and to reduce operational costs. This database located on the Web site of the Department of Informatics of the Unified Health System is the main source of the presented framework.

17.2.2 DATASUS

The DATASUS was developed in 1999, with the creation of the National Health Foundation. Its function is to enable the planning, operation, and control of health actions through information provided by its system. Today, this department is a major provider of software solutions for state and municipal health secretariats, adapting their systems to the needs of local managers and incorporating new technologies into their database.

The DATASUS maintains its network servers in two locations: Brasília and Rio de Janeiro. These servers host most of the systems from the Ministry of Health. The structure that enables the storage of the data has the capacity to store health information for the entire Brazilian population. The DATASUS is available in all regions of the country, carrying out activities of promotion and technical cooperation in computer science.

There are several systems available in DATASUS. These systems are divided into large databases separated by categories which allow multiple statistical analyses to be performed. One of these systems is the "Hospital System," which has medium and high complexity information. The access to these systems and in sequence the SIH–SUS database permits the identification of the variables associated with all hospitalizations that occur in Brazil. These hospitalizations are recorded from the guide of Authorization of Hospitalar Internation, AIH. The hospital units which belong to SUS, whether public or private, agree to send the information of hospitalizations made through the AIH to the municipal or state managers, depending on the legal sphere to which service is attached. This information is processed in DATASUS, generating the credits related to the services. The financial receipt related to admissions only occurs, therefore, from the registration of these AIH guidelines. Thus, the registration process of data is essential to the whole procedure, containing data from most of the hospitalizations performed in Brazil.

In this database, there is information about each hospitalization performed and paid by SUS within the national territory. The database has variables regarding hospitalization such as: the municipality in which the hospitalization was performed, the city of residence of the patient, CID 10 (International Code of Disease which refers to hospitalization), procedures performed during hospitalization, period of hospitalization, days of intensive care, whether the hospitalization was elective, that is, with a scheduled date, or if it was an emergency, if the hospitalization ended with death, among others. Multiple variables are available for the development of statistical analyses.

In addition, operational indicators that address indexes that favor the evaluation of the quality of care, in relation to basic care of low complexity, are also present in this platform. These indexes may indicate the severity of the disease at the time it was diagnosed and at discharge, allowing a comparison between these two moments. In terms of quantitative analysis, there are several procedures that can create proper data to develop assessments. The percentage of patients that were evaluated by the degree of severity of the disease, the percentage of cure of these patients, and many other.

This set of information is freely available on the Internet. After the data work, it is possible to develop information that allows the creation of studies. These data can be used to evaluate the efficiency of the population service, and later, they can assist in the management of health processes and operations. In addition, it is possible to analyze the regional differences between states, creating a mapping of the situation of operational management within the country.

17.2.3 Efficiency Assessment

There are multiple definitions of efficiency. For our study, it refers to using resources well so that they enable the production of more services, or "doing more with less" from the well-being of the population. Here, there is the sense of not wasting, of being sustainable, of spending only what is necessary, maximizing the satisfaction of the population from the available resources [8].

Data envelopment analysis (DEA) is a multivariable technique which provides quantitative data for monitoring productivity for the improvement of decision making regarding inefficient units [3]. This technique was used by Gonçalves and Noronha [4] to evaluate the efficiency of Brazilian hospitals from the DATASUS database and has since been used more frequently in the analysis.

The present study aims to develop a framework based on multiple analysis of indexes. This form consists of making a comparison between quality indexes from a georeferenced mapping in which a ranking of the more or the less efficient regions is constructed in a systematic way. Regarding healthcare attention of medium and high complexity cases, this profile can be raised through the study of the operational costs of hospitalization, the set of hospitalizations, length of hospital stay, and even through the number of deaths.

It is relevant to note that in statistical studies there is a possible presence of errors, or biases, which must be taken into account in the analysis. These biases can provoke inconsistencies, and thus, it is necessary to control these data to develop results closer to reality. The use of mortality rate as a parameter for efficiency, for example, requires attention due to some deaths would occur in a way that is unrelated to the quality of care or efficiency. Similarly, the same way of thinking must be applied in relation to the cost and duration of hospitalization. Hospitalization can be more expensive or last longer due to specific events, regardless of the efficiency of the service provided. Therefore, a certain event may not be associated with the initial association, especially when studying a large volume of data [1].

In terms of basic care, it is possible to build a ranking with operational indexes that indicate the severity of the disease at the time it was diagnosed and at the time of discharge, which quantitative in percentage terms, of patients, which was evaluated by the degree of severity of the disease at diagnosis and discharge, and what percentage of cure of these patients. The georeferenced efficiency mapping framework that will be created can be able to demonstrate how a region behaves in operational terms according to efficiency. Thus, it will be possible to analyze future causes of regional differences and systematize recommendations for strengthening the management structure.

17.2.4 Leprosy

Leprosy is an infectious and contagious disease that can be transmitted by the respiratory system, which affects mainly skin and peripheral nerves generating a high degree of physical incapacity [5]. The current goal of the Brazilian Ministry of Health has been the control of the disease, for analyzing that at the moment it is not possible to eradicate it due to the complexity of acting in regions of vulnerability. Due to the association between leprosy and factors related to poverty and vulnerability, the healthcare strategies must be aimed at social management. According to epidemiological data, Brazil has the second highest incidence of leprosy.[1] It is a disease that demands strict patterns of observation and control. Therefore, the registration of its care throughout Brazil requires compulsory notification.

The compulsory notification was created by federal law so that the registration of the disease is performed as accurately as possible. In the case of leprosy, all spheres of the SUS have access to notification information of this disease within a week. This is necessary so that all appropriate sanitary measures can be programmed with the greatest effectiveness.[2] Due to this process, leprosy presents a greater accuracy in the registration of data. Thus, the margin of error of the data regarding notifications is low, reducing the level of impairment of the analysis.

There are degrees of disability that can inform the level of development of the disease. These degrees are defined as 0, 1, and 2. The first one (0) is the least severe without disabilities. The second (1) delimits sensory disabilities, and the third (2), the most severe, refers to patients with sensory and motor disabilities [9]. Some operating indexes are based on these grades. Thus, they enable the evaluation of the efficiency of the service, as they track the number of patients who were already diagnosed with the disease at the most serious level, grade 2. They also enable the development of the percentages of the patients who were evaluated at the time of diagnosis and the degree of incapacities on discharge.

In addition to assessing the degree of disability, the leprosy program, instituted by the Ministry of Health, recommends that all family members living with the patient with a close diagnosis, also be screened for the disease. They have to assign a term called "contact tracking." Due to the fact that leprosy is transmitted through the respiratory tract, the members of the family that coexist more routinely with the patient are more likely to develop the disease [10]. In DATASUS, there are operational indexes divided by units of the federation, which measure the proportion of family

[1] http://www.ensp.fiocruz.br/portal-ensp/informe/site/materia/detalhe/34620.

[2] http://portalsinan.saude.gov.br/hanseniase.

members who passed the consultation with a qualified health professional to know if they have the disease. This proportion can also demonstrate the efficiency of care.[3]

17.3 Aims

17.3.1 General Aims

Create an analysis framework of the SUS public database based on data from Authorization of Hospitalar Internation, AIH, and Ambulatory Operational Indicators in Leprosy, mapping health services efficiency, using georeferencing, and establishing a ranking of the efficiency of the service rendered by region.

17.3.2 Specific Aims

- Analyze the database for hospital interns from the variables "time of hospitalization time," "average cost of hospitalization," and "mortality rate" in relation to leprosy, from 2001 to 2016, in all Federative Units;
- Analyze leprosy operational indicators from 2001 to 2016 for all Federative Units;
- Compare the data found longitudinally and between the Federative Units, creating a ranking of the efficiency of the service rendered, by region;
- Generate inferences regarding the efficiency of each Federative Unit, looking for the possible causes of the differences found;
- Generate inferences regarding the period of the highest efficiency in each state;

17.4 Methodology

17.4.1 Methods

This research is based on the quantitative, longitudinal, non-experimental, and descriptive method. Its basic purpose is to create an evaluation framework of the efficiency of public health care, from large databases, big data analytics. The target disease is Leprosy.

[3] http://tabnet.datasus.gov.br/cgi/sinannetbd/hanseniase/Planilhas_arquivos/sheet013.htm.

17.4.2 Management of the Research

Geographic Area of the Study

The study will use data from all Brazilian states, divided by months that will be compressed in years for better visualization.

Study Period

Data from 2001 to 2016.

Source and Treatment of Data

This study will use data available in the database of DATASUS, publicly accessible, within the page entitled "Decentralized Hospital Information System." The data of hospital admissions with ICD 10, International Code of Diseases, A30, A30.0, A30.1, A30.2, A30.3, A30.4, A30.5, A30.6, A30.7, A30.8, and A30.9, refer to the diagnosis of leprosy. These hospitalizations are located within the database of SIH–SUS, through the link titled "Reduced AIH." These data refer to authorizations of hospital admissions occurring in each UF, Federative Unit, available to download separately by month and UF, in a format called "Dbc." This data should be downloaded and later converted to the "Dbf" format through a program also available on the DATAUS platform called "Tabwin." When it is converted, a spreadsheet is generated that, to be better analyzed, must be transferred to the Excel program of the Microsoft Office suite.

The variables "length of hospitalization time," "average cost of hospitalization," and "mortality rate" of hospitalizations with diagnosis of leprosy in all Brazilian states will be evaluated. These variables will be used as a tool to study the efficiency of hospital care. A comparative analysis will be performed between the states, UFs, and another time, in the same state. This analysis will provide a parameter in relation to health care classified as medium and high complexity.

In order to analyze the efficiency of care classified as low complexity, which encompasses basic care, operational, and epidemiological indicators of leprosy will be analyzed through tabulations and spreadsheets available on the site "tabnet.datasus.gov.br," entering the option "Epidemiological and Morbidade" and accessing the link "Cases of Leprosy SINAN," having as last link "Worksheet of Operational and Epidemiological Indicators." These worksheets consist of the following information:

- Proportion of the Physical Impairment Assessment of the New Diagnosed Cases of Leprosy according to the Year of Evaluation, per Federative Unit, Brazil, 2001–16;
- Proportion of Cases of Healed Leprosy with Degree of Invalidity, according to the Year of Evaluation per Federative Unit, Brazil, 2001–16;
- Proportion of degree of disability 1 among new cases of leprosy, states, and regions, Brazil, 2001–2016;
- Proportion of degree of disability 2 among new cases of leprosy, states, and regions, Brazil, 2001–2016;

- Proportion of contacts of new cases of leprosy examined among those registered in the states and region cohorts, Brazil, 2001–2016;
- Proportion of cure in cohorts of new cases of leprosy, states, and regions, Brazil, 2001–2016;
- Detection rate of new cases of leprosy with disability grade 2 states and regions, Brazil, 2001–2006 and 2008, 2009–2016;

In this case, the comparative evaluation between states and the temporal evaluation by Federative Unit will also be carried out. At the end of this process, the efficiency of health services will be mapped through georeferencing, and a ranking of the classification of care provided by region will be established. The analysis of regional issues that may be interfering in the results, allowing a region to perform better or inferior, will be carried out, and inferences will be constructed from the results found.

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Chapter 18
The Cost of Parkinson's Disease: A Systematic Review

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Abstract Determining the costs of a disease facilitates the understanding and evaluation of their impact with its main stakeholders. The aim of this literature review is to deepen the studies on the individual costs of Parkinson's disease, reinforcing the understanding of its impacts on the healthcare system.

Keywords Parkinson's disease · Costs · Healthcare system

18.1 Introduction

Neurological disorders are among a population's leading causes of disability and represent a major burden to the public healthcare system since they are mostly incurable and get worse over time [8]. According to the World Health Organization (WHO), it is estimated that neurological disorders and their sequels affect about one billion people worldwide [10].

Parkinson's disease (PD) is considered a chronic and degenerative neurological condition that mainly affects older individuals, causing significant lifelong incapacities and decreased quality of life, being the second most common neurodegenerative disease after Alzheimer's disease and the leading cause of expenses for the patient, family, caregivers, and also for the healthcare system [6, 18, 30]. It is characterized by

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the predominant loss of the dopaminergic neurons, which are located inside the cerebral substantia nigra, causing the development of motor and non-motor symptoms [5].

The prevalence of PD reaches approximately 0.3% of the population in industrialized countries and increases to 1% in over 60-year-old people and 3% in over 80-year-old people [6]. Daneault et al. [5] consider that the prevalence rate of the disease is increasing and shall have increased from 10 million people worldwide in the late 1980s to 40 million people by 2020, mainly due to the aging of the population.

In the case of neurodegenerative diseases that cannot be prevented, such as PD, society's burden, whether financial, social, or psychological, is often very heavy [1]. Patients face increasingly severe symptoms as the disease progresses, which translates into increased treatment costs [14].

The financial impact of PD on society has been widely discussed in recent decades and is expected to increase in the future [9]. The purpose of this study is to conduct a systematic review of the literature on the costs of PD, identifying relevant studies that help in understanding the types of expenses brought with the disease and their impact on the patient's life and on the healthcare system.

18.2 Scientific Method

The bibliographic research was carried out in March 2018, using the SCOPUS, PubMed, Medline, and Web of Science search engines—with the aim of selecting original and reviewed articles on the cost of PD. The keywords have been defined according to three thematic axes—disease cost, Parkinson's disease, and healthcare systems—and organized as follows: (*"costs"* OR *"cost of illness"* OR *"cost of disease"* OR *"health economics"* OR *"health expenditures"* OR *"cost analysis"*) AND (*"Parkinson"* OR *"Parkinson's disease"*), AND (*"healthcare system"* OR *"public healthcare system"* OR *"private healthcare system"*). This method identified 847 documents in the above-mentioned databases, which have been selected and cataloged using the Zotero® software, allowing the formation of an initial database where all the information could be viewed.

After the documents were cataloged, initial filtering was carried out in order to remove any non-scientific articles (e.g., congress logs, book chapters, and study protocols), and at the end of this process, 21 documents had been excluded. Then, a second filter was applied that eliminated any inter- or intra-base duplicate articles. As a result of this filter, 31 duplicate articles were excluded. We carried out a third filter aimed at removing those articles that were furthest from the central subject of the research, conducting a reading of titles and abstracts. In this analysis, we considered the context of the research and each thematic axis, and as a result, 742 articles were excluded.

The inclusion criterion included only articles referring to costs related to PD and/or the use of medications. Works comparing procedures and/or medications, dealing with specific and/or alternative therapies, surgeries, or even related to caregivers, were excluded. In this way, a fourth filter was applied, and 26 articles were excluded.

As a result of the applied filters, the portfolio of articles was reduced to 28 documents aligned with the research topic and their respective thematic axes. Of these, four were written in a language other than English or Portuguese and were therefore excluded, consolidating the portfolio into 24 articles that met the search criteria.

The selected articles were fully read by one of the authors of this review and analyzed according to the following criteria: a country where the study was carried out, sample, design, type of cost studied, perspective, and values found. The results are organized in Table 18.1.

Table 18.1 Papers selected for review

Author	Country/region	Year	Design	Cost studied	Perspective	Value/year (US$)
Yu et al.	USA	[35]	RE	D/I	HS	7.022 (65–79 y)/8.267 (≥80 y)
Cubo et al.	Spain	[4]	RE	Int.	G	NA
Lindgren et al.	Europe (5 countries)	[15]	Rev.	D/I	S/HS	NA
Findley	UK	[6]	Rev.	D/I	NA	NA
Winter et al.	Germany	[32]	RE/PE	D/I	S/HS	21.138 (HY I-II) to 35.864 (HY II-V)
Von Campen-hausen et al.	Europe (6 countries)	[29]	RE/PE	D/I	S	2.968–11.124
Zhao et al.	Singapore	[36]	PE	D/I	S	10.129
Kowal et al.	USA	[14]	PE	D/I	S	22.800
Johnson et al.	USA	[12]	RE	D/I	IC	43.506
Richy et al.	USA	[21]	RE/PE	D/I	S	77.499 (compliant)/84.949 (non-compliant)
Johnson et al.	USA	[11]	Rev.	D/I/Int.	S/HS	36.362/442.429 (net monetary benefit, from slowing PD progress)
Tamás et al.	Hungary	[27]	PE	D/I	S/HC	6.831
Martinez-Martin et al.	Spain	[16]	PO	D/I	S	13.724,24/year 4

(continued)

Table 18.1 (continued)

Author	Country/region	Year	Design	Cost studied	Perspective	Value/year (US$)
Rodríguez-Blázquez et al.	NA	[22]	Rev.	D/I	NA	NA
Yoritaka et al.	Japan	[34]	SPO	D	S	5.828
Garcia Ramos et al.	Spain	[7]	Rev.	D/I/Int.	S/HS	NA
Gil-Prieto et al.	Spain	[9]	RE/PE	D	S/HS	138.697.858,20 (HS)/5.060,16 (average per hospitalization)
Bovolenta et al. (a)	Brazil	[1]	RE/PE	D/I	S	5.853,50
Bovolenta et al. (b)	NA	[2]	Rev.	D/I/Int	NA	NA
Mudiyanselage et al.	Australia	[18]	PO	D	S/HS	24.600 (HS)/15.137 (OOP)
Yang; Chen	China	[33]	RE/PE	D/I	S	3.225,94
Gaskin et al.	Canada	[8]	Rev.	D/I	S/HS	NA
Weir et al.	UK	[31]	RE/PE	D	HS	3.716 (year 1) to 6.021 (year 10)
Koay; Rose; Abdelhafiz	NA	[13]	Rev.	D	S/HS	NA

Notes: *SPO* semiprospective, *PO* prospective, *PE* prevalent, *RE* retrospective, *D* direct cost, *I* indirect cost, *Int.* intangible cost, *S* society, *HC* human capital, *HS* healthcare system, *HY* Hoehn and Yahr scale, *IC* insurance companies, *G* government, *NA* not applicable, *Rev.* review article, *y* year

18.3 Review of Results

18.3.1 Basic Concepts in Health Economic Assessment (HEA)

Before presenting the results of the study, it is important to address some basic concepts inherent to a Health Economic Assessment (HEA). The basic function of any HEA is to identify, measure, evaluate, and compare costs [1]. In this analysis, it is important to identify the HEA type, define the study design, classify the costs, and set the perspective to be adopted.

18.3.1.1 HEA Types

1. *Cost minimization*: Such are hardly used in health economic assessments since they require that different interventions produce the same consequences, with only the costs being compared [3]. The main advantage of such approach is simplicity since it reduces time and resources in relation to a complete economic evaluation [23].
2. *Cost-effectiveness*: This is a process that aims to determine, in a systematic and objective manner, the relationship between the costs and the benefits arising from preventive interventions [17]. In the cost-effectiveness assessment, costs are confronted with clinical outcomes, intending to understand the impact of different alternatives, identifying those with generally better treatment effects, in exchange for a lower cost [24].
3. *Cost utility*: In this type of HEA, the most important aspect is that the consequences of an intervention are not measured only with regard to the quantity of life (years of life), but also in quality of life, that is, the level of well-being of the individual is also taken into account [28]. This kind of evaluation is recommended where the interventions impact the patient's survival or where they increase the quality of life without changing the survival conditions, using a generic outcome that allows comparisons between different conditions and interventions, facilitating the allocation of resources based on the maximization of health gains [23].
4. *Cost-benefit*: Cost-benefit analyses measure both the costs and the consequences (or benefits) of interventions and traditionally hold a prominent place in the HEAs, especially among economists and managers, as they are considered those most comprehensive and that effectively covers all aspects of allocating efficiency, involving sanitary and non-sanitary issues of a given program or therapy [3].

18.3.1.2 Study Design

The design of the epidemiological study defines how the research will be performed in relation to the method adopted [2]. The most discussed study designs in the PD research are the following:

1. Prevalence and incidence: Prevalence-based studies investigate all the costs associated with a particular health problem found in a specific period of time—usually over one year [19]. On the other hand, incidence-based studies, according to Oliveira et al. [19], calculate the costs incurred with diseases diagnosed in a given year, throughout the life cycle.
2. Prospective and retrospective: There is a time relationship, where in prospective studies, the relevant events have not yet happened, i.e., studying the patient over

time, formalizing a data collection system focused on the research objective, such as questionnaires designed specifically for patients and/or their caregivers, in which everything is recorded in “real time.” In retrospective studies, all events had already taken place when the study was started. These are usually employed in long-term chronic diseases, such as PD.

3. Econometric method: This approach (either econometric or incremental) estimates the cost difference of two cohorts, paired by demographic characteristics and the presence of chronic conditions, using methods derived from econometrics associated with the cost calculations method, and the difference test can be applied between the average costs or the analyses for multilevel regression [25].

18.3.1.3 Classification of Costs

1. Direct costs: These include the value of all resources and services consumed in providing a particular intervention or in treating adverse effects as well as other present or future monetary consequences associated with it [28]. According to Oliveira et al. [19], such costs can be classified as medical costs (consultations, hospitalizations, medications, etc.) and non-medical costs (social services, changes to the residence to accommodate the patient, ancillary therapies, etc.).
2. Indirect costs: These are associated with the loss of economic productivity due to morbidity and mortality and can be measured through early retirements and pensions due to loss of income [20]. They also include informal care, defined by Martinez-Marin et al. [16] as unpaid help provided by family or friends;
3. Intangible costs: These are related to the pain, social exclusion and suffering of patients and their families, usually established through measurements of quality of life [26]. However, this category of costs, about which no consensus exists, is usually omitted because of the difficulty in quantifying it [20].

18.3.1.4 Definition of the Study Perspective

In HEAs, choosing a perspective is an important methodological decision, as it determines what types of costs will be analyzed and how to value them [20]. There are potential payers, such as the patient, the hospital, the healthcare system, the supplementary health insurance or even the society as a whole, and by choosing one of these perspectives the scope of cost estimation becomes restricted to what is ultimately the financial responsibility of the selected payer [26].

18.4 Analysis and Discussion of Results

The results obtained with this research will be presented throughout this section, according to the steps defined in the scientific method. This study as aimed at conducting a systematic review of the literature on the costs of PD, identifying relevant studies that could help to understand the types of costs brought with the disease and their impacts on the patient's life and on the healthcare system. Therefore, after researching four different databases, screening was carried out in accordance with the inclusion criteria set by the authors—according to the thematic axes of the subject, with the establishment of a portfolio of 24 papers (see Table 18.1).

The selected articles were developed according to different methodologies in several countries, thus generating different results. Thus, in an attempt to standardize the results obtained with regard to the calculated cost, all values were converted to US dollars (US$)—according to the currency rate of September 14, 2018—and the results were extrapolated to annual values.

Substantially all articles have calculated the disease costs without stating the type of economic evaluation. There was also a prevalence of social perspective studies, probably because they are more comprehensive and represent the public interest.

Since this disease has a long survival time, retrospective design studies are the most common for PD, despite the memory bias that can be generated as a result of the retroactive period. Prospective studies with patient follow-up are more expensive and time-consuming and rely on analysis using econometric models. Even so, three authors in the reviewed articles (see Table 18.1) opted for this study design. Similarly, prevalence studies are the best suited for PD costs since they are conducted based on an already established diagnosis. In this review, we identified ten articles that were in line with this research design.

The vast majority of studies found an increase in the cost of the disease according to the patient's age and the progression and severity degree of the disease. For example, in the study by Winter et al. [32], the annual cost of the disease for patients diagnosed in stages I–II of the Hoen and Yahr scale was US$21,138.00, while the more severe patients diagnosed in the stages II–V of the same scale had annual expenses in the order of US$35,864.00. This had already been found by Yu et al. [35], where patients in the 65–79 age group spent US$7022.00/year, while patients over 80 spent US$8,267.00/year.

In the study by Martinez-Martín et al. [16], the authors estimated the magnitude in which the symptoms set the PD costs over a period of four years. Total average costs increased by 92.5% (from US$2428.31 in year 1 to US$4675.00 in year 4). These findings agree with the studies by Jhonson et al. [11], in which the authors estimated how much an individual would save if the disease did not progress or if its progress was slower. The hypothetical scenario in which the PD progression was interrupted resulted in net monetary benefits of US$442,429.00/year per patient. This means that a reduction in the rate of progression of the disease could produce significant economic benefits.

In the study by Yoritaka et al. [34], the severity of the disease had no influence on direct medical costs. The researchers evaluated these costs in PD patients in a university hospital in Japan by calculating the average monthly direct medical costs in US$$485,74 per person. However, a multivariate analysis revealed that age, the presence of non-motor symptoms (such as hallucinations), and longer duration of the disease significantly increased the direct medical costs. This study also found that longer disease duration was significantly correlated with higher hospitalization costs.

In the total cost studies, there was a tendency to consider the direct and indirect costs of PD since intangible costs still lack a methodology adequate for quantification. Table 18.1 shows that 15 of the 24 articles opted for the total cost of the disease. In the study by Jhonson et al. [12], however, indirect costs were considered only from the perspective of insurers and human capital, while in another study, Cubo et al. [4] sought to evaluate intangible costs only through lost years of life. Other five studies evaluated only the direct costs of PD.

Direct costs accounted for the largest portion of the total costs, probably because they comprise a considerable number of variables, such as medications, hospitalizations, outpatient consultations, ancillary treatments, home care, transportation, and special equipment. Von Campenhausen et al. [29] investigated the costs of PD in 486 patients based on a survey conducted in six countries (Austria, Czech Republic, Germany, Portugal, Italy, and Russia), with economic data collected over a 6-month period. The average total costs per patient ranged from US$3,055.55 to US$11,452.50. Such variations were due to differences in the characteristics of the healthcare system specific to each country, macroeconomic conditions, as well as the frequency of use of resources. Direct costs totaled approximately 60–70% and indirect costs approximately 30–40% of total costs.

The PD costs impact the healthcare system considerably. Mudiyanselage et al. [18] estimated the annual cost of PD from a home care, social, and healthcare system perspective in Australia. The mean annual cost per person for the healthcare system was US$32,556.00, the largest component of which being the hospitalization costs (69% of total costs). In another study conducted in Spain by Gil-Prieto et al. [9], hospitalization due to PD did cost the healthcare system about US$138,697,858.20 per year, with a mean cost of US$5,060.16 per hospitalization.

Among the 24 articles analyzed, only one study was conducted in Brazil. In this study, performed by Bovolenta et al. [1], the annual cost per patient was US$5,853.50, including US$3,172.00 in direct costs and US$2,681.50 in indirect costs. However, this study considered only those diseases caused by the motor symptoms of the disease.

The discrepancy between the PD cost amounts obtained from the assessed articles is due to the different methods, designs, studied cost, and study perspective which were adopted. These results illustrate the importance of defining these variables when conducting economic evaluation studies.

18.5 Conclusion

The importance of researching the cost of PD and its impact on patient, family, society, and healthcare systems is undeniable. As shown in most studies evaluated, identifying modifiable risk factors associated with the onset and progression of the disease can facilitate the development of strategies to mitigate its burden, which affects individuals, caregivers, and the healthcare system.

The results of the research show large expenses with the disease, which stresses the importance of further research on the subject. Such costs overburden individual finances and the family budget (from a patient's perspective), public and private healthcare systems (from the perspective of the third-party payer), and also means a great social burden resulting from the limitation of labor and the payment of pensions caused by the course of the disease.

The articles selected in this review emphasized the direct and indirect cost analyzes of PD. However, the shortage of studies analyzing the intangible costs of the disease opens a considerable gap in HEA studies. The inclusion or exclusion of a cost category can represent a huge difference in the final outcome of the analysis. However, the valuation of intangible costs is still controversial and depends on the development of a methodology for this purpose. For future works, it is suggested the development of researches that include the intangible costs in the costing models.

The shortage of studies on the cost of PD in Brazil was evidenced in this review work. This fact makes it difficult to carry out forecasts and calculations of future estimates, impairing the evaluation of the economic impact of PD on an individual's life and also on healthcare systems, both public and private. The study on the cost of PD in Brazil, from several different perspectives, is revealed as an interesting niche for future research in different areas.

This research, including the construction of the revision method, the search in databases, the selection of articles and exporting them to the Zotero® software, and the statistical analysis (bibliometrics) of the studies, was carried out in March 2018. Therefore, as in any review, there was a time limitation on the data collection and should new authors or researches appear, those will not be included in the portfolio of selected articles. Moreover, the perception of the authors who developed this research is limited, from the decision on the alignment with the subject or even about the choice of inclusion and exclusion criteria. Finally, due to the identification of keyword-based publications, it is possible that some publications matching the focus of the research failed to be found due to the absence of the required keywords in their titles or abstracts.

In a study of systematic literature review, one should not have the pretension to exhaust the researched subject. On the contrary, one must raise the curiosity to develop new researches on the subject by using other keywords, or carrying out the research in other search bases, in order to identify new findings that could contribute with the construction on the researched subject.

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Chapter 19
A New Framework to Develop Healthcare Decision Support Systems in the Military Context

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Abstract In this paper, we propose a new framework that stimulates quantitative analysts, domain experts, and decision makers to work together in a military setting for the development of healthcare decision support systems. Our study case is the Brazilian Navy health system whose challenges are analyzed as complex societal problems.

Keywords Health system · Decision support system · Complex societal problem

19.1 Introduction

According to the World Health Organization [17], health is an inalienable individual asset that is not accumulative and is subject to a large set of stochastic risk factors. Its protection is thus very complex and expensive. However, this investment is justified since health problems reduce economic productivity and social cohesion [1]. This is particularly true in military settings where physical and mental fitness is a *sine quo non* condition for service. The healthcare system directly impacts the military personnel's motivation and so the combat readiness of a national armed force.

Nowadays, the Brazilian public health system is unable to provide efficient services to the population due to saturation. This also happens in the military services although with less intensity. The current political and financial crisis puts additional pressure to reduce costs and increase the overall efficiency of health systems. It is increasingly apparent that for this purpose, the modernization of the health system management processes leveraged by technological investment is a viable, economic, and sustainable option [11, 14, 17].

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In this context, healthcare decision support system (HDSS) is a useful tool that helps to design effective policies and to optimize operational and managerial processes. The materialization of these potentialities demands a framework that facilitates the interaction of physicians, quantitative analysts, and decision makers during the development of a healthcare decision support system. Shim et al. [14] and Sprague [16] highlight the importance of the interaction and cooperation between domain and technical experts to maximize the efficiency and effectiveness of decision support systems (DSSs). In the case of a HDSS, close and transparent communication between these two classes of professionals is even more vital because the development and maintenance of a DSS are often very expensive and time-consuming. Moreover, a HDSS impacts the quality of life of the overall population and may have legal ramifications.

We have observed that the Brazilian Defense Ministry does not have a framework that guides the development of a HDSS and systematically stimulates the interaction of domain experts, decision makers, and modelers. In this paper, we intend to fill this gap by customizing the complex problem handling method (COMPRAM) [7–9] for some particularities observed in the military context. This method provides decision makers and experts with a formal way to structure complex social problems, which includes healthcare problems. Based on its successful applications to environmental, health, economic, and security problems, DeTombe [10] argued that the COMPRAM has some advantages, such as: efficiency to accommodate conflicting interests; capacity to find a common ground between different world views; and flexibility to adapt to distinct domains. Collazo [4] discusses the viability of using this method in complex problems associated with the Brazilian defense establishment.

The objective of this paper is to develop a framework that stimulates close and positive cooperation between the different professionals that play key roles in the conception, development, and use of a HDSS in the Brazilian military setting. To pursue this, the paper is divided into six sections including this introduction. Section 19.2 presents some aspects associated with healthcare systems. Section 19.3 discusses the characteristics of the administrative decision processes in the military health domain based on the Brazilian Navy's healthcare system. Section 19.4 outlines the types of DSSs. Section 19.5 introduces the COMPRAM and proposes a version adapted to the Brazilian military reality. Section 19.6 concludes with a brief discussion of the relevance of the results. Remember that a method is a detailed plan to handle a specific process or problem. It differs from a framework that establishes a loose and open guidance without rigorous specify a set of tools or practices to be followed. In this sense, we prefer to adopt the nomenclature of framework for our proposal since it contrasts with a mature and well-developed structure given by the COMPRAM [10]. Some further investigations required to advance our framework into a method are summarily presented in the last section.

19.2 Healthcare Systems

The World Health Organization [18] defines a healthcare system as:

a. *all the activities whose primary purpose is to promote, restore and/or maintain health*; or
b. *the people, institutions and resources, arranged together in accordance with established policies, to improve the health of the population they serve, while responding to people's legitimate expectations and protecting them against the cost of ill health through a variety of activities whose primary intent is to improve health*.

It then follows that the first definition focuses on health activities and so leads decision makers to concentrate their attention on process management. In contrast, the second definition enlarges the scope of a healthcare system and adopts a human-centered perspective. It goes beyond traditional aspects such as health professionals, organizational structure, financial and physical resources, and political coordination. In doing this, it emphasizes not only the patients but the whole population protected by a healthcare system. All individuals should have their healthcare expectations fulfilled. They should also be protected against financial costs due to accidents or diseases regardless of their current need for healthcare assistance. In this sense, this definition is more holistic and organic. It stimulates the understanding of all these elements as a dynamic and integrated organism whose main objective is to promote health for each of its living elements, i.e., for each individual eligible to be protected by the organic system.

Frenk [11] enumerates three misconceptions that prevent improving the performance of a healthcare system: the "black box" misconception; "black hole" misconception; and "laundry list" misconception. In the "black box" misconception, the complexity of a healthcare system prevents its analysis. This approach tends to favor the adoption of technological solutions without a deep understanding of their consequence for the real-world process. The "black hole" misconception leads managers to see the healthcare system as giant organism that demands a great amount of financial, material, and human resources. In this case, it is impossible to implement the required improvements that are necessary to close the gap between the population's expectation and the current performance of a healthcare system because the demands are too great for the scarce resources. The "laundry list" view represents managers' beliefs that a healthcare system is a simple collection of organizational structures, individuals, and resources without taking into consideration their synergic and frictional interactions.

To avoid these misconceptions, it is fundamental not only to explicitly include the supply chain and institutional elements in the description of a healthcare system but also the population [11]. Decision makers and experts should view the inclusion of the population as a basic requirement to stimulate the proactive and positive participation of individuals in the design of healthcare policies and in the control of public spending. According to Frenk [11], this can be achieved if they highlight and strengthen the five roles that individuals play in the healthcare system as citizens, consumers, clients, taxpayers, and co-producers. First, an individual has some rights as a citizen and as an eligible member of the healthcare system. As a consumer, he has expectations to be fulfilled to some extent by the system. Third, he is a client when he becomes a patient and then demands medical or hospital assistance. Furthermore, he is a financial contributor to the system because he pays taxes or some other charges. Finally, an individual can also play a role as a co-producer since he can perform actions that promote or damage his own well-being or that of others. In this way, embracing the population corresponds to the organic perspective that unfolds from the second definition of a healthcare system and preempts decision makers from adopting misconceptions for the reasons discussed below.

Active public participation forces managers and decision makers to keep closer contact with the system, increasing their knowledge about the system's dynamics and reducing their "black box" feeling. On the other hand, the public control reduces the expenditure of funds on complex and bureaucratic control structures, optimizing the application of resources in activities in line with population's expectations, and so minimizes the risk of "black hole" beliefs. Lastly, the organic perspective precludes decision makers from interpreting the population as an exogenous element of the healthcare system. When decision makers realize the five roles played by the population and include them in the system, they recognize the synergic and dynamic aspects of the healthcare system. This keeps them from having the "laundry list" misconception.

Note that decision makers, healthcare professionals, and technical analysts must work together and collaboratively to guarantee that a healthcare system translates clinical and management knowledge into concrete actions that satisfy the population's needs. For this purpose, they need to identify, filter, and prioritize the population's expectations through the socio-institutional mechanisms of public representation. According to Frenk [11], this result is obtained when technology, institutions, system design, and leadership are in place. Particularly, it is necessary to adopt a framework that includes and stimulates individuals to take part in the definition and solution of the problems.

19.3 Military Healthcare Macrosystem

In this section, we identify the main characteristics of the Brazilian military healthcare macrosystem in terms of its organization, decision structure, and eligible population. This macrosystem has three systems: Navy healthcare system, Army healthcare system, and Air Force healthcare system. Since each armed force manages its own system, they are financially and administratively independent. However, the Ministry of Defense performs the political coordination of these systems to harmonize the procedures and institutional macrostructures. For this reason and for the sake of brevity, we base our analysis on the Navy healthcare system and inductively argue that the key aspects highlighted can be assumed to apply to the other military healthcare systems. We made this choice because of our long experience working in the Brazilian Navy and Ministry of Defense as quantitative analysts and project managers.

From the previous section, we start by examining the target population of the Navy healthcare system, which is composed of three different groups of individuals [3]. The first group consists of all active and retired Navy personnel, and their wives and children. They contribute monthly to the Navy health fund, which financially supports the Navy healthcare system. Each consumer must pay 20% of the cost associated with any medical or hospital assistance required from the system. Members of the family circle who are financially dependent on a military individual constitute the second group. Despite not regularly contributing to the Navy healthcare fund, they must fully refund all cost associated with medical or hospital care received in the Navy healthcare system. The last group corresponds to special individuals such as cadets of Navy training centers and foreign military liaison personnel. They are not charged any financial contribution for using the Navy healthcare system. The whole eligible population is thus highly heterogeneous with individuals from different social, ethnic, age, and demographic backgrounds. Any framework for the development of HDSS in the military context should guide the different experts and analysts to take this demographic diversification into account.

To meet the users' expectations and the administrative requirements, the Navy healthcare system is organized into three subsystems: healthcare subsystem, health inspection subsystem, and operative medicine subsystem [3]. The healthcare subsystem is the largest and most used one. It is divided into three levels according to the complexity of the medical attention required. The second subsystem controls the physical and mental health of all military personnel and candidates for entry into the force through health inspections. Finally, the operative medicine subsystem plans and implements actions to maintain the health of the personnel employed in real-world operations in times of peace, crisis, or conflict. We note that a framework for the development of a military HDSS (MHDSS) needs to lead experts to clearly identify which subsystem is their primary and secondary objective and the expected impacts on each subsystem. Otherwise, the framework will lack operative adherence and conflicts will flourish between technical analysts and medical experts, particularly toward the end of the MHDSS development.

The Navy healthcare system has three management levels: execution level, coordination level, and direction level. The execution level is the lowest level of management performed in each naval healthcare organization such as hospitals, polyclinics, outpatient clinics, dental centers, and pharmaceutical laboratories. The middle level promotes the coordination of all activities performed in the healthcare subsystems. Being the upper rank, the execution level is responsible for the strategic management and control of the entire healthcare system.

Because of the increase of uncertainties involved in the healthcare dynamic, the decision process becomes more unstructured as the decision level rises. At the middle and top levels, decisions often concentrate on administrative aspects about process management and financial control. The focus is on the population rather than the individual. Decision makers require consolidated data to obtain a global vision of the system using business intelligence and analytic tools since their decision impacts large sectors of the system during long periods. Conversely, at the execution level the clinical aspects come to the fore. Of course, the management aspects exist and are very important, but they are often subordinated to the clinical ones. Decisions have a direct and immediate impact on individuals and are made under great pressure. To support the decision process at this level, health professionals demand fine-grained, frequent, and reliable data. These decision levels thus have distinct characteristics that should be taken into consideration for the development of a HDSS.

19.4 Decision Support Systems (DSSs)

A DSS is a computational tool whose purpose is "to support complex decision making and problem solving" [14, p. 111]. Power et al. [13] identify five types of DSSs:

- Communication-driven DSS—they are based on network and communication technology. Their aim is to accelerate the informational flow in an organization.
- Data-driven DSSs—they facilitate the storage, access, and use of data required by the processes in an institution.
- Document-driven DSSs—they allow storage and retrieval of documents using different tools that act on large document datasets.
- Knowledge-driven DSSs—they use statistical and machine learning models to support decision makers to formally structure the problem and find solutions.
- Model-driven DSSs—they are built on mathematical models to perform simulation.

Note that a DSS can be included in more than one of these categories. This often happens when a DSS passes through some software evolution in its life cycle. For example, a data-driven DSS and a document-driven DSS often provide an organization with substantial gain of efficiency from the onset of their installation because they accelerate the information flow and decision cycle. The variety, velocity, and volume of data greatly increase and then saturate the traditional decision structures. At this moment, decision makers start demanding algorithmic tools to process this data deluge and provide them with useful and timely information. These resources are usually added as a business intelligence or business analytics layer to the original system. The updated DSS becomes also a knowledge-driven DSS, a model-driven DSS or both, besides its original classification.

The correct identification of the type of DSS required to support healthcare decision-making processes plays a key role to successfully develop a HDSS, since this contributes to align the objectives and expectations of all individuals involved, directly or indirectly. Furthermore, the precise definition of the necessary type of DSS enables building teams that match the technical requirements specified by domain experts, decision makers, and senior analysts. For instance, a communication-driven DSS, a data-driven DSS, and a document-driven DSS demand a software development team with a strong background in software engineering. In contrast, a knowledge-driven DSS or model-driven DSS emphasizes the mathematical, statistical, and machine learning skills of the development team.

19.5 A Method for the Development of a Healthcare Decision Support System

In this section, we present the COMPRAM and then customise it to the peculiarities associated with the development of a HDSS in the Brazilian military context.

19.5.1 The COMPRAM

The COMPRAM [7–9] is a prescriptive structure that guides decision makers, technical analysts, and domain experts to find a solution to complex societal problems (CSPs). According to the DeTombe [7, 8], a CSP is a dynamic problem that has large economic, environmental, political, or psychosocial impacts in time and space and involves a variety of agents at the local, national, or international levels. It also embeds a high degree of uncertainty, since the information is scarce, nonexistent, or even contradictory. Its definition is then very difficult, the identification of its origins is dubious, and its probable outcomes are unknown. Its solution then demands a long-term multidisciplinary approach that emphasizes the political aspects and the construction of common understanding to handle the political interferences and the socioeconomic restrictions. This type of problem directly links with the population's well-being and includes questions of employment, security, or health.

The COMPRAM [7–10] has six steps:

- Step 1. A neutral team of technical and domain experts analyzes the problem to outline the different perspectives.
- Step 2. A panel of key non-specialist actors and stakeholders studies the targeted CSP.
- Step 3. A working group (panel of key actors and team of experts) identifies viable solutions to the CSP.
- Step 4. The working group tries to anticipate the reactions of the target population.
- Step 5. Decision makers choose a solution and implement it.
- Step 6. The working group assesses the results.

DeTombe [7, 8] argues that decision makers need to handle the CSP in two phases. The first phase corresponds to steps 1 and 2 where the problem is included in the political agenda, the problem is formally structured, and the team of experts is constituted. The other four steps constitute the second phase where the solution to the problem is identified and implemented. The COMPRAM also includes the use of graphical tools to facilitate the communication between all agents involved in the solution. It does not define which method facilitators should use in this context. For example, we recommend using mental maps [12] in the first phase to help the elicitation of the conceptual model associated with the problem. In the second phase, we advocate adopting statistical graphical models. Some examples of these models can be found in Collazo et al. [5], Cowell et al. [6], and Smith [15].

19.5.2 The COMPRAM-MHDSS Framework

Note that it is straightforward to characterize most problems faced in the military healthcare system as CSPs. For example, they are complex and dynamic problems that impact many individuals (military personnel and their families, health professionals, decision makers), different kinds of organizations (governmental and private ones), and the national power. They are time resilient and pass through different levels of actions and decisions. For this reason, their solution tends to shift from technical aspects to political and organizational consensus building.

However, the use of COMPRAM to develop a military HDSS (MHDSS) requires some customizations that we briefly discuss here. First, the armed forces are based on hierarchy and discipline according to the Brazilian Constitution [2]. This implies that high-ranking decision makers at the level of coordination or direction of an armed force healthcare system need first to realize the CSP and to mobilize the different organizational sectors that need to be involved in the solution, particularly the technological sector. This constitutes an additional Step 0 to the original COMPRAM and enables making the highest level decision makers accountable for the solution and its consequences.

In Step 1, the panels of experts should describe a CSP in terms of its administrative, clinical, and technological aspects. Next, the main actors need to identify the most important healthcare subsystems and management levels on which they observe the consequences of the target CSP and its root causes. This enables them to clearly define the responsibilities and to concentrate on key technical and managerial points to be considered in the solution. This step also needs to bring into the discussion the view of the military personnel and their families. For this purpose, the leading facilitator may opt for satisfaction surveys or the selection of a group of representatives. At this point, it needs to be recognized that the last alternative is a somewhat challenging initiative in the military context given the strong hierarchical nature of the decision-making process. Last, it is vital to consider the participation of representatives of non-military organizations in the public and private sectors.

In Step 3, the working group must first analyze if the development of a HDSS contributes to solve the CSP. If this is the case, they should then define the type of DSS and specify the business requirements. Otherwise, the group may keep sorting through non-technological solutions to the problem. The last three steps require simple adaptations in their textual descriptions. Adding the changes discussed to the COMPRAM, we obtain a framework called COMPRAM-MHDSS, which has the following seven steps:

Step 0. Decision makers at the level of direction or coordination identify the CSP and mobilize the necessary sectors of the corresponding armed forced.
Step 1. A neutral team of technical and domain experts analyzes the problem to outline the different perspectives in terms of administrative, clinical, and technological aspects.
Step 2. The main non-specialist actors and stakeholders study the targeted CSP and identify the key healthcare subsystems and levels of management involved in the CSP. They should take into consideration the views of the military personnel and their families as well as the interests of non-military organizations in the public and private sectors.
Step 3. A working group (main actors and team of experts) identifies viable solutions to the CSP. They should consider if a HDSS contributes to solve the problem. In this case, they need to define the type of DSS and its business requirement.
Step 4. The working group tries to anticipate the reactions of the target population (military personnel and their families) to the use of a HDSS.
Step 5. Military decision makers choose a solution and implement it.
Step 6. The working group assesses the results.

19.6 Conclusions

In this paper building on the COMPRAM, we propose a new framework called COMPRAM-MHDSS for the development of an effective HDSS in the Brazilian military context. This framework creates the systemic conditions for the establishment of a virtuous cycle of collaboration among domain experts, technical analysts, and decision makers during the conception and construction of a HDSS. The following three guiding aspects included in the framework guarantee the achievement of this purpose: focus on understanding and structuring the problem; improvement of communication channels among the technical team, domain experts and decision makers; and incorporation of perceptions and expectations of the population to be impacted by the HDSS.

In the future, it is necessary to create a roadmap that enables formally incorporating the COMPRAM-MHDSS framework into the juridical-normative structure of the Brazilian Ministry of Defence. This development is an important condition to use the framework to solve large-scale problems in the military real-world setting. Another interesting proposition is to develop methods compatible with our proposed framework that further stimulate the participation of the military personnel in the development of a HDSS. We also stimulate researchers to explore the connections between graphical models and our framework. Recall that graphical models are a useful tool to facilitate the communication between actors with different backgrounds and perspectives. However, there are myriads of graphical models. Therefore, it is necessary to issue a guideline that helps technical analysts to choose a set of appropriate graphical models to be used along the six steps of our framework.

Disclaimer The authors are the sole responsible for the contents, which does not necessarily reflect the policies and views of the Brazilian Ministry of Defence, Navy, Army and Air Force.

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Chapter 20
The Healthcare Operations Management and the Industry 4.0: The Disruptive Technology Use in the Continuous Education

Gláucya Daú, Annibal Scavarda, Fang Zhao and Meena Chavan

Abstract The industry 4.0 can contribute to the healthcare operations management through the disruptive technology use in the continuous education of the healthcare professionals. This research study analyzes the interaction between the theoretical information and its practical applicability in the healthcare operations management safe process development. The researchers developed this study between May and July, 2018, and search to answer two questions. The questions are: How to use the disruptive technologies in the continuous education for healthcare professionals? How to enable professionals present on healthcare operations to use these technologies? The Global Competitiveness Index by the World Economic Forum report [14] was the basis of the data for this study. The results and discussion section have two highlights: "the professional adaptation to the disruptive technologies" and "the use of the disruptive technologies on continuous education." The Conclusions section shows that the insertion of the disruptive technology brings the work optimization time of the professional for a specific activity. The implementation of the annual training schedule, the adjustment of the sector dynamics, and the adhesion of the professional on the educational program are presented in the conclusions. This research study

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contributes the insertion of the healthcare professional on the educational program and the fourth industrial revolution.

Keywords Disruptive technologies · Healthcare operations management · Industry 4.0

20.1 Introduction

The fourth industrial revolution brings the worldwide scenario a production and management model in which the automation is fully inserted [1, 8], as well as digitalized processes and artificial intelligence features [16] in many fields of the society. This incorporation can be noticed on the healthcare institution through the diagnose equipment, the electronic health record, and the information obtained by man–machine interaction. The three stages that preceded this revolution also brought value to the development of the society and contributed to arrive to the fourth stage [7]. These contributions can be exemplified by the steam machines (first stage), the electric energy and mass production (second stage), and the automation (third stage). Within the proposition brought by the industry 4.0, the disruptive technologies like as the Internet of Things and the Internet of Services [10] were inserted on daily routine of the people [16], getting more and more space every day. This integration among people, software, and system is also noticed in the healthcare institutions. In this case, the healthcare institution is called "hospital 4.0" and aim to accelerate the worshiping for the final client while delivering goods and services.

All these changes motivated the authors of the present study to search for the answer for two questions: How to use the disruptive technologies on continuous education of healthcare professionals? How to enable active professionals in the healthcare area for the use of these disruptive technologies? This is a challenging task and should have a broad vision for the observation of the stages of the work and health management operations.

The education while on duty is one of the ways used by the institutions to search for the balance between costs and quality. The implementation of the management tools like as lean helps to adjust work steps and reduce costs with quality improvement [6]. One of the aspects to keep the quality programs is directed to how much and in which way the healthcare institution establishes its annual continuous education plan. Many institutions have professionals who are dedicated to this task, but who face many barriers to accomplish the schedule previously set for this.

The Fig. 20.1 brings a representation of the research questions presented. The disruptive technologies can be inserted in the healthcare professional education program and the implementation of the educational program can use the disruptive technologies. The association between work and the corporate social responsibility is possible [2, 9] through the integration of the professional on the digital universe [15, 16].

Thus, the opportunities are presented and enable disruptive technologies [15] to be introduced as an auxiliary method to conduct sectorial continuous education. The

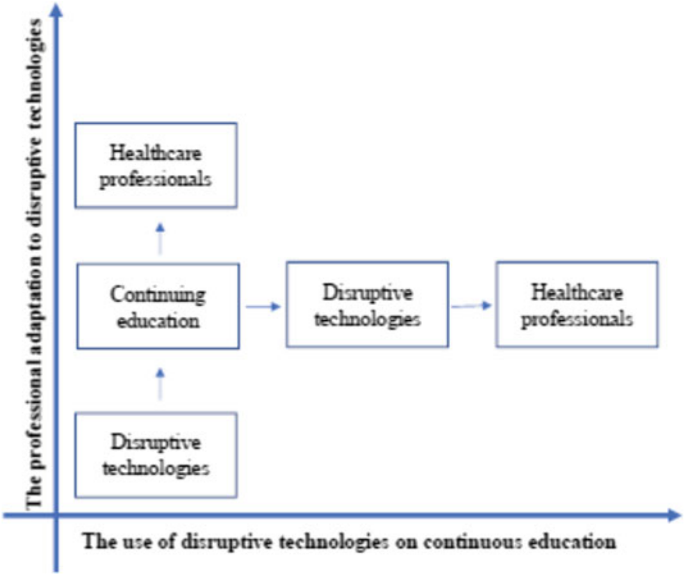

Fig. 20.1 Disruptive technologies as a basis and target of continuous education

central proposition of this research is to bring the knowledge and the information, besides developing skills for the quality improvement in the healthcare institutions. Some barriers for the implementation of this program can be observed. These barriers can be exemplified by the time the professional has to be available for an educational activity, due to sectorial dynamics, to the accomplishment on an annual training schedule, and the adhesion of the professional on the educational program. A connection is established between the possibility of widening the insertion of the industry 4.0 on Brazilian healthcare sector and the adaptation of the professional to this new step. The technologies used by the hospital 4.0 should allow that wherever the professional might be, could connect and access online trainings, updating the knowledge, and the information about the subject.

20.2 Materials and Methods

The present study has the aim to answer two questions: How to use the disruptive technologies in continuous education for healthcare professionals? How to enable professionals present on healthcare operations to use these technologies? The study was developed between May and July, 2018, and was based on the Global Competitiveness Index presented by the World Economic Forum report [14] data, which established 12 pillars by the gathering of 114 indicators. These pillars were: the institutions, the infrastructure, the macroeconomic environment, the health and primary education, the higher education training, the goods market efficiency, the labor market efficiency, the financial market development, the technological readiness, the market size, the business sophistication, and the innovation.

The report assessed 137 economies toward the 12 pillars results. This report enables the assessment of the insertion of the countries on the fourth industry revolution. Therefore, the authors of this research understood that the base of these pillars is on the educational programs, by analyzing the data collected. On the present study, particularly, the educational programs are headed to the healthcare operations management. The productive chain of the health sector present different complexities, if compared to the industrial productive chain, since it is connected to treatments made on a healthcare institution with each of the patients.

Two subsections are highlighted in the results section, the first one: "the professional adaptation to the disruptive technologies," four groups are identified: those who do not have skills to operate computers, those who have skills and have already operated computers previously, the group that works with low complexity systems and software (like as receptionists and stockpile), and the group that work with more complex systems (like as computer technology professionals). The second topic, "the use of the disruptive technologies on continuous education" discussions and propositions are presented for the following challenges arisen by the authors for this study: the availability of the professional for an educational task, due to sector dynamics, the accomplishment of an annual training schedule, and the adhesion of the professional on the educational programs.

20.3 Results and Discussion

The section "results and discussion" is divided in two subsections, which aim to present propositions to answer the questions arisen on the present research. The two subsections are "the professional adaptation to the disruptive technologies" and "the use of disruptive technologies on continuous education." These topics put the disruptive technologies not only as a mean to promote continuous education, but also as a goal for it.

20.3.1 The Professional Adaptation to the Disruptive Technologies

The healthcare professionals face new technologies on healthcare institutions daily, like as equipment and software that enable the integration of the systems and provide a number of information about a certain process and patient. The fourth revolution brings stimulus [10] for the healthcare professionals to be their own transformation agent, influencing their own career. It is also questionable how much preparation the professional has to absorb all the new information provided by industry 4.0.

Two paradigms are presented as a concern for this new stage: the unemployment and the professional skilling on the man–machine adaptation. Therefore, it is stimulated the professional to be their own transformation agent. On the other hand, at the same time, the professional has skills, the hospital institution also does. The hospitals embrace the corporative and social responsibilities in order to prepare their employees to know and handle new technologies.

The continuous education service is stimulated to know the profile of all the staff under their responsibility. The strategy aims to identify groups, according to the level of knowledge and how they operate systems and software. After that, the mapping of the groups according the skills might be positive for the learning process. This mapping enables the groups to be the more homogeneous they could. Then, four groups are identified: those who do not have skills to handle computers and those who do so, the group that works with low complexity systems and software (like as receptionists and stockpile), and the group that works with more complex systems and software, like the computer technology professional. A distinct planning for each group is presented and the industry participation as a support brings pertinent information for the technologies use.

For the first group, those who do not have any technology skills, it is important to have a program that provides the presentation, the insertion, and the adaptation to the digital universe. The healthcare institution can create an ambiance that gives the possibility to develop simple tasks. This ambiance establishes a connection between man and machine and the possibility of the professional change as a consequence. The stimulus for this kind of the project becomes wider when the social sustainability is inserted. The valorization of individuals and the possibility of professional growth opens space for new ideas and paths for the health institutions and for the country evolution.

For the second group that has technology skills at some ground, like the use of the computers and the cell phones, there should be an educational program based on: How to deal with the new tools to be used? In the case of online training, for example: How to access the health institution course platform? Which resources are obtained through the digital platform? The knowledge of the platform digital stimulates the professional to search for more information with safety and quickly. The fourth group described can be exemplified by the computer information professionals. The proposition here is to invert the role of this group, who become the trainers of the first. Figure 20.2 presents the four groups described, the role of each integrant on the educational program, and the aims expected from each of them.

The study highlights that there is an opportunity for the continuous education staff may be interdisciplinary. In every units of the institution, the education while is service should be implemented. An interdisciplinary movement allows integrating the knowledge and educational programs improvement, the professional valorization, and the search for new goals. This movement provides the exchange of the experience and establishes the corporate social responsibility. The corporate social responsibility is presented in many studies [3–5, 13].

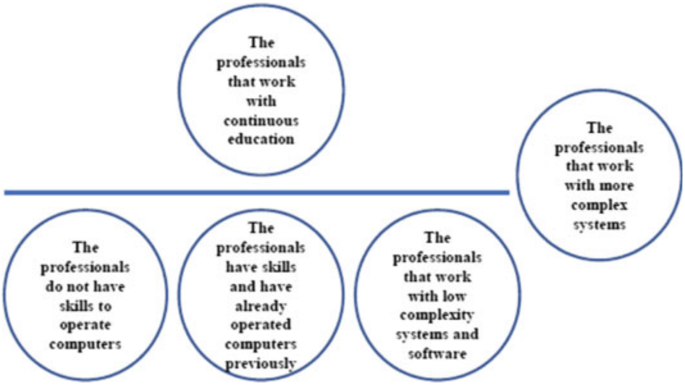

Fig. 20.2 Each integrant on the educational program

20.3.2 The Use of the Disruptive Technologies on Continuous Education

The common sense among the authors is that once the professionals who did not have skills to operate computers were adapted, the structure for the implementation of an educational program involving the use of the disruptive technologies can be fully implemented. The challenges presented previously like the availability of professionals for training sessions, due to unit's dynamics, for the accomplishment of the annual training schedule, and by the adhesion of the professional on the educational program build the structure of the subsections below.

20.3.2.1 The Time Availability for the Professional to Be Trained

The healthcare institutions can structure a schedule so that once a month, their staff has half an hour to work on educational purposes. The staff rotation with members of the same teams is one of the requests to make this half-hour training happen. During this period, the professional should perform activities guided by the continuous educational service provided by the institution. An example of these activities can be the online courses, webinars, and short videos with technical information. For these, a computer, in a specific area of the institution and destined to train while on duty, is used. The attendance and permanence are obtained monthly through reports provided by the system. By the end of each month, the professional is assessed so that the acquisition of knowledge is tested as well as the effectiveness of the tools used.

20.3.2.2 The Sectorial Dynamics

The sectorial dynamics is one of the reasons why training sessions are commonly interrupted and not done. The possibility of understaffing cannot compromise the training routine. At the same time, it is noticed that the automation and the insertion on the digital universe [11] facilitates release of the professional from some activities. These activities were performed manually at first. The interruptions of the training should be evaluated, as well as the creation of strategies to reduce these interruptions. A particular situation commonly observed is the phone calls demand while on surgical rooms to order extra material for surgeries. This situation may lead to rethink the structural management of the surgical kits. They need to be customized and if tools like Kanban would solve the issue. Thus, the main cause might be in other management aspects which affect so many structures of the hospital unit.

20.3.2.3 The Accomplishment of an Annual Training Schedule

The accomplishment of an annual training schedule is to identify the specific needs of the person to be trained, and then establish a schedule that is truly possible to be executed. The offer attractive themes stimulate the employee to participate and to be integrated to this schedule. The two points presented have full impact on the final result. To make the virtual environment attractive also enables adhesion and proper attendance. The simple and different tools can be used, like as the videoconference, in order to achieve these goals. There is no obstacle for the training of these people, like as the shift of employees, because it can be done online through the cell phone, for example. Then, the Internet of Things brings new experiences by integrating the systems, the software, and the people [12, 15].

20.3.2.4 The Professional Adhesion to the Educational Process

The fourth point presented can be eliminated with assertiveness. The implementation of the activity development to accomplish the annual schedule, the adjustments on the sectorial dynamics, and the time availability for the educational purposes are the topics that can achieve this point. The education becomes the basis for the solution of issues and for the structuring of aspects that bring quality for the programs. The implementation of a proper educational plan that is dynamic, feasible, and attractive is part of the role for any manager, which in case of the present study is the person in charge of the healthcare managing. The quality programs cannot be fully implemented in case a solid educational basis is not set and internalized by all the health institution professionals involved. The professional adhesion goes through aspects like motivation and recognition. When recognition comes from a well-performed activity, the professional is being stimulated to become better their professional performance. So, the professional, the healthcare institution, and the patients who seek for health problems solution are all benefitted by the process.

20.4 Conclusions

The fourth industrial revolution brings development in different scenarios [1, 8], as the health sector shows by the management of the health operational routines. This development is presented by the automation and the digital universe [16] as opportunities for the insertion of the disruptive technologies that help many tasks performed on the healthcare institutions. One of these activities is the education while on duty, performed by a number of units. The interdisciplinarity and the creation of an ambiance for exchange of the experiences and the knowledge should be stimulated within the educational group. Two main questions were answered by the study, which are "How to use the disruptive technologies on the continuous education for professionals of healthcare operations?" and "How to enable healthcare professionals to use the disruptive technologies?" In order to do so, the authors identified four distinct groups involved on these routines: those with no computer skill and knowledge, those who have some ground of digital skills, those who can handle low complexity devices, and those who handle high complexity systems. Two subsections were created then, "the professional adaptation to the disruptive technologies" and "the use of the disruptive technologies on continuous education". The points to achieve these goals were then presented and discussed with proposes for the insertion of technologies. The insertion of these technologies aims to optimize the time of the professional availability for a specific activity, the adjustment of the sector dynamics, the accomplishment of an annual training schedule, and the adhesion of the professional on the educational program. Many of these initiatives can be a target and effective on healthcare institutions routine. Thus, the present study also aims to contribute for the improvement of processes involved through an integrated proposal of tools, insertion of the healthcare professional on the educational programs, and on the fourth industrial revolution as a consequence. The limitations of this study were the amount of the research information between the healthcare and education with disruptive technologies.

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Chapter 21
Hierarchical Non-capacitated Location Model for Allocating Oncological Treatment Units in State of Rio de Janeiro

Isabella Fischer Guindani Vieira, Matheus Ferreira de Barros and Allan Cormack

Abstract The paper aims a proposition of a mathematical model for allocation of oncological treatment units in Rio de Janeiro, Brazil. The mathematical models of location in the literature were reviewed and based the choice by the two-level hierarchical PQ-median model with additional constraints of maximum distance and vertices eligibility. The same was implemented in the CPLEX optimization software.

Keywords Facility location problems · Integer programming · Oncology

21.1 Introduction

The central objective of a National Health Service (NHS) is to provide universal and free care, health care, and medicines for all citizens, and this system is financed through taxes and the general budget of the State. In Brazil, this model has been adopted since 1990 with the creation of the Unified Health System (SUS), in accordance with the Federal Constitution of 1988 [3].

However, by reducing the scale in the units of the federation, failures in the system are observed that go against the right of the citizen. Especially in the State of Rio de Janeiro (ERJ), the quality of service provided to the population appears to contradict the doctrinal principles of SUS. At the end of 2017, the Regional Council of Medicine announced the state of technical calamity in the health area in the state due to problems such as lack of medicines and personnel, delays in salaries and broken equipment, calling society's attention to the real bankruptcy of the structure

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public health system. This is justified by the report entitled Impact Assessment and Data Openness in Planning and Financial Health Management, produced by the Public Prosecutor's Office of Rio de Janeiro in March of this year, which shows that at least since 2014, the ERJ has stopped applying the minimum of 12% of annual tax revenue in public health actions and services [9]. The complaint also covers aspects relating to transparency. According to him, the State Government does not keep the data of the Transparency Portal up to date, clear and with easy access, being in the last position in the ranking of the Brazil Transparent Scale.

On the other hand, Cancer today is the second largest cause of death in Brazil, according to data from the mortality information system (SIM). For the biennium 2018–2019, it was estimated by INCA that there will be approximately 582 thousand new cases in the country and it indicates that the number of cases is increasing each year, as well as the severity of the disease in the first diagnosis. Therefore, it is necessary to rethink the structure of cancer care at the SUS to meet the growing demand, diagnosed at increasingly advanced stages, especially for the state of Rio de Janeiro, where the sector is already deficient and the statistical control of the disease seems even more inefficient. The state has, according to INCA, 27 units qualified for the treatment of cancer distributed in only 11 cities, 4 in the interior of the state. For this reason, the interior regions will be the target of this study, in a total of 46 cities.

Given this general outline, the present work proposes to perform the selection and adequacy of an optimization model for facilities location, to suggest the ideal network of oncological units in the interior of the State of Rio de Janeiro and its computational implementation. Different scenarios were considered, by varying the number of facilities, since this is an exogenous parameter to the model. With this, it is possible to evaluate the optimal location model as a tool to support health management.

21.2 Bibliographic Survey

A search for similar work was done at the Scopus and Web of Science databases (Table 21.1). First, the keywords of the group [A] referring to the method used, in the case of the hierarchical localization model, were inserted. Given the high number of publications located, their individual analysis would be expensive and unfeasible, and therefore, the research was submitted to another filter, with keywords [B] referring to the application sector, health systems. The number of publications (words [A] AND [B]) decreased considerably, but still very large. Soon, the words of the group [C] were included, on the segment of oncology and treatments for cancer (search for the words [A] AND [B] AND [C]), this time resulting in a reasonable value of publications. However, of the 15 works found, none presents technical deepening in facilities location as expected.

Finally, this paper presents an application of a level 2 non-capacitated PQ-median model and its computational result focused on the Brazilian public health reality.

Table 21.1 Number of search results for keywords in Scopus and Web of Science databases

	Search terms	Scopus	WoS
Method [A]	[Hierarchical location model OR hierarchical service location model OR hierarchical location problem OR hierarchical facility location OR hierarchical unit location OR median-based hierarchical model]	212	2926
Method[A] + Sector [B]	[A] AND [Health OR health system OR health care OR public health OR public health system OR health centers OR health units]	3	221
Method [A] + Sector [B] + Segment [C]	[A] AND [B] AND [Oncology OR oncological OR cancer OR cancer treatment OR oncological treatment OR oncology center OR oncological center OR oncology unit OR oncological unit]	0	15

Source Research conducted on April 29, 2018

This modeling appears in few publications in Brazil, and still with modifications in the restrictions made by the authors, it is hoped to contribute to the knowledge in the area and stimulate researches of innovative methods that bring benefits to the common good.

21.3 Facilities Location in Health Care

In general, location studies are concerned with studying ways to optimize the network of facilities, whether in the deployment or operation, in the face of costs, transportation time, quality of customer service, or whatever the objective of the organization. The subject was widely discussed by Ahmadi-Javid [1], Farahani [6], Drezner and Hamacher [5], Daskin and Dean [4], and applied in several contexts such as the humanitarian logistics, explored in Boonmee [2]. Ortiz-Astorquiza [10] offers a wide review of Hierarchical facility location models (HFLM), which is the kind of facility location model that will be developed.

The health system, including oncology, already in its foundations, has a hierarchical structure of two or more levels, varying with the species, complexity of the procedure, structure and capacity of the facility, as shown in Peng [11] and Günes [8]. In this way, demand naturally divides into two levels: the first one of procedures with lower risk and lower aggregate structural cost and the second of procedures with greater complexity and with high structural value, as explored in Galvão [7].

When financial resources intended to expand the network are scarce, the greater is the need for informed decision making. With the hope that the scenario will revert to the ERJ, this paper will present a proposal for a facility location model to be used by the organs responsible for strategic public health decisions to obtain the optimal locations of future service points, in order to optimize the access of oncology services. It is emphasized here that the most used cancer treatments are surgery, radiotherapy, chemotherapy, hormone therapy, and bone marrow transplantation, either alone or combining more than one modality, and the research was restricted to the data of these procedures.

21.4 Proposed Model

The construction of new public units in this context allows us to consider two alternatives in terms of optimization: optimize the use of resources by minimizing costs to the public coffers or optimize the access of the population to the service, minimizing the distance traveled by users to the points of service. The first would be easily adapted to HFLM full coverage, and the second would be globally inclusive HFLM based on median, or PQ-median. Both models would respect the basic guideline of the SUS of universalization, but as far as the integrality of the service is concerned, the complete coverage model is negligent, since it covers the distance aspect limiting the maximum acceptable, but not as an object of improvement.

However, it cannot be ignored that the limitation of the maximum distance covered in the coverage models could benefit the user. It would be a guarantee that he will have a designated unit to serve him, and this unit will be within an acceptable distance from his residence. This benefit was then increased to the PQ-median with the addition of the constraint of the distance between the allocated facility and the demands assigned to it. Another parameter added to the model was eligibility, which refers to the ability of cities to receive level 1 or 2 facilities. The criterion chosen was the population of the cities, which in itself should not be an obstacle to the allocation, but reflects some indirect factors of the urban structure as the organization in the treatment of waste, sanitary infrastructure, public mobility, supply of skilled labor or the structure necessary to receive workers and users of other cities. In this way, the constructed model has the parameters, decision variables, objective, and restrictions presented below.

Parameters

$I =$	set of all cities that must be met
$J =$	set of all candidate cities to receive a facility
$K =$	service levels
$n =$	number of demant points. $I = \{1, \dots, n\}$
$m =$	number of candidates to receive a facility. $J = \{1, \dots, m\}$
$s =$	number of network levels. $K = \{1, \dots, s\}$
$d_{ij} =$	distance matrix, with $d_{ii} = 0\, \forall i \in I$
$\text{dem}_{ik} =$	demand for level $k \in K$ at vertex $i \in I$
$d\text{max}_k =$	maximum acceptable distance between a facility of level $k \epsilon K$ and their demand.
$z_{jk} =$	$\begin{cases} 1 \text{ if city } j \in J \text{ is eligible to receive a facility of level } k \in K \\ 0 \text{ otherwise} \end{cases}$
$P_k =$	number of facilities of level $k \in K$ to be allocated

Decision variables

$$y_{jk} = \begin{cases} 1 \text{ if a facility of level } k \in K \; is \text{ allocated at vertex } j \in J \\ 0 \text{ otherwise} \end{cases}$$

$$x_{ijk} = \begin{cases} 1 & \begin{array}{c}\text{if the demand of the vertex } i \in I \text{ by the level } k \in K \text{ is} \\ \text{satisfied by the facility located at the vertex } j \in J\end{array} \\ 0 \text{ otherwise} \end{cases}$$

Objective function

$$\text{Min} \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} \text{dem}_{ik} d_{ij} x_{ijk} \tag{1}$$

Restrictions

$$\sum_{j \in J} x_{ijk} = 1 \quad \forall i \in I; k \in K \tag{2}$$

$$z_{jk} \geq y_{jk} \quad \forall j \in J; k \in K \tag{3}$$

$$\sum_{j \in J} y_{jk} = P_k \quad \forall k \in K \tag{4}$$

$$x_{ijk} \leq \sum_{g=k}^{s} y_{jg} \quad \forall i \in I; j \in J; k \in K \tag{5}$$

$$d\text{max}_k \geq d_{ij} x_{ijk} \quad \forall i \in I; j \in J; k \in K \tag{6}$$

$$\sum_{k \in K} y_{jk} \leq 1 \quad \forall j \in J \tag{7}$$

$$x_{ijk} \in \{0, 1\} \quad \forall i \in I; j \in J; k \in K \tag{8}$$

$$y_{jk} \in \{0, 1\} \quad \forall j \in J; k \in K \tag{9}$$

Equation (1) minimizes the distance between the demand and the installation which will be designated, weighted by demand. Restriction (2) determines that the demands of each city should be met by an installation of the appropriate level. Restriction (3) ensures that facilities will be allocated only in eligible cities, and (4) defines the exact number P of installations to be allocated at each level. Equation (5) determines that the demand for a vertex at service level k can only be met by an installation if the level is equal to or greater than k. Equation (6) ensures that the distance from the demand by one level to the facility designated to it will be less than the maximum allowable distance for each level. Function (7) determines that a facility can be allocated in each city, and (8) and (9) refer to the binary nature of the decision variables. In this application, the model has 2208 binary decision variables and 8696 linear constraints, which is, therefore, a pure binary programming model.

The 46×46 matrix of distances between all cities in the interior of the state of Rio de Janeiro was obtained using the Distance Matrix tool of Google Maps APIs. Matrix elements refer to the distance in kilometers of the route between the centroids of each pair of cities. Level 1 facilities will offer the services of lower complexity, where there is no need for long-term or high-risk procedures, requiring less investment. Level 2 facilities would be responsible for high complexity interventions in addition to lower level services, equipped with a surgical center and intensive care units, resulting in high-cost structures. By approximation, based on the data consulted in the DATASUS platform, the proportions 60% and 40% were used, for levels 1 and 2, respectively.

The demand for the service in this application refers to the number of patients who seek the different oncological treatments by SUS in each city. However, this information was not found with the desired reliability in the official databases made available to the public. As an alternative to this problem, instead of using the proportion of the levels over the average annual number of registered cases, it will be applied directly to the population of each municipality, obtained from the estimate made by IBGE for the year 2017, the most recent. This application can be performed without loss to the quality of the results, mathematically, since the demand works as weights attributed to the vertices of the model, only in comparative character, and this was one of the reasons for the facilities being considered with unlimited capacity.

The eligibility criterion is qualitative and permeates the social and economic aspects of the candidate cities. The lower limit of the resident population was considered twenty thousand habitants for level 1 and forty thousand for level 2, resulting in 28 cities eligible to receive level 1 facility and 14 for level 2. The maximum distance in this application equals a greater distance minimum distance between an ineligible city and a candidate city which is, for level 1, 51.7 km (distance between Carmo and Cordeiro), and 91.9 km (between Santa Maria Madalena and Nova Friburgo) to level 2. They used the illustrative values of [60,110] kilometers for levels [1, 2], to give greater flexibility to the model and to test its effectiveness. The number of facilities of each level to be allocated was determined arbitrarily, since it involves budgetary aspects of the state government together with the municipalities. Six different configurations were established, considering the number of facilities in the levels 1 and 2, as shown in Fig. 21.1, where the index $P = \{n_1, n_2\}$ denotes the number of levels 1 and 2 facilities.

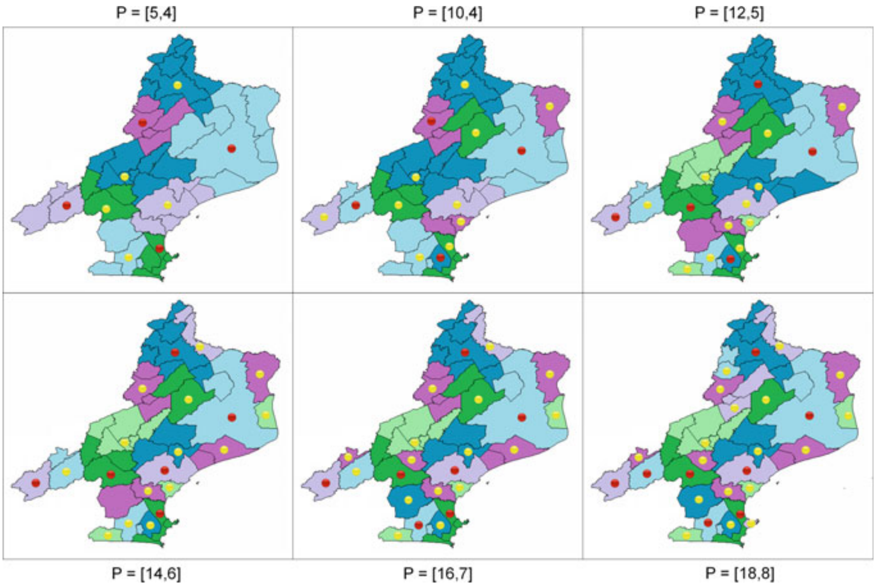

Fig. 21.1 Facilities location that offers level 1 services and the respective attended region

21.5 Results

The model was implemented computationally in the IBM ILOG CPLEX Optimization Studio, in its version 12.7.1. The binary results determined by the model were tabulated, obtaining the information of which cities would receive facilities of each level, and which cities each one of them would be responsible for attending. The information in the tables was arranged in maps of the study region, with Fig. 21.1 for level 1 services and Fig. 21.2 for level 2 services. Yellow dots represent level 1 facilities, while level 2 reds. The cities being served by the same instance are grouped by color.

It can be observed that the model allocated facilities uniformly and dispersed throughout the study area and centralized in the demand groups, an expected result due to the natural characteristics of the median-based models. However, it is not possible to visually assess whether the model prioritized the maximum distance to demand, mathematically expected. Apparently, this was due to the large number of facilities for a small region. For this reason, it is expected that the assessment in level 2 installations will be more conclusive in this regard. It is possible to notice in the mapping that the increase of the parameter P reduced the number of cities served by the same installation and the groups of demand became, in general, smaller and independent cities appeared that they serve only themselves.

Given the application in the public sector, and in the case of facilities of medium complexity and lower cost in relation to level 2 services, this characteristic is fundamental to make possible the SUS hierarchy concept. A single city responsible for

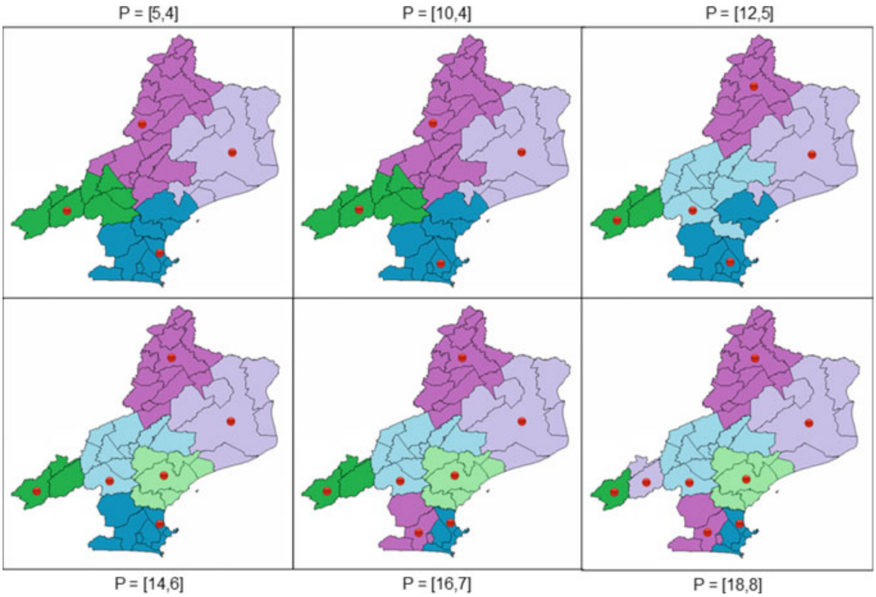

Fig. 21.2 Level 2 facilities location and the respective attended region

serving users from many neighboring cities will be burdened not only in the health service, but also in other sectors of the municipal organization such as hospital waste, sanitation and vehicular traffic, and political and budgetary issues may hamper the deployment and operation of the unit. Therefore, it is desirable that the demand groups be composed of a single city, and in the proposal of the model, the largest groups remaining in scenario 6 (of higher P values) are those in which there are many ineligible cities in the regions, showing sensitivity to this need of the system.

In the maps of level 2 facilities, the prioritization by the maximum distance parameter is evident. In scenarios 1 and 2, in the purple and green groups, it is noticed that the facilities were not located in the most populous cities (Itaperuna and Petrópolis) that minimize the median, but in the most populous cities able to meet the admissible distance requirement (Santo Antônio de Pádua and Teresópolis). As for the division of groups by increasing the value of P, it can be seen that from scenario 4 to 5, the dark blue demand group split into two with no change in neighboring groups. The same happened from scenario 5 to 6 with the green demand group. This shows that the model has the necessary sensitivity to determine when the network becomes saturated. Although for the user, the more installations the better, the treatment network should have the lowest possible cost. To analyze how the maximum and average distances travelled are affected by the number of installations, table 21.2, shown below, was constructed.

Quantitatively, the scenarios revealed, as expected, that the higher the number of installations in each lower level is the average distance traveled by the user (Table 21.2).

Table 21.2 Results for maximum and average distances traveled for each level

	Level 1		Level 2	
	Maximum	Mean	Maximum	Mean
Scenario 1	59.28	29.74	109.14	57.76
Scenario 2	57.94	24.03	109.14	56.41
Scenario 3	51.76	20.50	91.88	48.59
Scenario 4	51.76	17.70	91.88	45.13
Scenario 5	51.76	15.30	91.88	42.31
Scenario 6	51.76	13.41	91.88	40.45

It is possible to analyze (also graphically), the sensitivity of the model applied to the different configurations, in relation to the maximum distance between a user and the installation that covers it and the average distance traveled between users and the corresponding installations, shown in Fig. 21.3.

With the proposed variation of the parameter P, the maximum distance traveled by a user decreased 12.8% for service level 1 and 15.8% for level 2. The average distance presented a substantial reduction of 66% for level 1 and 29.9% for level 2.

We can add to the analysis a data that facilitates the understanding of the importance of these results. According to INCA, there are eight units of oncology care in the region that is the subject of this study, which approximates scenario 1, with nine, of the actual configuration in number of facilities, although they do not have standardization of the treatments offered and detrimental to the type of unit and well distributed as the model suggests. This indicates that if the goal of implementing a network such as scenario 6 is adopted, the distance traveled by all users would fall one-third at level 1 and more than half at level 2.

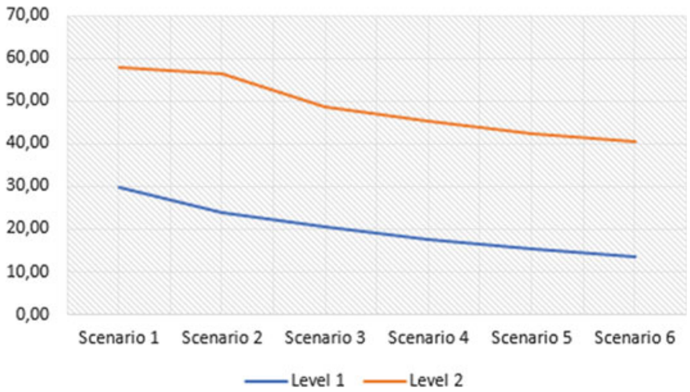

Fig. 21.3 Mean distance traveled by users in each level

21.6 Final Considerations

Given the facts, it is advantageous to use the model chosen to optimize the allocation of health facilities or any other system with the same characteristics, as other public initiatives. It is worth emphasizing that the model will never replace the health manager. On the contrary, the model improves its ability to analyze and make decisions. For future related work, it is suggested to include in the scope a real data collection stage, including the capacity of health facilities to implement the enabled model, which would allow a more accurate and realistic result. In addition, construct a suitable heuristic and reduce the scale of the geographical space. With the model enabled in the scale not of cities, but of zones or neighborhoods, it would be possible to better understand the needs of the population and to locate with much more precision and quality the facilities, in bigger regions of the territory.

The research was limited to showing that the model is efficient in locating facilities of a successively inclusive hierarchical system, given the parameter P. The exact value of facilities to be built was not an objective and is not due to the lack of knowledge in public health policies of the authors. In addition, the application required official public data, the questionable quality of which made it prudent to use parameters parallel to the information sought, then illustrative values, and to make considerations that would not be necessary if reliable real data were available. Therefore, it should be noted that the results obtained do not suggest any immediate action to change the network, but rather that the proposed model be used as a decision support tool, based on concrete data.

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Part IV
Humanitarian Operations and Crisis Management

Chapter 22
Successful Experience Report: Design and Development of a Temporary Shelter Management Course in Brazil

Luana Toralles Carbonari, Aderbal Vicente Lapolli, João Carlos Souza and Lisiane Ilha Librelotto

Abstract This work aims to develop a Temporary Shelter Management course for the Brazilian context. It was carried out by a multidisciplinary group, led by members of OFDA, using the method of Course Design and Development and Interactive Teaching. The resulting proposal aims to qualify professionals to work in disaster response.

Keywords Experience report · Course development · Temporary shelter

22.1 Introduction

According to the United Nations International Strategy for Disaster Reduction—UNISDR [12] Strategic Framework 2016–2021, disasters are taking a huge toll with hundreds of thousands of lives and US$ 1.5 trillion lost in the last decade. Based on the University Center for Research and Disaster Studies of the Federal University of Santa Catarina—UFSC/CEPED [10], this fact is related to a considerable increase in the frequency and intensity of disasters and in the impacts generated. One of the main reasons for this increase is the intensification of manmade changes in the environment, to modify and adapt it to its needs and uses. As stated by Bedoya [1], the presence of disasters contributes to the deterioration of the environment and cultural memory of a place, destroying public infrastructures and habitable structures and causing many losses of human lives. In addition, these disasters leave thousands of people homeless, leading to mobilizations in governments and in society and resulting in the need for temporary shelters.

The right to shelter is implicit in the Universal Declaration of Human Rights and in several documents prepared by multilateral organizations. In 1996, the first International Emergency Settlement Conference was held in Wisconsin, USA. At this

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conference, it was established that the access to basic and contextually appropriate shelter is an essential human need. The standards for this shelter may vary depending on the cultural context, on the situation, on the climate and other factors [7]. However, it is highlighted the complexity of determining performance standards for shelters, since there are many variables that affect their suitability. Thus, the actions of the various agencies, institutions and professionals in the phases of prevention, mitigation, preparation, response and recovery to disasters are essential to minimize the suffering of the population.

In Brazil, the constant disasters that occur in all regions of the national territory have generated many homeless people and, consequently, the need for temporary shelters. According to UFSC/CEPED [10], between the years 1991 and 2012, 287,986 people were homeless in the South Region, 271,816 in the Southeast Region, 215,856 in the North Region, 2,429,589 in the Northeast Region and 15,390 in the Central West Region.

Added to this, millions of refugees are forced to leave their homes every year around the world for their freedom and security. The United Nations High Commissioner for Refugees (UNHCR) aims to protect these refugees and displaced populations from war, conflict and persecution by aiding and seeking adequate and lasting solutions. In recent decades, according to the UNHCR [11], over 67 million people worldwide have been forced to leave their places of origin, including some 22 million refugees. Based on data from the National Committee for Refugees—CONARE [2], by the end of 2017, the country recognized the amount of 10,145 refugees of different nationalities. In total, 33,866 people applied for refugee status in 2017. Venezuelans account for more than half of the claims, with 17,865 requests. Following are the Cubans, the Haitians and the Angolans. The states with most requests for refuge are Roraima, São Paulo and Amazonas. Nowadays, the country faces a serious problem due to the crisis in Venezuela, which has led more and more Venezuelans to come to Brazil. These immigrants seek shelter mainly in the State of Roraima, which is experiencing a difficult situation of vulnerability. Across the state, shelters are crowded, and many refugees live in street situations. Most arrive in the small municipality of Pacaraima, with 16,000 inhabitants, and then goes to Boa Vista, which is 212 km away. In view of this, it is observed the extreme urgency of places to be used as temporary shelters and the availability of qualified professionals to manage them [5].

According to the Organic Law of Social Assistance—LOAS [3], the responsibility for the management of temporary shelters in Brazil is from the Social Assistance and it is up to the Civil Defense to maintain and activate them. The Social Assistance Policy is organized through a Single System of Social Assistance—SUAS, ordered in a decentralized and participatory manner. In this system, the services, programs, projects and benefits of Social Assistance are reorganized by levels of protection, which are: Basic Social Protection and Special Social Protection. The Special Social Protection services can be of medium or high complexity, being in the high complexity of this protection the focus of this work: The Protection Service in Situations of Public Disasters and Emergencies. This service promotes support and protection to the population affected by emergency situations and public calamity, with the provision of temporary shelter, care and material supplies, according to the needs detected. Also ensures articulation and participation in joint intersectoral actions to minimize the damages caused and the provision of verified needs.

In order to standardize and improve the quality of response actions in disaster situations was started in 1997, the Sphere Project, developed by a group of NGOs and the International Red Cross and Red Crescent Movement. The output of this project defined a set of universal minimum standards synthesized in the document entitled Humanitarian Charter and Minimum Standards for Humanitarian Response in Disaster Situations. Since then, according to the Secretary of State for Civil Defense of Rio de Janeiro—SEDEC/RJ [8], this publication has been a reference in the administrative actions of temporary shelters and more than 80 countries adopt their guidelines and indicators for the organization and management of shelters. In Brazil, some organizations adopt procedures based on information from the Sphere Project. However, it is necessary to obtain national documents that are appropriated to the country's reality, since the Sphere Project presents some peculiarities that do not fit the Brazilian reality, because it deals with some disasters and situations that are not common in this country.

This article reports a work experience developed by a multidisciplinary group of professionals, with the objective of developing a Temporary Shelter Management course for the Brazilian context. Nineteen people participated in the group, composed of professionals from the Federal District Fire Brigade (CBMDF), the Brazilian Red Cross of Brasília (CVBB), the Secretariat of Public Security and Social Peace (SSP/DF), the National Secretariat for Civil Protection and Defense (SEDEC) and the Federal University of Santa Catarina (UFSC), led by members of the Non-Governmental Organization Office of U.S. Foreign Disaster Assistance and United States Agency for International Development (USAID/OFDA) from Latin America and Caribbean (LAC) Regional.

22.2 Methodology

For the development of the course, OFDA's course Design and Development method—D&D was used associated with the Interactive Teaching Method—ITM [6]. During the activities, the instructors first made a presentation of the knowledge and skills necessary for the development of the course based on objectives. The participants had an active and permanent participation with continuous feedback. The goal was to acquire knowledge and skills to achieve pre-established performance objectives, providing the members with the exchange of information and the collective construction and design of a Temporary Shelter Management course. The ITM combines elements of several schools of thought. It is openly participatory and stimulates the interaction between all the components of the learning situation. The method contains the following elements: Objectives, Content, Interaction, Feedback and Evaluation, which are closely related.

To develop the course materials and contents, four meetings were held in the city of Brasília between May and September 2017.

22.3 Results and Discussions

Since the participants were mostly from the city of Brasília, the works were developed there, and four meetings were held, described as follows:

- First meeting: The first meeting lasted five days and took place between May 22 and 26, 2017. In this occasion was presented to the workshop participants some aspects related to the methodology that would be used for the course development, as well as fundamentals of the Training Course for Instructors—CPI [6], important questions about the management of temporary shelters and about The Sphere Project [9]. Following, a presentation was made on the management of shelters in Itajaí and Brusque, Santa Catarina, with emphasis on the experiences and challenges. It was also exposed the available materials on the shelter theme and identified the current problem and their categories, regarding the legal and conceptual framework, organizational aspects and the area of training and capacity.

The first meeting had as main objective the exploration of the necessary content for the theoretical and conceptual foundation in the process of design and development of the course. This phase resulted in the definition of:

- **Course title**: temporary shelters management course.
- **Target audience**: civil defense agencies and humanitarian workers.
- **Strategic Public**: public servants involved in the area, NGOs, health agents, Army, among others.
- **Profile of the participants**: experience with public, leadership.
- **Formation of the participants**: complete elementary education.
- **Age of participants**: over 18 years.
- **Attitude of the participants**: proactive, decision making.
- **Course load**: 40 h.
- **Purpose of the course**: to provide professionals, technicians and humanitarian workers who carry out tasks related to the Management of Temporary Shelters, knowledge and methods that allow them to improve their performance.
- **Performance Objective**: at the end of this course, given a simulated situation the participants, in groups of five to eight members, in a maximum period of four hours and applying the knowledge learned during the course will be able to manage a temporary shelter.
- **Training Objective**: at the end of classes students will demonstrate the following skills: carry out the risk analysis of the conditions of a temporary shelter; prepare the Contingency Plan, adapting to the conditions of the site and temporary shelter; manage, structure and organize a temporary shelter; demobilize a temporary shelter and prepare the final report.

– **Training method**: in the course will be used the Interactive Teaching Method. The objectives express the knowledge and skills to be obtained and indicate what will be evaluated. At each class, the objectives will be evaluated, and, at the end, the objective of the discipline will be evaluated. The teachers will observe the personal characteristics of each participant and their performance in the discipline.
– **Materials**: Participant Manual—MP and Reference Material—MR.

In the end of the activities were defined the necessary methods and instruments for the development of the workshop, being assigned tasks to the members, who were in charge of compiling the contents of the course Reference Material. For this, a participatory strategy was used, associated with several didactic resources.

- Second meeting: The second meeting lasted five days and took place between June 19 and 23, 2017. In this occasion was organized and adapted the course Reference Material and delivered to the systematization group. It was also determined the lessons of the course, reorganized and improved its content and training goals.
- Third meeting: The third meeting lasted three days and took place between July 11 and 13, 2017. In this occasion was organized the contents of the Reference Material in a single document, with the final definition of lessons of the course, their duration, contents, training objectives and evaluation activities. It was also planned the final exercise of the course. This exercise was configured as a table simulation, with the objective of evaluating students' ability to manage a temporary shelter from a simulated situation. Table 22.1 shows the result of the systematization of the lessons, contents, training objectives and course evaluation activities, established in the third meeting.
- Fourth meeting: The fourth meeting lasted five days and took place between September 18 and 22, 2017. In this occasion, the members of the group developed the simulated exercise. According to Brazil [4], the simulations are considered as exercises and training, and can be organized in different ways and carried out for specific sectors, actions or procedures of the Contingency Plan, such as shelters, search and rescue, community preparation, etc. Among the existing modalities, table simulations have been used by Civil Defense to improve the Contingency Plan and improve response and care to the affected community. This type of exercise aims to simulate the referral of measures in a case of calamity caused by natural events, such as floods, gales, etc. During the activity, a disaster scenario is presented, and the response organs present their action plan, allowing a systemic view of the entire response operation.

Similarly, at the end of the Temporary Shelter Management course, given a simulated situation, the participants, divided into groups within a maximum of four hours and applying the knowledge learned during the course, should be able to manage a temporary shelter. For this, participants are initially presented with the characterization of a disaster scenario and the purpose of the activity. Participants are divided into groups and proceed with the development of the simulated exercise. During the execution of the activity, they must carry out the risk analysis of the conditions of the shelter; prepare the Contingency Plan, adapting to the conditions of the site and the

Table 22.1 Systematization of course lessons, contents, training objectives and evaluation activities

Lessons		Contents	Training objectives	Evaluation activities
Introduction	4 h	Goal	– Receive personal and institutional information from participants	–
		Performance Objective	– Inform participants about: teachers; purpose, objectives and methodology; materials to be used, logistical details, agenda and evaluation; general aspects of the Course	
		Training Objective		
		Course Teaching Method		
		Materials to use		
		Course Target Audience		
		Conditions for approval		
		Practical aspects		
		Annotations on the Chest		
		Course Schedule		
1. Introduction to Planning, Organization and Incident Command System		1.1 Planning Definition	– Conceptualize planning and organization	(1) Define planning and organization
		1.2 Definition of contingency plan	– Describe the components of planning	(2) Describe the basic components of planning
		1.3 Planning Components	– Define organizational structure	(3) Define organizational structure
		1.4 Definition of organization, types of organization	– List the principles of SCI	(4) List the principles of SCI
		1.5 SCI Functions		
2. Introduction to Risk and Disaster Management	4 h	2.1 Threat	– Explain the concepts of threat, vulnerability, risk, acceptable risk, resilience, adverse event, disaster, emergency, incident and development	(1) Explain the concepts of threat, vulnerability, risk, acceptable risk, resilience, adverse event, disaster, emergency, incident and development

(continued)

Table 22.1 (continued)

Lessons		Contents	Training objectives	Evaluation activities
		2.2 Risk	– Define Risk Management	(2) Define Risk Management
		2.3 Vulnerability	– Describe the areas and components of Risk Management	(3) Describe the areas and components of Risk Management
		2.4 Disaster		
		2.5 Adverse event		
		2.6 Risk and Disaster Management		
3. Introduction to Temporary Shelters and Shelter Management	2 h	3.1 Legislation, Law 12.608, Classification of Social Assistance, Brazilian Constitution	– Explain the concepts of homeless, displaced, affected and temporary fixed and mobile shelter	(1) Explain the concepts of homeless, displaced, affected and fixed and mobile temporary shelter
		3.2 Definitions of homeless, displaced, affected, shelter, temporary fixed and mobile shelter	– List the functions of the shelter	(2) List the functions of the shelter
		3.3 Shelter functions	– Describe the functions of the shelter manager	(3) Describe the functions of the shelter manager
		3.4 Risks associated with shelter		
		3.5 Assignments of the Shelter Manager		
4. Sphere Project	4 h	4.1 Humanitarian Charter	– Describe the minimum standards of shelter	(1) Describe the minimum shelter standards according to the Sphere Project
		4.2 Minimum requirements: water supply, sanitation and hygiene	– Develop and apply minimum standards of shelter	
		4.3 Minimum requirements: food safety and nutrition		
		4.4 Minimum requirements: shelters, human settlements and non-food items		

(continued)

Table 22.1 (continued)

Lessons		Contents	Training objectives	Evaluation activities
		4.5 Minimum requirements: health actions		
5. Organizational structure of the shelter	4 h	5.1 Shelter's functional/organizational structure	– List the functional/organizational structures of the shelter	(1) List the functional/organizational structures of the shelter
		5.2 Shelter manager, external security and external communication	– Describe the assignments of the shelter manager	(2) Describe the assignments of the shelter manager
		5.3 Reception and registration of homeless	– Fill out the registration form	(3) Given a simulated disaster situation fill out the registration form
6. Administration, finance and logistics	4 h	6.1 Administration, finance and logistics	– Explain the functions related to administration, finance and logistics in the shelter	(1) Explain the functions related to administration, finance and logistics in the shelter
		6.2 Internal security		
		6.3 Food and Nutrition		
		6.4 Basic sanitation and water		
		6.5 Internal Communication		
		6.6 Warehouse		
		6.7 Storage of goods		

(continued)

Table 22.1 (continued)

Lessons		Contents	Training objectives	Evaluation activities
7. Multidisciplinary Team	2 h	7.1 Assignments of the multidisciplinary team	– List the assignments of the multidisciplinary team in the shelter, related to health, psychology and Social Assistance	(1) List the assignments of the multidisciplinary team in the shelter, related to health, psychology and Social Assistance
		7.2 Health		
		7.3 Psychology		
		7.4 Social Assistance		
8. Biosafety	2 h	8.1 Precautionary measures	– List the biosecurity aspects associated with the shelter	(1) List the biosecurity aspects associated with the shelter
		8.2 Conduct for accidents		
9. Animals and Shelter	2 h	9.1 Screening	– List the functions related to animal care in the shelter	(1) List the functions related to animal care in shelter.
		9.2 Management		
10. Demobilization and Reporting	2 h	10.1 Demobilization of the shelter	– List shelter demobilization activities based on inventory	(1) List shelter demobilization activities based on inventory
		10.2 Elaboration of the demobilization report of the shelter	– Prepare a report on the demobilization of the	(2) Given a simulated disaster situation build a report on the demobilization of the shelter

shelter; manage, structure and organize a temporary shelter; demobilize the shelter and prepare the final report. To assist in the development of the activity, the groups should systematically identify in the simulated scenario: problems, strategies and solutions, resolutions and supporters. In addition, they receive an inventory containing a list of infrastructures, facilities and materials available in the temporary shelter and their operating conditions.

With the results of the work, the group leaders systematized the material according to the standards required by USAID/OFDA. The documents that integrate the temporary shelter management course are the Reference Material and the Participant Material. The Reference Material contains the theoretical basis of the course, with contents and fundamental concepts to train managers of temporary shelters. This material is composed of twelve chapters, namely: Introduction to Planning, Organization and Incident Command System; Introduction to Risk and Disaster Management; Introduction to temporary shelters and shelter management; Sphere Project; Organizational structure of the shelter; Administration, finance and logistics; Multidisciplinary team; Biosecurity; Animals and shelter; Demobilization and reporting; Glossary; and Bibliographic references.

The participant's material is organized in lessons, which will be developed during the course. In the introduction are presented some aspects of the course, such as its purpose, performance objective, training objective, evaluation, teaching method, materials to be used, logistical details and schedule. For each chapter, the main objectives are defined, highlighting what the participants will be able to do at the end of each lesson, with some exercises to fix the studied content. At the end of the course, participants make a final exercise. This exercise has the objective of evaluating students' ability to manage a temporary shelter from a simulated situation.

22.4 Final Considerations

It is hoped that the results of this work can contribute to the post-disaster action process in a more agile and effective way in Brazil, favoring the affected population and enabling the professionals to work in the management of temporary shelters. For this, the course aims to provide professionals, technicians and humanitarian workers who perform tasks related to Temporary Shelter Management, knowledge and methods that allow them to improve their performance.

In addition, it is hoped to foster in an expressive way the advance and integration of public policies such as Social Assistance and Civil Protection and Defense creating frameworks for action among the professionals involved and generating synergy in actions.

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Chapter 23
System Dynamics for Procurement and Transport in Brazilian Humanitarian Operations

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Abstract Humanitarian relief organizations need to be operationally effective to grip with disasters. We proposed simulating scenarios on procurement and transport of essential items in a Brazilian case, using System Dynamics. This study will allow a systemic view of the humanitarian supply chain providing information about time rates for decision making.

Keywords Humanitarian logistics · Humanitarian operations · System dynamics

23.1 Introduction

Disaster situations, such as rains, landslides, cyclones, earthquakes, typhoons, tsunamis, man-made situations, complex emergencies such as conflicts and wars, are problems that humanitarian logistics proposes to study.

Because of the unpredictability of these situations, the success of an operation depends on good logistics planning, both in terms of infrastructure, storage, transportation, and material coordination.

The speed of response in an emergency has vital importance and depends on a good logistic performance to receive, transport, and deliver the supplies to the affected site [20]. In this context, humanitarian organizations claim for more effective management of disaster response to meet the greatest number of demands. Because of its high cost and complexity, managing the humanitarian supply chain can benefit significantly from an appropriate methodology to study its effects. Developing models and tools to mitigate the consequences and risks of disasters is a key issue in today's global world. Respectively, the main objective of this study is to define a model that analyzes the systemic effects on order acquisition and processing. In this way, a systemic thinking of the humanitarian supply chain is sought, providing information on the time rates for decision making.

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In the next sections, you will find the theoretical reference on humanitarian logistics (HL) is explained, System Dynamics (SD) followed by the characterization of the researched environment, the proposed model, the simulation, the final considerations, and finally the references used for the elaboration of this paper.

23.2 Humanitarian Logistics

As envisaged by the International Federation of Red Cross and Red Crescent Societies [9]:

"Humanitarian Logistics consists of processes and systems in mobilizing people, resources and knowledge to assist vulnerable communities affected by natural disasters or complex emergencies. It seeks a quick response for meeting the greatest number of people avoiding lack and waste, organizing various donations and, mainly, acting within a limited budget."

To simplify, in HL you can come across a set of plans and actions that aim to save lives, displace people and supplies, promote the information flow, and manage procurement, storage, transportation, and distribution to take care of people affected by disasters or complex situations [14]. To make sure that this set is efficient, a plan is necessary, which can be directly connected to the disaster's life cycle. This life cycle is divided into three phases. The preparation phase (phase 0) must be planned for several months and it occurs before the impact, anticipating the disaster. The phase of the immediate response (phase 1) occurs as soon as the disaster happens and the time of service for a humanitarian operation depends on whether the disaster is sudden or not. Then, it goes to the support phase (phase 2) and the disassembly phase (phase 3).

Throughout phase 0 and the beginning of phase 1, it is the time that humanitarian organizations must design the entire humanitarian supply chain, so they can manage and operationalize this projected chain. For sudden onset disasters, the phase 1, at the beginning of the cycle, the time is critical and there is an urgent need to remove bottlenecks for humanitarian assistance to reach the disaster site quickly [20].

Then, phase 2 is when the situation is under control and the humanitarian operation is sustainable. In the disassembly phase there is a deceleration [5]. In this way, the coordination between phases should be highlighted and cooperation between those who are acting needs to be encouraged. In comparison with business logistics, HLA differs in the ambiguous objectives, the human and financial resources restrictions, the high level of uncertainties and the chaotic environment, as well as the demand, lead time, distribution central, as well as to the focus, because in business logistics, it is searched the higher quality at minimum costs, seeking a satisfied client, and in HLA, the focus is a low rate of life losses and suffering [13].

23.3 System Dynamics

The systemic reasoning, which is a discipline to see the underlying “structures” in complex situations and to discern variables of high and low influence on the changes, is necessary for managers of organizations. Systemic reasoning simplifies the lives of managers by helping to see the deeper patterns under the events and details [15].

Industrial Dynamics contributed with a set of four principles for the effective modeling of complex systems [11]:

1. The anti-intuitive system behavior is driven by the structure of the system;
2. The structure of the system involves nonlinear relations;
3. Computational simulation is required to explore behavior;
4. Applying the three ideas above provides a rigorous but pragmatic pathway for managers to improve the design of organizations.

Thus, with the evolution of the studies, System Dynamics (SD) allows managers to understand the behavior of complex systems over time. They are systems that deal with feedback cycles and delays, which are impacting variables in the behavior of the system as a whole [6, 7, 18, 19].

For a better understanding of organizational behaviors and potential policies that could be used to improve organizational performance, managers can develop systemic thinking and a better understanding of the system’s complexities to sharpen their skills. This could increase the ability of analyzing the consequences of interactions between the variables and defining their possible strategies [7].

Stock and flow diagrams assist in the study and analysis of the system quantitatively; currently, these models are built using computer software. Flows represent the rates of change at which stocks accumulate over time. They characterize the state of the system and generate the information upon which the decisions are made. Actions create delays by accumulating the difference between the input flow for a process and its output. By decoupling flow rates, inventories are the source of the disequilibrium dynamics in the systems [18].

Some publications have used SD in supply chain modeling, especially with reference to commercial supply chains [1, 3, 17].

Researchers have confirmed the good fit of this method for the field of disaster management. Gonçalves [7] used SD to model disaster response operations, mainly to study the decision making of International Humanitarian Organizations (IHOs) that use resources both for responding to emergencies creating capacity. For the author, allocating more resources to disaster operations rather than training reduces IHO’s long-term efficiency. Heaslip et al. [8] used SD to build a theoretical model on NGO–military partnerships in a conflict-based context. Besiou et al. [4] presented the initial stages of two SD models in humanitarian operations. The first model analyzed a well-defined subsystem of humanitarian operations—fleet management of field vehicles; the second studied the impact of the media on unsolicited donations for a specific disaster. Altay and Green [2] have found that the social and political nature of disaster management operations makes this field suitable for research approaches such as SD, which can integrate smooth factors in operations analysis.

23.4 Research Methodology

The proposed system was developed based on the logistic processes of acquisition and processing of requests in Brazilian humanitarian operations.

23.4.1 Methodological Steps

The data on the maximum delivery time of the item were made available by the Secretary of State for Civil Defense/SC and the variables used in the simulation were important to allow the view of information contained in the document.

Figure 23.1 presents the research steps, which are the data collection by the humanitarian research methodology, the access agreement to System Dynamics, the definition of the behavioral scenarios, and the data analysis with updates to improve the system's performance.

For the simulation and scenario definition steps, a diagram was developed using the System Dynamics (SD) approach. Figure 23.2 illustrates the proposed steps within the SD approach.

23.5 Application of System Dynamics

The following session presents the development of Fig. 23.2, stages of System Dynamics approach.

Fig. 23.1 Stages of the research methodology

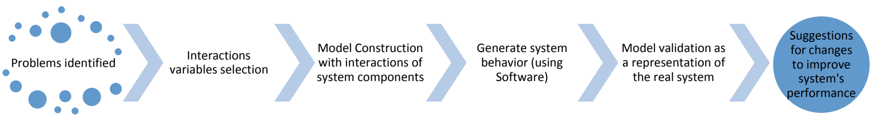

Fig. 23.2 Stages of System Dynamics

23.5.1 Problems Identified and Interactions Variables Selection

The state of Santa Catarina has suffered from several disasters over the years. Highlighted are atmospheric advents characterized by high rainfall levels. Intense rains in the valleys of the state's main rivers, these exceptional rains usually cause flooding, landslides, and falling blocks, leaving a large number of homeless and dead [21].

The city of Rio do Sul is located in the northeast of the state of Santa Catarina and has its territory within the largest basin of the state, the Itajaí-Açu River Basin [16]. Figure 23.3 illustrates this location.

Rio do Sul is susceptible to the river's outflow directed to the coast. This occurs due to its location being in areas higher than the other water systems of the region. In this way, a large part of the floods become major disasters, with floods being one of the main problems in the region [16].

The study that developed in this paper analyzes a real situation, occurred in Santa Catarina—Brazil, in the city of Rio do Sul in the year of 2015. The phenomenon's study is limited by the analysis of the response phase in a humanitarian operation, mainly in the processes of acquisition and delivery of an item of first necessity. In this system, hypothetically, there is a supplier, a distribution center (DC), and a demand for those affected by the disaster. As a model experiment, we searched for the item with the greatest demand at the event. According to the analysis in secondary data with the state's Civil Defense Department, water was one of the items of great representativeness for the demand. The requested quantity was 365 gallons of water, and this demand should be delivered to the affected population within a maximum of 12 h after the request. Considering that the disaster management operation is an appropriate field for SD type research approaches, as indicated by area researchers such as Gonçalves, [2, 4, 7], among others, the proposal is to simulate this scenario using System Dynamics (SD).

Fig. 23.3 Itajaí-Açu River Basin

23.5.2 *Model Construction with Interactions of System Components*

The STELLA/iThink® software from Isee Systems v9.0 was used for plotting (Fig. 23.4).

Figure 23.4 represents the humanitarian logistics system for acquiring and processing non-gas mineral water orders in 365 PET containers with a capacity of 5 L each. The maximum delivery time to those affected should be 12 h, as mentioned.

The model with four stocks (processing, supplier water inventory, expected demand rate, and distribution center water inventory) was used to represent a system of fourth-order differential equations with nonlinear interrelations between these stock variables.

Key supplier production and inventory management decisions made by the vendor include:

(i) Order fulfillment: determination of the capacity to fill orders from the humanitarian logistics organization, based on stock adequacy.
(ii) Production scheduling: determination of the production rate initiated based on the forecast of demand and the supplier's stock position.

The vendor maintains an inventory of order processing. Increased by the start of order processing and decreased by the processing rate.

The expected throughput rate is fed by the work in process (WIP) correction and the expected delivery rate. WIP is the product waiting for release, that is, the product waiting for further processing in a waiting queue. Therefore, the WIP correction influences the expected processing start rate.

The expected delivery rate is affected by the expected ordering stock, and the expected ordering stock is fed by the demand of forecast adjustment. Forecasting demand is the activity of crucial importance to other subsequent activities, in which

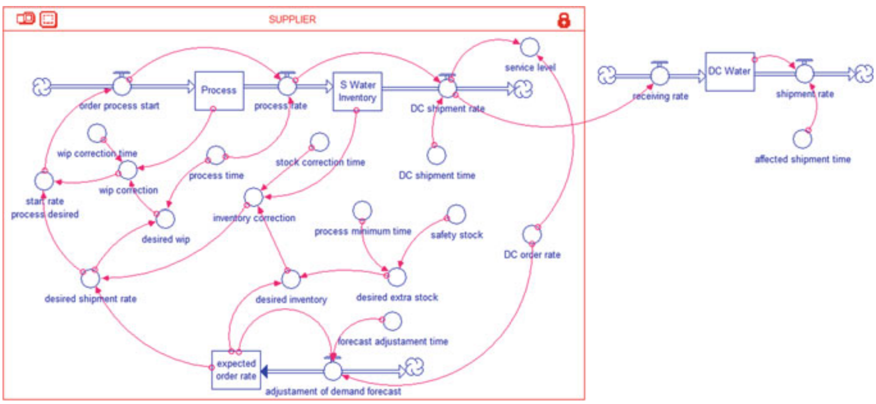

Fig. 23.4 Diagram of acquisition and order processing in humanitarian logistics operations

it is executed the predictive analysis to understand the client's needs (organization of humanitarian logistics) of the product.

In humanitarian logistics operations, there is a demand forecast. However, subsequent events may cause significant variation in this demand, often because of environmental events. Knowledge of how demand varies allows the supplier to maintain the correct amount of inventory available to satisfy it. In our case, the forecast is underestimated, and deliveries are lost due to the lack of good stock.

The supplier maintains a water stock, increased by the processing rate and decreased by the delivery rate to the distribution center. But there are delays in the processing rate, and this rate is the beginning of the processing of the request by the time of processing. And there are delays in the delivery rate to the distribution center (DC).

Finally, for the water to get to those reached by the event (disaster), the distribution center stock (DC) is externally supplied, fed by the receiving rate, and decreased by the delivery rate to those reached. The delivery rate of the distribution center (DC) is fed by the delivery rate to the distribution center (DC).

23.5.3 Generate System Behavior

Figure 23.5 presents the graphical representation of what occurs with the *S* Water Inventory and the water supply inventory of the distribution center over time. The time variation is given in hours, from 0 to 96.

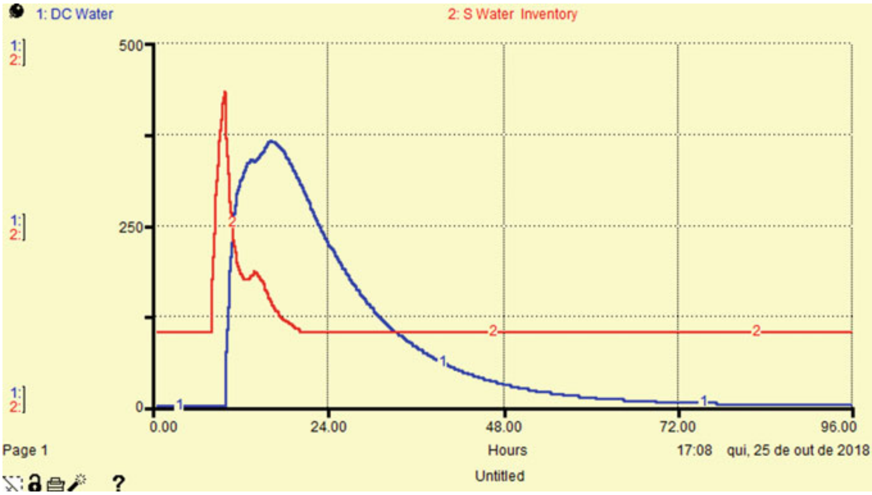

Fig. 23.5 Graph of supplier water inventory and stock of water containers from the distribution center

In this initial simulation, there are no restrictions on labor or capital capacity, and it is observed that the supplier starts to take orders after 9 h.

When the water supplier has an increase in deliveries, he makes the adjustment of his forecasts and increases the volume of orders to restore his stock levels. However, this increase in volume is influenced by the increase in demand and by the decrease in supplier stock levels.

The delivery rate of the distribution center (DC) reaches its maximum value at 9.25 h, with 300 units, but the DC water supply only reaches 300 units after 11 h.

At 12 o'clock, the distribution center has 323 units, and the ideal scenario would be 365 units. But, the 365 units are only available in DC at 15.50 h.

At 21 h, the rate of receipt of the DC reaches 0, and the DC delivered only 85 units of water containers to those affected by the disaster. Half of the demand from those affected by the disaster is met in the first 26 h. However, it is only after 83 h that all deliveries are made to those affected by the disaster.

In this way, the increase in the quantity of water in the distribution center (DC) is higher than the delivery rate in the distribution center (DC). This amplification is reflected in the demand data that the supplier will use in its management. In situations where the delivery lead time is long, the tendency is for the worsening of the fluctuations in the acquisition orders, which is called the bullwhip effect [12].

23.5.4 Model Validation as a Representation of the Real System

The meteorological monitoring sector of the state's Civil Defense Department of Santa Catarina with the use of radars can predict natural events and, based on a scale of intensity of events, can declare a state of attention, and thus, the ordering process is initialized. Responsible for the disaster response department, they can analyze what assistance materials are needed, and suppliers are notified of a possible need to provide products. On average, this notification is made 12 h before the disaster occurs, which allows the uncertain forecast of demand, with a short time horizon (hours) for an item of humanitarian assistance. When the affected municipality declares an emergency, then the responsible sector in the CDS begins. The municipality sends the request for humanitarian assistance materials and, upon receipt, this request is validated, and the request is made to the suppliers by means of a provision authorization. In most cases, orders arrive before the maximum delivery time provided in the price register, due to the geographical location of the suppliers and the prior notification of the same. At the end of the process, once the items are delivered to the requested location, the accountability is done [10].

In the SD model proposed here, it is verified that the faster the order processing is done, the tendency is to reduce the service time to the affected population. In contrast, the oscillation of demand causes a high lead time of delivery which aggravates the bullwhip effect.

23.5.5 *Suggestions for Changes to Improve System Performance*

The impacts of a disaster are rarely limited to one day, which means that they can extend for a week or more. Thus, demand can grow over the days, and new orders are made for the supplier.

The bullwhip effect is defined as the distortion of the perception of demand along the supply chain in which the orders for the supplier have variance different from the variance of deliveries for the applicant. The bullwhip effect is common in supply systems [6, 12] and was observed in a situation of humanitarian logistics operations.

Some of the solutions found in the literature to alleviate the bullwhip effect are: to optimize the requests' treatment since the reduction in the activities execution times has an impact on the variations in amplitude [6]. Making chains shorter [6] improves the quality of information, as it is extremely important for all organizations involved in the chain to have access to delivery information [6]. Adjusting stock levels, therefore, inventory changes must be adjusted in a sequence of future products [6].

Finally, realizing the real system change in the direction that the model experiment showed can lead to improved system performance.

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Chapter 24
Disaster Waste Management Using Systems Dynamics: A Case Study in Southern Brazil

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Abstract Disaster waste (DW) is important impediments to response and post-disaster operations. We present the main phases in the DW management process and compared to Brazilian case using systems dynamics. This study will allow a systemic view of DW management policy considering the main strategic and operational parameters involved in this operation.

Keywords Disaster waste · Systems dynamics · Humanitarian logistics

24.1 Introduction

According to the United Nations International Strategy for Disaster Reduction [27], disaster can be defined as a serious breach of the functioning of a community or a society, involving widespread losses of human, material, economic and environmental resources. A disaster is the result of a combination of threats, conditions of vulnerability and insufficient capacity to reduce the negative and potential consequences of the risk.

Disasters and conflicts can generate large amounts of solid and liquid wastes that threaten public health, impede reconstruction and affect the environment. Disaster waste (DW) can be generated immediately by sudden onset disasters, at the moment of impact, such as earthquakes, tsunamis, hurricanes, cyclones or also can be generated by slow onset disasters such as drought and famine, during phases of response and post-disaster. DW is a complex issue and poses a recognized threat to health, safety and the environment and can also be a major impediment to response and post-disaster operations. According to UNOCHA [28], DW is often managed

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ad hoc; however, substantial improvements can be made in future response efforts toward a more sustainable system. Despite the calls for research and practice to increase the sustainability of disaster rehabilitation operations [19, 29], the theory of sustainable management of the supply chain management (SCM) is still very scarce [15], which justifies the need for research in this area. The proposal for this article is understood and initiates a discussion with focus on the recovery post-disaster phase, since this has been the less studied between all three phases: pre-disaster (prevention, mitigation and preparation), response (warning, impact and emergency response) and recovery (transition, rehabilitation and reconstruction) [17]. Given this context and due to its high cost and complexity, DW management can benefit significantly from an appropriate methodology to study its effects. Therefore, the main objective of this study is to define a model that analyzes the systemic effects of DW management policy.

Taking this into account, this model demonstrates the stocks and flow of debris between the point of occurrence of the disaster and the point of disposal, summarizing the good practices of waste management according to some of the main world bodies related to the subject. The work systematically suggests the appropriate actions at each moment of the flow for a good contingency plan. Chapter 5 presents a case study, pointing out which actions of the contingency plan of the city of Rio do Sul could be improved according to these good practices.

The use of the system dynamics—SD methodology provides information about system behavior rather than precise solutions to subproblems that may arise [9]. According to Kunz et al. [14] and Santos et al. [23] in addition, the use of SD models allows the exploration and evaluation of alternative scenarios in a risk-free manner, making their impact on the performance of the system. Another reason that justifies the use of SD is that this modeling tool is highly appreciated and well understood by managers because it enriches brainstorming and has less reliance on hard data than other methods [13].

Thus, with the use of SD modeling, the DW management process in the management of the humanitarian and sustainable supply chain can be modeled and analyzed the performance of different scenarios for the post-disaster phase.

This study can help manage DW risks and to support recovery and development outcomes in the affected regions. Understanding how to handle, remove and manage waste safely, this can assist humanitarian organizations in decision making as to what destination can be given to post-disaster wrecks in order to assist contingency plan for municipalities.

24.2 Humanitarian and Sustainable Supply Chain Management (SCM)

The DW management policy addressed in this article is based on humanitarian and sustainable SCM concepts. The sustainable SCM supply chain management research field refers to a comprehensive concept of how to analyze and manage interlinked business activities for the general benefit of all members of the supply chain and society where the supply chain operates, respecting the capacity ecological transport. Thus, the concept of sustainable SCM is based on the concept of sustainable development, defined by the Brundtland Commission as "a development that meets the needs of the present without compromising the ability of future generations to meet their own needs [6]." The humanitarian supply chain is defined by the Fritz Institute [12] as the process that integrates and controls the flow of materials and information from suppliers and donors to meet the requirements of beneficiaries, quickly and efficiently. In the bibliographic search for the management of the humanitarian and sustainable supply chain, we highlight the work of Kunz and Gold 15; the authors propose a management framework for the supply chain of humanitarian and sustainable. Haavisto and Kovacs [12] developed a framework for analyzing how humanitarian organizations address different expectations for sustainability. Some articles focused on disaster management present indirectly the theme of sustainability, when they try to relate LH with actions that can lead to a sustainable concept such as Peretti et al. [20], Lorca et al. [18]. Kunz and Gold [15], engaging local partners in the rehabilitation effort is another way to increase the sustainability of humanitarian SCM. Thus, it is possible to benefit from its "social capital," which consists, for example, of deep knowledge of the local environment or of its existing relations. Investing in disaster management capabilities such as staff training, waste management operations can be one way to overcome this constraint. In most cases, DW places more burdens on communities already struggling to cope with the disaster. According to UNOCHA [28], DW also presents opportunities, may contain valuable material such as concrete, steel and wood, as well as organic products for composting. This value can be perceived as a source of income or as reconstruction material and reduce the burden on resources that could be harvested for reconstruction. The practice of DW management usually involves any action, in which waste is left to accumulate and decompose, or improper action, in which waste is removed and dumped uncontrollably. In the latter case, inadequate dumping can create long-term environmental problems that affect the community or occur on economically significant land and require the waste to be moved again, creating additional costs such as the problem of garbage caused by wrong donations [28]. Public health hazards can arise directly from contact with street waste, hazardous waste such as asbestos, pesticides, oils and solvents, and indirectly from vectors such as flies and rodents and post-destruction of unstable structures. Environmental impacts, which are closely associated with human impacts, may include inland waterways, agricultural areas, communities contaminated by chemicals and heavy metals. Safe handling, removal and management of DW are therefore important issues for humanitarian SCM in both the disaster response and disaster recovery phases. Effective approaches can help manage DW risks for life and health and seize waste opportunities to support recovery and development outcomes.

As suggested by Lorca et al. [18], before the onset of the disaster (preparation phase), each local community can consider possible disaster scenarios and corresponding predictions of quantities and composition of debris, and plan workforce and equipment requirements, as well as possible waste management facilities such as waste processing facilities, recycling and disposal areas. In the immediate aftermath of a disaster, the amounts and compositions of debris can be estimated and the workforce and equipment requirements assessed. During this stage, debris must be removed from the roads to facilitate response activities such as search and rescue and transportation of relief. The disaster recovery stage involves the collection of debris, i.e., the waste must be transported from the sides of the road and sidewalk to temporary processing sites, where it can undergo certain processes, such as sorting, separation, milling, incineration, cutting wood and concrete crushing. After being processed, the debris components can be disposed of in landfills, recycled, reused or sold. In this way, the activities are centered on the collection and disposal of debris and decisions regarding the location of waste processing sites, selection of specific processes and respective levels of capacity to be installed at each processing site, transportation of debris between facilities and quantities and types of waste for recycling or disposal in landfills are complex decisions that depend on the type and impact of the disaster in the region.

24.3 System Dynamics

As presented by Silva [24], system dynamics (SD) is a simulation method developed by Jay Wright Forrester at the MIT—Massachusetts Institute of Technology, from the concepts of servomechanisms, his ideas and methods applicable to natural systems. The emergence of the SD was in function of dealing with problems characterized by dynamic complexity, that is, systems where the actions of a given agent generate reactions in other agents, also called feedbacks. It is proposed, for this study, the use of the SD method, in the context of humanitarian and sustainable SCM. The methodology should be appropriate to study complex SD with multiple feedbacks formed in the disaster life cycle. SD also fosters an understanding of changes occurring within an environment, focusing on the interaction between physical flows, information flows, delays and policies to improve system performance. The system to be studied is dynamic and may have multiple comments and delays related to DW operations. The adequacy of SD to capture the behavior of complex systems with multiple feedbacks [25], where short- and long-term effects are important, makes this methodology an appropriate tool for this research.

SD has been applied to various business policy and strategy problems [7, 9, 26]. Some publications have used SD in supply chain modeling, especially with reference to commercial supply chains [1, 3, 25]. In addition, several researchers have confirmed the good fit of this method to the field of disaster management, for example, Gonçalves [10], Besiou et al. [5], Altay and Green [2] have found that the social and political nature of disaster management operations makes this field suitable for research approaches such as SD, which can integrate smooth factors in operations analysis. Thus, the studies illustrated that SD has the ability to represent the dynamic complexity of RD management in humanitarian and sustainable SCM.

24.4 Model Development

For the modeling stage, the guidelines proposed by UNOCHA [28] and FEME [8] were used as the basis and the elements and main agents involved in the supply chain. Humanitarian and sustainable supply chain (SCM) were defined as well as their attributions, in order to assist in the construction of the model. It was identified the variables of the problem under study and thus were drawn causal diagrams for the understanding of the problem, its variables and interdependencies. The structure of the model and the decision rules were specified, as well as the estimations of the behavior of the relations and the initial conditions of the parameters, the definition of the operating limits and the assignment of initial values.

Debris management influences both evacuation and rescue response time, as well as impact on human health and the environment in disasters [28, 18].

The most common way to understand the flow of the humanitarian logistics process in disaster situations is to divide it into two distinct stages: pre-disaster and post-disaster [4]. The post-disaster phase, also known as the collection phase [4], can be divided into two other phases: response period, established in a short term, and recovery period, which occurs more in the long term [4, 28, 18]. Figure 24.1 demonstrates how each of these steps occurs.

Although the focus of this work is in the post-disaster recovery stage, because it is a dynamic and systemic process, and the commitment or not of actions in the previous stages, preparation and response affect the way the recovery stage should happen. Therefore, even before the catastrophe occurs, some factors are already predetermined, depending on the existence or not of prevention strategies and the predictions of possible amounts of generated debris.

With the purpose of facilitating the reading and understanding of the model, a stocks and flows diagram was developed (Fig. 24.2). It uses a numeric sequence (in parentheses) and serves to reference each element of the diagram whenever necessary during the text.

Items 11, 13, 15 and 18 represent the stocks in the different phases of the flow, and the items 12, 14, 16 and 17 represent the flows between these stocks. Items 19, 20 and 21 represent the outputs of the process, although most of the debris is permanently

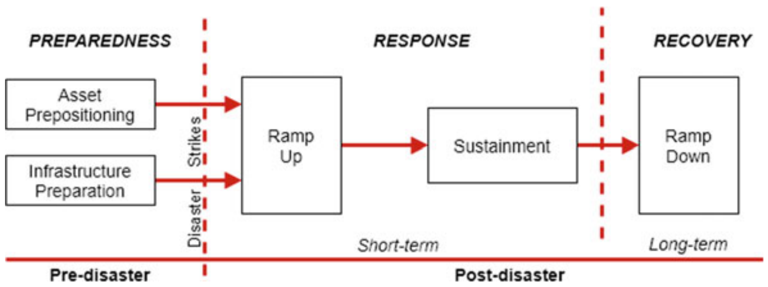

Fig. 24.1 Time line of the humanitarian supply chain. (*Source* Apte [4])

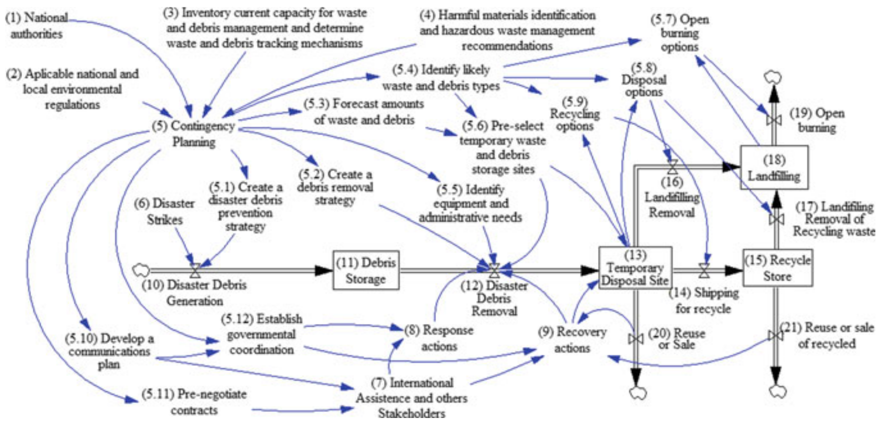

Fig. 24.2 Stock and flow diagram. (*Source* The authors)

deposited in landfills [18]. Item 5 and all its subitems represent the contingency plan itself, acting on the flow, and items 3 and 4 are relevant information that feed into the contingency plan. Items 8 and 9 are the post-disaster actions themselves. The model suggests that the items 1, 2 and 7 represent the exogenous variables, since the contingency plan has little or no control over them. All other variables of the model were considered control passive, therefore endogenous variables.

The objective of the diagram is to demonstrate how the flow of debris occurs along the post-disaster stage, starting with the rate of generation of debris [12], the result of the disaster strikes [6], influenced by the existence or not of preventive strategies of catastrophe in question (5.1). Once the catastrophe has occurred, debris stocks are generated [10], which require certain types of action, either for the purpose of responding or minimizing the impact on human health and the environment.

A disaster debris removal [11] for a temporary disposal site [13] can occur during response actions [8], necessary to enable rescue, rescue and relief actions [28]. But, it is during recovery actions [9] that most of the disaster debris removal occurs [11]. The speed at which this removal occurs is influenced by the existence of a debris removal strategy (5.2), by the identity equipment and administrative needs (5.5) and by the preselect temporary waste and debris storage sites (5.6). Item (5.6) has the capacity to accelerate the choice of temporary space and depends on an adequate forecast of the quantities (5.3) and possible types of debris generated (5.4) by the disaster in question. The recovery actions foresee a selection of the different types of waste in the temporary space [13] for appropriate disposal, which may be the shipment for recycling [14], the removal to final sanitary landfills [16] or reuse for revenue generation through sale or reuse during recovery actions in affected areas [20]. The material sent to the recycled stock [15] can also be reused [21] or once unrecovered, sent to the final landfill as recycle bin [17]. Once in the final landfill [18], there is still the possibility of burning waste in open space [19], which allows a greater capacity of the landfill, an important factor in disaster situations. Therefore, prior identification of the incineration options (5.7) allows for faster and more efficient recovery actions, as well as items [14] and [16] are also influenced by the prior identification of definitive removal options for landfills (5.8) and (5.9). The use of these options provided for in items (5.8) and (5.9) naturally depend on the material deposited in the temporary space [13] after the removal of the waste from the disaster [11], so the use of the incineration option [19] depends on the material sent for the final landfill [18].

24.5 Case Study—Rio do Sul

The city of Rio do Sul is located in the northeast of the State of Santa Catarina and has its territory within the Itajaí-Açu River Basin [16]. Rio do Sul is in higher areas than the other water systems in the region and is therefore susceptible to rapid and violent deflúvios directed to the coast, causing much of the floods to become catastrophes.

According to the technical report on the removal of transportation and disposal of waste in the city of Rio do Sul, in 2013 and 2015, the values with removal, transportation and final destination of the flood residues reached more than 370 thousand in national currency and 584 thousand national currency (NC), respectively. In the flood of 2017, the city spent more than R$ 577 thousand NC on prevention, response and disaster recovery actions, with 52.74% of this amount being used for the destination of the post-flood waste, which was directed to hiring of specialized companies to provide transport service to the final destination of the rubbish collected after the flood. In this way, we can verify the recurrent problem of the region in the service to the management of the trash in the post disasters, considering also that this municipality always had a history of floods and floods. In 2015, the Rio do Sul Civil Defense (CD/RS) elaborates the current version of the Rio do Sul disaster contingency plan (DCP/RS), focused on floods and gradual flooding. According to the document, the objective was to obtain the maximum utilization of the services of public agencies, volunteers and entities, under the coordination of the Directorate of Civil Defense of the city of Rio do Sul, in disasters [22].

For the development of this study, this contingency plan was analyzed to identify the key actions and elements used in the waste management process in the municipal disaster response. Thus, a comparison of these with the base model proposed in this work was developed. In this way, each step of the base model is represented with comparative analytical information.

24.5.1 Debris Flow Analysis

According to the data recorded in the Technical Reports on Removal, Transportation and Disposal of Floods of the 2013 and 2015 floods in Rio do Sul, after the water level returned to normal, there was an accumulation of waste in public roads. These residues came from the residences and trades affected by the waters during the period of floods of the municipality. The types of residues were remnants of furniture (sofas, tables, chairs, cabinets), clothing, toys (plush, plastic), mattresses, logs and tree branches, pieces of cement pipes, PVC pipes, asphalt, tires, mud, packaging of products of various segments and other household objects.

In 2013, 35% of the debris was classified as Class IIA, 65% of the debris classified as Class IIB. Part of the Class IIB debris (1%) was made up of tires and its destination was made in a differentiated way so that this material could go to the landfill. The total amount of debris generated was 1692.20 m^3, approximately 1447 tons. By 2015, 96% of the residues were classified as Class IIA and IIB and were sent to landfills. However, 4% of the debris contained tires, metals, pipes and appliances and was sent for treatment of decharacterization before being destined for landfills. The total amount of solid debris in the flood of 2015 was 2574.54 m^3, approximately 1924.46 tons.

According to this information, it is understood that the flow of the debris/waste generated by disasters [12] follows the removal logic for temporary space [11], and in this space [13] the differentiated products are sent for decharacterization, and once debris removed safely to landfills [18]. However, the great majority of the waste, 99% in 2013 and 96% in 2015 were removed directly to these landfills [18]. Figure 24.3 represents the flow of debris from disasters in Rio do Sul.

There was no evidence that there was any reuse of recyclable materials [21]. Likewise, no evidence has been found that material has been burned in open space in landfills [19] to make better use of these spaces. Historically, the recurrent disasters in the city of Rio do Sul are of gradual flooding, which allows some degree of preparation.

As a preventive strategy (5.1), the former National Department of Works and Sanitation (DNOS) developed three flood containment dams, the Itajaí River hydrographic basin alert system operating center was created and a law was created to provide for the master plan of the municipality of Rio do Sul, which regulates the mapping and occupation of the “flooded areas of the municipality,” preservation and environmental sustainability [21]

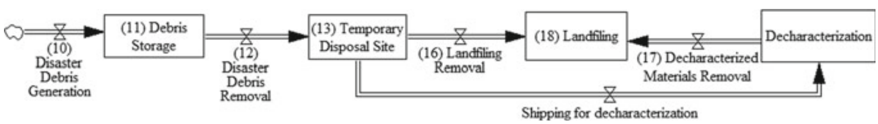

Fig. 24.3 Flow of debris from disasters in Rio do Sul. (*Source* The authors)

24.5.2 Analysis of the Contingency Plan in Disaster Situations in Rio do Sul

In 2015, the Rio do Sul Civil Defense (DC/RS) elaborates the current version of the Rio do Sul disaster contingency plan (PCD/RS), aimed at floods and gradual flooding. According to the document, the objective is to obtain maximum utilization of the services of public agencies, volunteers and entities, under the coordination of the Directorate of Civil Defense of the city of Rio do Sul, in disasters [22]. The components of disaster risk management used in the PCD/RS were five: prevention/mitigation, preparation, response, rehabilitation and reconstruction [22]. Comparatively, in the PCD/RS, the components of disaster risk management fit into the two phases of humanitarian logistics (pre-disaster and post-disaster), cited by Apte [4]. In the pre-disaster phase of the PCD/RS, prevention/mitigation involves activities such as the study of threats and vulnerabilities, and the preparation already involves activities such as planning, capacity building, community preparedness and warning and alarm measures. Both prevention/mitigation and preparedness can be considered as prevention strategies, provided for in the base model under number (5.1). In post-disaster, the response phase [8] has two groups of actions occurring simultaneously, rescue actions, search and rescue actions and rehabilitation. This is likely to be due to the small number of victims (one injured and 32 patients in 2013, one dead, two injured and 35 patients in 2015, for example) and a larger number of homeless people (690 homeless and 8010 displaced in 2013 and 866 homeless and 17,636 displaced in 2015, for example), making rehabilitation equally relevant. The recovery phase [9] is distinct and exclusive and provides for recovery actions of physical, social and economic damages. The interesting thing is that the document indicates that recovery should occur at a higher level than before the adverse event, closing a cycle of return to the prevention and mitigation phase for a possible recurrence of the same disaster in the city.

The PCD/RS formalized the creation of the coordinated activities group (GRAC), composed of representatives of federal, state and municipal public bodies, as well as representatives of non-governmental organizations, all under the operational responsibility of the executive secretary and chaired by the director of this group corresponds to the item “Establishment of a governmental coordination” indicated in the base model proposed under number (5.12). The GRAC is divided into 29 clusters and each receives assignments and guidance on each of the five components of risk management whenever there is involvement with any of them. For purposes of organization, the PDC/RS provides for the division of the city of Rio do Sul into five Community Protection and Civil Defense Centers (Nupdec) and the creation of 34 civil defense shelters and the Civil Defense Operations Center (CODEC).

24.6 Discussion of the Model and Suggestion Form Future Work

Analyzing this PCD/RS, it is observed that the city of Rio do Sul does not have a waste management plan, responsible for guiding the community in determining appropriate waste management options before a disaster [28]. It has a general contingency plan, which aims to establish attributions to the various members in the face of a flood or gradual flood disaster, in order to minimize their effects in the phases of prevention, preparation and re-establishment of normal conditions [22]. So the effort here was to understand and discuss what steps in the overall contingency plan of the city and actions related to waste management were identified.

Although actions are distributed in the PCD/RS, there is overlapping of responsibilities and lack of clarity as to how these actions should occur and their accountability. It was concluded that the city has effective preventive strategies, such as dams and the river level alert system, but the PCD/RS seems to have been developed to meet government demands for the transfer of recovery funds. In addition, although quoted in the document, little clarification is made on environmental concerns. Waste reuse actions and recycling were not evident in the documents available for this work. As a suggestion, for future work, we intend to have an even greater focus on waste management in disaster situations in the city of Rio do Sul, in order to promote a specific waste management plan.

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Chapter 25
Water Distribution for Victims of Drought: The Case of the Brazilian Semi-arid Region

Yesus Emmanuel Medeiros Vieira, Renata Albergaria de Mello Bandeira, Luiz Antônio Silveira Lopes and Leandro de Oliveira Silva

Abstract This paper proposes a procedure and a computational tool for helping the decision-making process regarding the water supply for beneficiaries in regions affected by drought, considering the transport and routing of water distribution. The proposed procedure was applied to a real case scenario in the Brazilian semi-arid region.

Keywords Drought · Disasters · Operations management

25.1 Introduction

Disasters are sudden and calamitous events that disrupt the activities of a society or community, causing casualties, economic or environmental damages that exceed the society or community's ability to recover only with their own resources [11]. These events may be classified according to their origin, natural or anthropogenic, or, according to their evolution, as slow or sudden-onset [10].

Natural sudden-onset disasters, such as earthquakes, hurricanes and tornadoes, tend to attract more attention from the media and, consequently, from the general population, attracting more resources and donations [15]. However, slow disasters, as drought, do not usually receive such media coverage, and thus do not trigger such level of solidarity. This type of disaster has not attracted more attention from the academy either, and there is a lack of research on the topic [9]. According to Natarajarathinam [11], most researchers still focus their studies on sudden-onset natural disasters. Kunz and Reiner [8], when developing a systematic literature review on humanitarian logistics, found out that, of the studies published until 2011, 76% focus on sudden-onset disasters, 19% in any type of disasters and only 5% focus on slow disasters.

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However, slow disasters tend to be more extensive and destructive in the long run than sudden-onset disasters. According to the World Disaster report [16], drought and famine are the disasters with the highest rate of casualties worldwide. Since 1994, almost half of the total of deaths caused by natural disasters was due to the drought phenomenon [18]. In this way, the UN [19] classifies drought as the worst kind of natural disaster. Furthermore, droughts probably will become more severe in southern Africa, southern Europe, Southeast Asia, in the USA and Brazil, among other areas, resulting in increased periods of evapotranspiration, with reductions in the availability of arable land and an increase in food insecurity [17]. In Brazil, drought is the type of disaster that most affects the population: only in the Northeast more than 41 million people were affected by droughts between 1991 and 2012 [3]. Therefore, measures for improving the resilience to the expected impacts of this kind of disaster has increased due to the likely intensification of climate change in the country, and in many regions of the planet.

Mitigating the negative consequences of crises, such as droughts, has been a challenge in many regions of the world, especially in highly vulnerable areas, poorly structured to deal with the water crisis. In Brazil, water supply programs to diffuse populations still lack the capacity to meet the expected demands [6]. The use of water trucks, transport commonly employed for mitigating the effects of drought Brazilian, has been insufficient to remedy the water demand of the population in emergency situations [4]. The increasing transport distances for water distribution, along with other operational peculiarities, constitute obstacles for the drought combat in the country, which lacks a specific approach under the focus of humanitarian logistics.

In this context, this paper develops a procedure for structuring the process of water distribution for beneficiaries in regions affected by drought, considering the transport and routing of water distribution. The proposed procedure was applied to a real case scenario in the Brazilian semi-arid region. Currently, the distribution of drinking water is the responsibility of the Brazilian Federal Government through the *Operação Carro Pipa* (OCP) [2], a program that helps all Brazilian States affected by drought. Although this operation counts with the support of a computerized system that registers and monitors the water delivery, this procedure is limited for checking the confirmation of water delivery to the population in the end point. There is no methodology or tool for helping managers in selecting water sources or defining distribution routes that reconcile the limited availability of resources with the operational priorities of humanitarian aid. Therefore, in context with the practices and policies of the Brazilian Government, this paper proposes a procedure that allows a new logistics approach to operation OCP, enabling the reduction of the transportation distances among water fountains and the points of demand and resizing the fleet employed.

After this introduction, the remainder of this paper is organized as follows: studies on the implications of the drought and the emergency actions used in mitigation of its effects are presented in Sect. 25.2, which also describes the OCP operation in the Brazilian semi-arid region. In Sect. 25.3, the proposed procedure for helping the decision-making process regarding the water supply for beneficiaries in regions affected by drought is presented, as well as a description of the application of the developed computational tool. In Sect. 25.4, the concluding remarks and possibilities of future research on the topic are presented.

25.2 Drought and Its Scenery in the Brazilian Northeast: The Case of *Operação Carro Pipa*

Drought is one of the natural phenomena of higher incidence worldwide, set due to a prolonged period of low or absence of rainfall, which causes the loss of soil moisture. Drought causes significant damage to the population's living conditions, as well as ecological, economic, social and cultural systems [12]. The implications of drought for survival are usually felt in the short term. However, some impacts are indirect and have long-term effects, such as malnutrition, which can have its effects months or even years after the periods of drought.

According to Alpino et al. [1], the history of droughts is marked by social and health tragedies. Almost 32,000 events of droughts were registered between 1991 and 2010, affecting more than 96 million victims. Estimates are that three million casualties due to droughts occurred between the beginning of the nineteenth century and the late twentieth century [1]. During this period, losses per event reached up to eight billion dollars in the USA and Mexico. In China, it reached up to 2.4 billion dollars in its worst event and, in Brazil, 11 billion dollars [7, 13].

Large areas in the Northeast of Brazil have experienced a severe and prolonged drought between 2010 and 2017. This drought, as well as those that hit the south of the country in recent years, has sparked new discussions in search of improvements in drought management policies in federal and state levels.

The Brazilian Government, through the Ministry of National Integration (MI), has been developing actions and projects that add up to R$ 30 billion to mitigate the effects of drought [14]. These projects focus on ensuring, as well as improving, water supply for beneficiaries, both in quantity and in quality, as well as on mitigating economic losses for farmers and revitalizing river basins, mostly from San Francisco river. In this context, the MI has set up emergency measures, such as *Operação Carro Pipa* (OCP), for water distribution and the installation of cisterns, so that people can both collect rainwater and store water from water trucks, such as presented in Fig. 25.1.

In order to receive water supply, the population must be registered in the OCP program, which distributes water exclusively for human consumption and food preparation. The program supplies 20 L of water per person per day for such purposes. A comparative parameter to such daily consumption of water can be found in the Sphere Project—minimum standards for water supply, sanitation and hygiene promotion, which suggests the value of 15 L per person per day, including the needs of consumption human, cooking and basic hygiene. The total demand for each location that requires water supply is then calculated considering a daily consumption of 20 L per beneficiary, the value that guides the vehicle fleet dimension as well as the number of trips required during the period of drought.

(a) Operação Carro Pipa, managed by Civil Defens,e in city of Quixeramobim. Credits: Juliana Lima Oliveira (FUNCEME).

(b) Cistern. Avaliable at: http://www.asabrasil.org.br/acoes/p1mc

Fig. 25.1 Operação Carro Pipa (OCP)

In the OCP operation, water delivery occurs from the chosen water source to a single demand point (PA), which is a community that demands water supply and where there is a cistern, structure that enables storing the water transported by truck. Hence, the water stored in the cistern allows extending the period of time between deliveries. This type of distribution operation, applied on a large scale to geographically dispersed rural populations, requires the use of a significant vehicle fleet, due to the large number of points of supplies with individual routes in the system. Moreover, in cases of intense or prolonged droughts, the water trucks that before were only used in the countryside are also requested for urban deliveries, demanding thus a larger fleet.

Currently, in the state of Rio Grande do Norte, the OCP operation attends 17,621 beneficiaries in 16 municipalities. A fleet of 163 contracted vehicles currently delivers water to 1110 demand points, traveling a total of seven million kilometers in 17,565 trips per year, according to data provided by the 1st *Batalhão de Engenharia de Construção* (1st BEC), the army battalion responsible for the distributing drinking water in *Seridó*, a micro-region of the Brazilian semi-arid region.

The trucks employed in this operation are contracted by the Brazilian Government from private individuals who own them in the region. Due to regional availability and accessibility conditions to these communities, the water trucks more frequently used in the distribution have 10,000 or 12,000 L capacity. The service is paid according to the transport activity, measured by the product of the volume transported by the distance traveled from the water source to the demand point (in m^3 km), so that the return of the empty truck to the origin is not remunerated. Nonetheless, due to an increase in transport distances (since more communities, which are distant from water sources, are requesting the service due to the spread of the drought) together with the constant increases in fuel prices, the financial viability of the operation is being under threat; there have been constant supply disruptions in the operation and requests for readjustments in payment fees.

Therefore, seeking for improvements to this current scenario, the Brazilian Army, in partnership with the MI, started drilling wells in Minas Gerais and seven other states in the Northeast of the country. This operation started in May 2016 with a cost

Table 25.1 Successful well drilling cities1

City	Latitude	Longitude
Equador	06°56′36.7″	36°43′12.7″
Carnaúba dos Dantas	06°33′26.4″	36°35′46.9″
São João do Sabugi	06°37′17,1″	37°10′27,7″
Bernadino Batista	06°30′33.8″	38°34′00.2″
Nazarezinho	06°55′07.5″	38°19′40.7″
Triunfo	06°34′67.2″	38°35′95.0″
São João do Rio do Peixe	06°55′29.6″	38°23′46.5″

of US$ 4 million. Since then, 500 artesian wells were drilled, aiming to increase the availability of water and water security in the Brazilian semi-arid population.

In the specific context of the areas of responsibility of the 1° BEC, the semi-arid operation continued its focus on drilling and the installation of artesian wells in the municipalities registered in the OCP, succeeding in finding water in compensatory flows in 07 (seven) municipalities, as presented in Table 25.1 (Fig. 25.2).

The prospect is that, as the number of wells drilled and installed increases, the level of water safety in these communities also increases. Nonetheless, there are still challenges related to the water safe for human consumption. For instance, water desalination may be required. Moreover, another challenge that needs to be addressed, in addition to well drilling, regards the logistics process of the operation in order to improve the efficiency of the operation meanwhile minimizing its costs. Therefore, we propose a study regarding the water transport and its distribution, considering that the routes proposed by the algorithms to be implemented must meet the specific conditions of water accessibility faced by the Brazilian communities that suffer from

Fig. 25.2 Well drilling in semi-arid Northeast (1° BEC 2018)

drought, besides guaranteeing the per capita consumption agreed to the operation and increasing the logistic efficiency of the distribution system. The following section presents a procedure to be applied in the Brazilian semi-arid region to optimize the process of water distribution for beneficiaries in regions affected by drought.

25.3 The Proposed Model: Solution Procedures and Application

The proposed method for structuring the water distribution process, presented in Fig. 25.3, is developed in five steps, as follows:

Step 1: As the drought period starts, population demand in each register demand point (PA) must be verified. This procedure is followed by the survey of existing water sources, generally composed of dams or underground water sources that have an adequate water supply throughout the year.

Step 2: In this step, drilling points for new artesian wells must be investigated, in an attempt to meet the demand level. In the Brazilian context, this stage can be developed by the Ministry of Defense (MD), the government agency to which the Brazilian Army is subordinated, which has the human resources and equipment necessary for the activity.

Step 3: This step consists in the process of drilling the wells at the places indicated in the investigation proceeded in step 2. Water flow values obtained in this phase will indicate whether or not water wells will be installed at the drilled points. If this is the case, the well is installed and the possibility of water desalination is considered. This decision must be made on the basis of the water quality assessment and the estimated

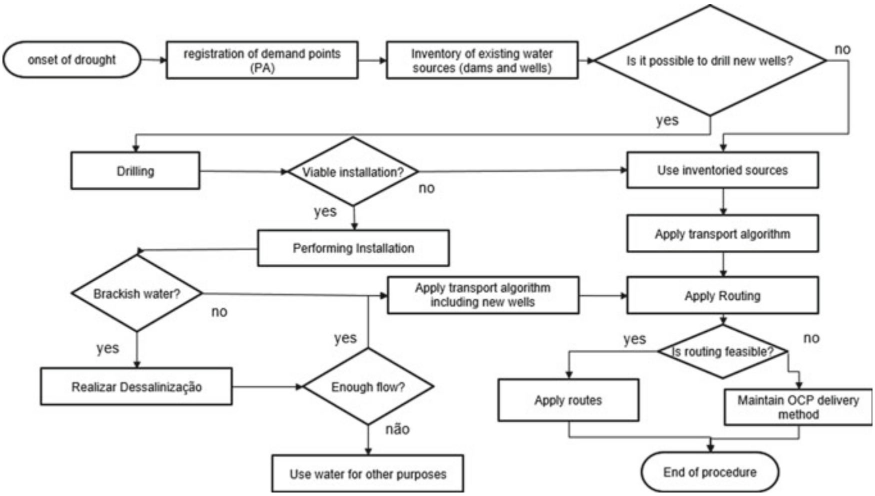

Fig. 25.3 Flowchart for water sources allocation and distribution routes

volume of drinking water available after that process. If desalination is not feasible, the water obtained in these artesian wells may be used by the local population for complementary destinations other than human consumption and food preparation.

Step 4: For this step, we propose a mathematical model, based on the transport algorithm, whose results in the allocation of water sources to the municipalities are to be benefited. Hence, the result of this step consists in a list of which water supply point will attend each community.

Step 5: For this step, we propose a mathematical model to solve this multiple-supply, multiple-demand, multiple-vehicle routing problem with time windows, based on Clark and Wright algorithm [5], particularized for the case where the window of delivery time are additional constraints to the capacity of the vehicle routing problem with time windows, and two opt heuristic. The result of this step consists in the different routes to be followed by each vehicle, considering that all demand points must be attended. Each proposed route should attend, preferably, more than one point of demand, respecting the needs of per capita consumption, operating regime of water sources and safety in the working day of the drivers.

For the application of the proposed procedure, a computational tool was developed in Visual Basic for Applications (VBA), within Excel software. The following information is required for the use of this computational tool: location (latitude and longitude) of sources and demand points; need for water in each PA; capacity of the vehicle that will transport the water, average time of water discharge in each PA; and the time window limit within which water should be delivered during the journey. Figure 25.4 shows some input and output screens for this tool.

The proposed procedure was then applied to a set of 16 municipalities in the state of Rio Grande do Norte that suffers from drought, in an attempt to optimize the water distribution for 17,621 beneficiaries, dispersed along 1110 geographically demand points. Data was collected from the 1° BEC, the base of the OCP operation.

The application of the proposed procedure made possible the determination of water supply routes that attend a greater number of demand points per working day, thus providing an improvement in the response time to the communities and, consequently, leading to an increase in the number of beneficiaries attended. Results from this application are presented in Table 25.2.

It is important to stress that, with the application of the proposed procedure intervals between deliveries, which were previously irregular and far apart from each other, could then be planned in advance. As a result, they were stabilized, with deliveries being held each week according to the actual needs of the communities. Consequently, additional costs with large water stocks, previously unevenly distributed between communities, could be eliminated. With these changes, the operation could be held by a smaller number of vehicles per municipality. Considering the 16 municipalities, the reduction in the total number of vehicles employed in the operation dropped from 110 trucks to 69, after applying the proposed procedure. Such modifications generated a 29.08% reduction in the transportation costs paid for the government. This budget saved could then be reversed in readjustments of the payment fees requested by the truck owner, such as previously discussed (Sect. 25.2), in an attempt to avoid possible strikes by the providers of water transport services.

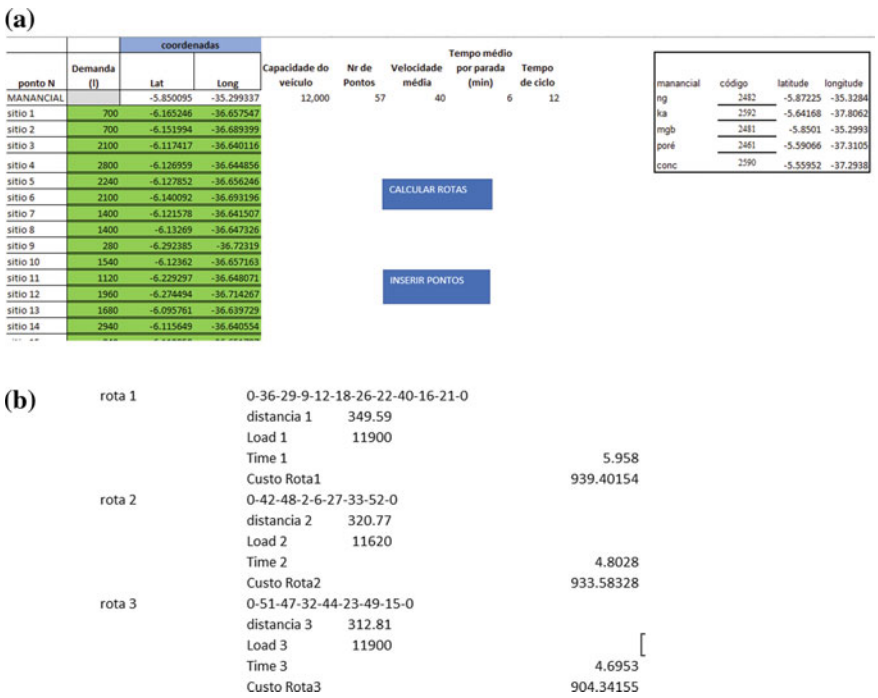

Fig. 25.4 Computational tool for decision support in the distribution of water to drought victims2

Tabel 25.2 Results of the proposed procedure

Scenario	Number of vehicles used	Number of possible single demand point attended	Response time to the communities	Total distance traveled per year (Km)
Actual OCP procedure	110	1110	Variable time between deliveries (On average, from 2 to 12 weeks)	6,380,054.70
Proposed procedure	69	1422	Weekly	3,715,763.44

25.4 Concluding Remarks and Implications

This paper proposes a procedure and a computational tool for helping the decision-making process regarding the water supply for beneficiaries in regions affected by drought, considering the transport and routing of water distribution. The procedure was developed, considering the drought scenario in Brazil, for structuring the sequence of decisions that cover drilling wells, choice of sources and routing techniques applied to the context of *Operação Carro Pipa*. Nonetheless, adaptations can be made so the procedure can be applied to other contexts as well.

The proposed procedure was applied to a real case scenario in the Brazilian semi-arid region. Results obtained indicate a decrease in the total distance traveled, in the number of vehicles used and in the annual costs of water distribution. Considering that the budget for the OCP operation will be maintained, such gains may lead to an expansion on the humanitarian logistics network applied to tackle the drought, benefiting thus a larger number of beneficiaries. This is an important contribution because, due to the increasing effects of climate change, an increasing number of people may be subjected to the effects of the phenomenon of drought, particularly in developing countries, which lack infrastructure and suitable governmental investment. Therefore, the development of solution models and techniques similar to those discussed in this paper are highly recommended for future studies.

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Chapter 26
Mitigation and Prevention of Droughts: A Systematic Literature Review

Raissa Zurli Bittencourt Bravo, Adriana Leiras and Fernando Luiz Cyrino Oliveira

Abstract This paper analyzes the evolution of research on drought mitigation and prevention over the years through a systematic literature review. The results indicate the publication trends for future studies.

Keywords Drought · Mitigation · Prevention

26.1 Introduction

Drought can be defined as a recurrent weather phenomenon that results from the rainfall reduction and makes the available water insufficient to meet the needs of humans and ecosystems [6].

Wilhite et al. [16] defend that increase in demand of water due to the population growth, the limited and uncertain water supplies, added to the increase of temperatures, and the extreme precipitation regimes will become drought more frequent and severe over the years. According to Sesha Sai et al. [7], in 1970, the area affected by drought was less than half of that in the year 2000. Besides being a disaster that is growing in term of area, Sivakumar et al. [9] show that disasters caused by drought are also devastating in terms of people affected, as in Africa, where drought represents less than 20% of the occurrence of the disaster but account for more than 95% of the death. According to Carrão et al. [2], the financial impact of droughts damage in the USA causes on average \$6–8 billion per year.

From these propositions, Wilhite et al. [16] believe that it is essential to understand the future impacts caused by severe droughts and, therefore, studies that focus on the anticipation of the droughts, on a long-term scale, are essential to minimize vulnerability and create innovative strategies to deal with drought mitigation. Mitigation can be defined as a set of actions taken, before the occurrence of the disaster, aiming to minimize or avoid the impacts [16].

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In this paper, we conduct a systematic literature review (SLR) on drought mitigation and prevention and point out the trends of this area.

This paper is organized as follow: Sect. 26.2 presents the methodology used to conduct the literature review, Sect. 26.3 presents the results, and the concluding remarks are presented in Sect. 26.4.

26.2 Methodology

Thomé et al. [11] proposed a step-by-step approach, to guide a literature review in operation management, consisted of eight steps: (i) planning and formulating the problem, (ii) searching the literature, (iii) data gathering, (iv) quality evaluation, (v) data analysis and synthesis, (vi) interpretation, (vii) presenting the results, and (viii) updating the review.

In the first step, planning and formulating the problem, we aim to understand the publication trends about mitigation and prevention of droughts through the following indicators: publications over the years, main journals (number of papers and number of citations), principle authors (number of papers and number of citations), papers categorized by document type, and keyword map.

In the second step, searching the literature, we choose the Scopus and Web of Science databases because they are the two central and largest databases, according to Mongeon and Paul-Hus [5], and by using both, we can mitigate the chance of bias related to journals indexed in a single database besides making the research more comprehensive. Thomé et al. [12] reinforce the use of both databases mentioning that their coverage is about 22,000 journals from the leading publishers of peer-reviewed papers. The keywords used were: (relief OR humanitarian OR disaster OR emergency OR crisis) AND drought AND (mitigation OR prevention), and we have filtered the results according to the document type (articles, article in press, and review) and the language (English). Finally, we have removed the duplicated documents and read their abstracts to decide what is relevant and what is not. Relevant articles were those that developed methods of prevention and mitigation of droughts. Articles that addressed climate change and cited drought just as an example were not considered relevant. The second step resulted in 191 relevant papers.

In the third step, data gathering, we have extracted some attributes of these 191 relevant papers, which were authors, title, year, source, volume, issue, pages, abstract, document type, DOI, and link.

In the fourth step, quality evaluation, we choose only peer-reviewed papers which are the primary indicators of the quality of the papers considered in the research.

In the fifth step, data analysis and synthesis, the authors focused on the contextual data, such as publications over the years, leading journals, and main authors, which comprise the case descriptors.

The sixth step, interpretation, is presented in Sect. 26.3 with the analysis of the results. The analysis considers publications over the years, main journals, principle authors, and papers categorized by document type and keyword map, which was made through VOS viewer software.

The seventh step, presenting the results, is the primary objective of this study and will be presented in the next section.

The eighth step, updating the review, is suggested for future works.

26.3 Results

Figure 26.1 shows the number of publications over the years.

We can see the increase in the number of publications from 2011. Seventy-three percent of the studies published in this area have occurred in the last ten years, which shows that this is a growing area. In 2012, the increase in the number of publications was 5.8 times the historical average of 1986–2011, being two-thirds of the publications related to the Asian continent and 40% related to China. In China, drought is a difficult challenge because it is a treacherous, slow-onset disaster that rapidly reaches the population rather than striking suddenly and violently. According to Ye et al. [18], from January 2009 to April 2010, China suffered three severe droughts which intensity in each of them reached the once in every 100-year level. East Africa has also suffered from droughts in 2010–2011, causing famine to 9 million people [3].

Table 26.1 shows the top 20 journals in the number of citations that account for 70% of the citations and 32% of the papers.

Journal of Water Resources Planning and Management was the first journal to address mitigation and prevention of droughts in 1986. Natural Hazards, the journal with most cited papers, account for 10% of the citations and 7% of the papers. It is a journal focused on all aspects of natural disasters, including studies about the

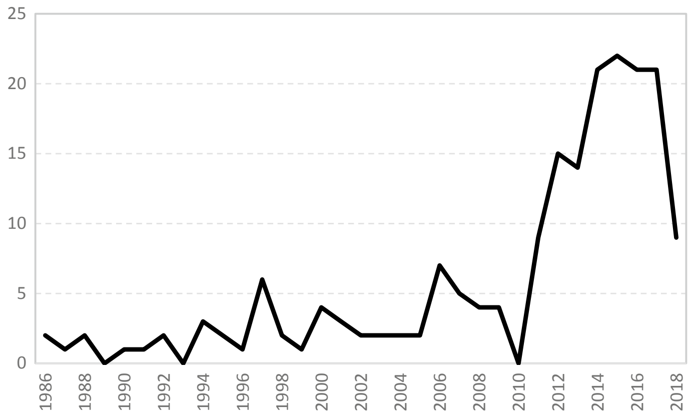

Fig. 26.1 Publications over the years

Table 26.1 Numbers of papers and citations per source

Source	No. of papers	No. of citations
Natural Hazards	13	230
Water Resources Management	5	163
Disasters	4	146
Journal of the American Water Resources Association	2	132
Natural Hazards Review	4	121
Weather and Climate Extremes	3	105
Scientific data	1	94
Physics and Chemistry of the Earth	1	73
Bulletin of the American Meteorological Society	2	60
Philosophical Transactions of the Royal Society B-Biological Sciences	1	60
Environmental Research Letters	2	57
Hydrology and Earth System Sciences	3	48
Weather, Climate, and Society	3	47
International Journal of Climatology	6	46
Climatic Change	1	41
Agricultural Water Management	2	37
Applied Geography	1	37
Journal of Hydrology	4	36
International Journal of Water Resources Development	3	34
Policy Sciences	1	34

forecasting of catastrophic events, risk management, and the nature of precursors of natural and technological hazards. It should be noted that 30% of the top 20 journals are related to water resource, and 25% are related to climate and meteorology, which are directly related to the cause and intensification of droughts.

Table 26.2 presents the top 20 authors in the number of citations. Together, they account for 30% of the citations and 7% of the papers.

Wilhite, the top one author with most papers and most citations, accounts for 3% of the citations and 1% of the publications, his first publication on the theme was in 2000, and the last was in 2014. His most cited paper is a review paper [15] with 115 citations, which presents a revision of a ten-step drought planning process that has been widely applied in the USA. His second most cited paper [17] has 89 citations, and they discuss the concept of drought and the objectives and principles of US drought policies principally.

The second top, Hayes, accounts for 2% of the citations and 1% of the publications, his most cited paper is also Wilhite et al. [15], followed by Svoboda et al. [10] with 40 citations that address a drought classification system called the Drought Monitor.

Table 26.2 Numbers of papers and citations per author

Authors	No. of papers	No. of citations
Wilhite D. A.	7	288
Hayes M. J.	5	227
Knutson C. L.	3	198
Rossi G.	4	182
Shahid S.	2	174
Cancelliere A.	3	171
Behrawan H.	1	157
Pulwarty R.	2	142
Bonaccorso B.	1	129
Mauro G. D.	1	129
Svoboda M. D.	6	117
Smith K. H.	1	115
Sivakumar M. V. K.	2	104
Hao Z.	2	99
AghaKouchak A.	1	94
Farahmand A.	1	94
Nakhjiri N.	1	94
Wilhelmi O. V.	1	78
Brewer M. J.	2	74
Heim Jr. R. R.	2	74

The author in the third position, Knutson, is most cited through Wilhite et al. [15] too. His second most cited paper is Hayes et al. [4] with 78 citations. In this study, they present a simplified and flexible framework to conduct a drought risk analysis.

The work by Shahid and Behrawan [8] is most cited paper and presents a method for spatial assessment of drought risk in Bangladesh.

Cancelliere et al. [1] is the second most cited reference and provides two methodologies for the seasonal forecasting of standardized precipitation index (SPI), considering the uncorrelated and normally distributed monthly precipitation.

Hao et al. [3] is the fourth most cited paper, after Wilhite et al. [15], and they present data sets available from the Global Integrated Drought Monitoring and Prediction System (GIDMaPS).

Figure 26.2 shows the papers categorized by document type.

As it can be seen in Fig. 26.2, 93% of the papers are classified as “Article”, while there are only nine studies addressed as “Review.” It is important to note that none of these nine papers adopt the systematic literature review methodology, which is one of the main contributions of this paper.

The most recent review is from Wang and Xie [14] in which they present the best practices, technologies, and applications of remote sensing and GIS for water

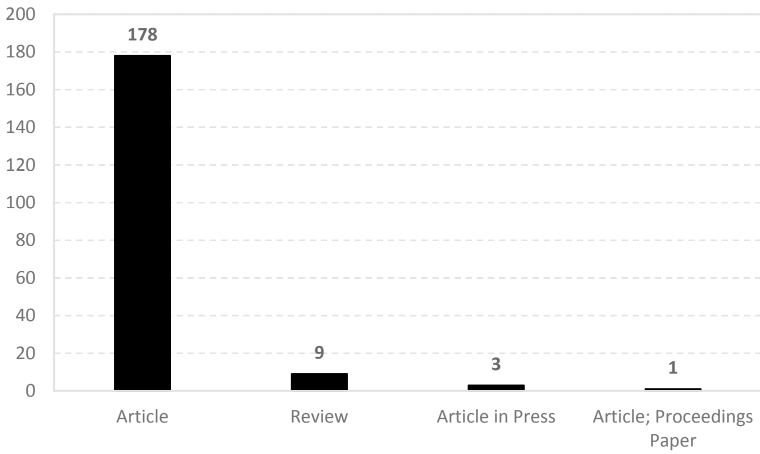

Fig. 26.2 Papers categorized by document type

resource mapping, measures of satellite rainfall, runoff simulation, flood inundation mapping, and risk management.

According to Wang and Xie [14], the most recent technologies include 3D surface model analysis, drones video image classification for irrigation planning, ground penetration radar for soil moisture estimation, and satellite radar.

Figure 26.3 shows the keywords map developed in VOS viewer.

In Fig. 26.3, we can see the occurrence of the keywords through the size of the balls, while their distance represents the relation between keywords. They were collected through the title, abstract, and keywords exported from the databases in a binary search, which means that only the presence or the absence of a term in document matters, the number of occurrences of a term in a document is not considered.

We can also group the terms above into clusters, as can be seen in Table 26.3.

The clustering technique used by VOS viewer is presented by Waltman et al. [13]. The first cluster shows a strong relationship between the studies that aim to predict droughts through the magnitude, occurrence, severity, and frequency of the rains as well as the analysis of indicators such as the standardized precipitation index.

The second cluster addresses the studies that approach disaster planning and management through preparedness and response policies as well as the challenge to create early warning systems to deal with the vulnerability reduction.

The third cluster addresses the prevention and mitigation of extreme weather-related disasters: floods and droughts.

We may highlight some keywords in each cluster: index, precipitation, and China (in cluster 1), resource (in cluster 2—green) and disaster (in cluster 3—blue). The relation in cluster 1 (red) can be explained by the high number of papers about the forecast of the precipitation index in China.

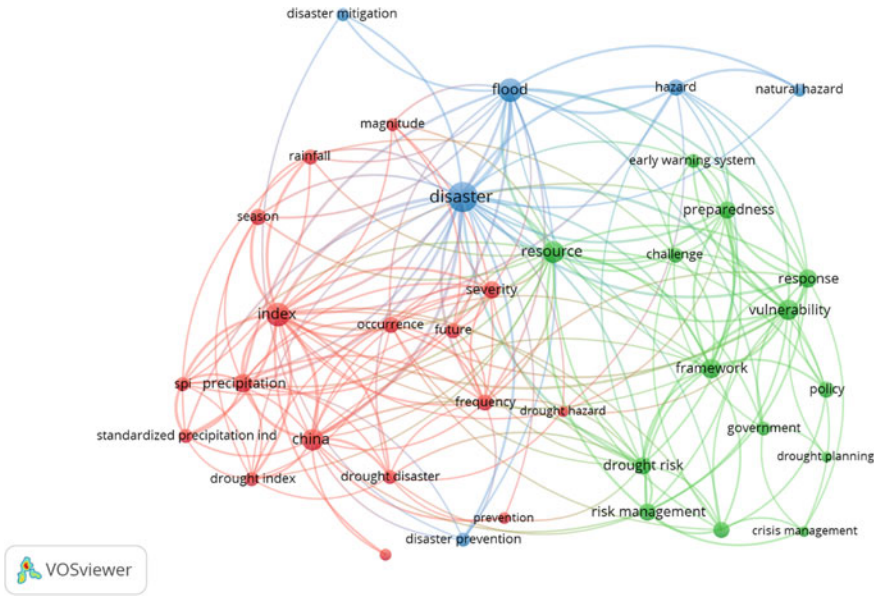

Fig. 26.3 Keywords map

26.4 Conclusion

In this paper, we consider drought as a slow-onset disaster that has affected the lives of many people over the years. Therefore, this subject has attracted academies attention in recent years. Up to our knowledge, through a systematic literature review methodology, this is the first paper to systematically analyze the trends in humanitarian relief with a focus on drought mitigation and prevention.

Although this is a recent research area and with most of the publications in the last ten years, there are already quite widespread and cited works. As future works, we suggest the content analysis of the literature, according to the prevention and mitigation methods, to understand the techniques used to minimize the damages caused by droughts.

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Table 26.3 Keywords clusters

Cluster 1	Cluster 2	Cluster 3
China	Challenge	Disaster
Drought disaster	Crisis management	Disaster mitigation
Drought hazard	Drought management	Disaster prevention
Drought index	Drought planning	Flood
Frequency	Drought risk	Hazard
Future	Early warning system	Natural hazard
Index	Framework	
Magnitude	Government	
Occurrence	Policy	
Precipitation	Preparedness	
Prevention	Resource	
Rainfall	Response	
Season	Risk management	
Severe drought	Vulnerability	
Severity		
Spi		
Standardized precipitation		

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Chapter 27
Performance Indicators in Humanitarian Operations from the Beneficiary Perspective: A Systematic Literature Review

Brenda de Farias Oliveira Cardoso, Tharcisio Cotta Fontainha and Adriana Leiras

Abstract This paper aims to analyze, through a systematic literature review, the research scenario related to performance indicators in humanitarian operations from the perspective of the beneficiary. The results cover a descriptive analysis of the main research characteristics and trends in the existing literature.

Keywords Systematic literature review · Humanitarian operations · Key performance indicators

27.1 Introduction

Performance measurement provides organizations with data for monitoring, evaluation and possible changes in organizational processes, guiding decision making to improve activities and better performance in the market. In the case of humanitarian organizations (HOs), which are responsible for assisting people affected by disasters, the implementation of precise metrics is necessary for the development of HOs, as well as being used as parameters to move organizations toward your goals [1]. In addition, measuring the performance of humanitarian operations reflects better results and still meets stakeholder demands [2, 3]. Thus, one of the primary functions of performance assessments in this context is related to how HOs projects and programs can be effective and efficient in helping beneficiaries [4]. In this sense, it is essential to analyze performance measures from a different perspective, including those who receive the humanitarian relief and can be considered the final clients of HO [5].

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Despite their relevance, the development of performance indicators is considered a challenge in the humanitarian context due to aspects, such as the intangible nature of the services provided; the magnitude and variety of missions and the different levels of interest limitation of resources (human and material) and high level of information uncertainty [3, 6, 7]. Besides that, the analysis of performance considering the beneficiary's perspective is also not mainly addressed in the academic literature, as observed in the results of the systematic literature review (SLR) recently developed by Behl and Dutta [8]. In their work, Behl and Dutta did not mention the perspective of the beneficiary in the discussions related to performance evaluation in the humanitarian supply chain. However, Fontainha et al. [9] argue that beneficiary is the main stakeholder in disaster response and humanitarian operations, but this stakeholder is still not the primary focus in most of the academic publications. Considering such a research gap, this paper aims to identify the current state of the art related to performance indicators in humanitarian operations from the perspective of the beneficiary. The research applies the SLR as a suitable method for developing a holistic conceptualization and the synthesis of a new or emerging topic (herein performance of humanitarian operations according to the beneficiary's perspective), providing results to reinterpret previous research or a first step for further research on the topic [10].

This paper is organized as follows: After this introductory section, Sect. 27.2 presents the research methodology used in this study. Next, Sect. 27.3 shows the results obtained through the analyses. Finally, Sect. 27.4 presents the conclusions, limitations and potential future work.

27.2 Methodology

The present research applies the eight steps for a SLR as a structured method proposed by Thomé et al. [10]: (i) planning and formulating the problem, (ii) searching the literature, (iii) data gathering, (iv) quality evaluation, (v) data analysis and synthesis, (vi) interpretation, (vii) presenting the results, and (viii) updating the review.

Considering the first step, the application of the method aims to address the research problem regarding the difficulty of developing and analyzing performance indicators in humanitarian operations from the beneficiary's perspective. In this sense, the research examines the existing literature related to the topic to answer the following research question: What is the current state of the art associated with the literature of indicators of performance indicators in humanitarian operations from the perspective of the beneficiary?

The second step considers the bibliographic search in the Scopus and Web of Science (WoS) databases due to the capacity of complementarity between indexed journals between the two bases [10, 11]. Also at this stage, the set of keywords is defined by the combination of three groups that covers the topic broadly enough to avoid any artificial limitation of the documents obtained, at the same time providing limits to exclude undesirable results. The search considered the following structure in the titles, abstracts, and keywords: (disaster OR relief OR “humanitarian logistics” OR “development programs”) AND (indicators OR “performance measure” OR “performance measurement” OR “performance evaluation” OR “performance assessment” OR KPIs) AND (beneficiary OR victim OR consumer OR customer OR client). This search returned 428 documents (298 in Scopus and 130 in the Web of Science) on August 15, 2018, and these documents were analyzed according to the following criteria to decide for the inclusion or exclusion in the present research:

- Inclusion criteria: addresses performance indicators in humanitarian operations; consider an approach according to the beneficiary’s perspective;
- Exclusion criteria: do not address performance indicators in humanitarian operations; do not address indicators from the beneficiary’s perspective; develop research outside the humanitarian context; treat applications or algorithms for system optimization; deal with post-disaster medical assessments; duplicate documents; documents in other languages than English.

Following these criteria, 81 documents were excluded because they did not address performance indicators in humanitarian operations; 33 were outside the humanitarian context; 41 did not consider the beneficiaries’ perspective on the performance of humanitarian operations; 46 presented applications or algorithms for system optimization; 61 addressed the results of post-disaster medical evaluations; 23 papers in other languages than English and 99 were duplicated. Also considering the criteria, 44 articles were selected for the research.

The third step, data collection, was performed by identifying and compiling into auxiliary tables the data related to the year of publication, a number of citations, keywords among others. The quality evaluation stage was ensured by the description of the method followed in all the SLR.

The fifth stage, analysis, and synthesis, is performed through bibliometric analysis consisting of some basic statistics, such as evolution per year, more popular journals, outliers according to the number of citations, as well as the co-occurrence map of keywords associated to keyword groups retrieved from the papers and built by the VOSViewer software. The next step consists in interpreting the results, which is addressed by the discussion of the impact of findings for the topic of performance in disaster and humanitarian operations. The presentation of the results is described in this paper, and the updating of the revision is the last step, proposed as future research.

27.3 Results and Discussions

In this section, the research presents the bibliometric analysis developed according to the papers’ characteristics.

Figure 27.1 presents the evolution of the number of publications per year.

Among the papers selected in the SLR, the first publication appeared in 1990 and after 2011 the number of publications increased to a plateau level ranging between

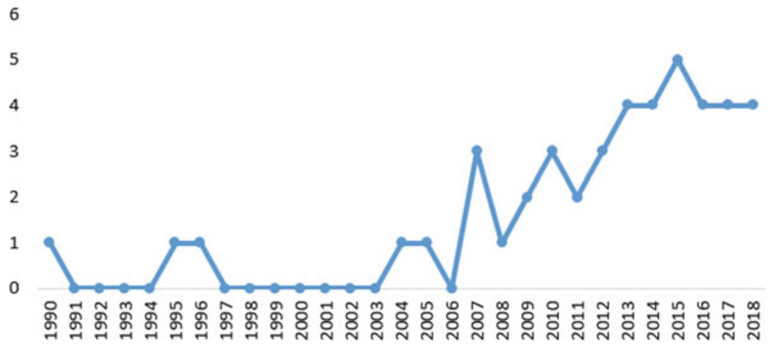

Fig. 27.1 Evolution of publications per year

four to five documents per year. This pattern can be explained by the creation of the Journal of Humanitarian Logistics and Supply Chain Management (JHLSCM) in 2011, which changed the dynamics of publications in the area of humanitarian logistics together with other various special issues [8].

Aligned to this perspective, the JHLSCM is one of the most published journals with three documents, along with Disasters with also three papers, followed by the Evaluation and Program Planning with two papers. The remain journals have among their research lines, topics related to humanitarian logistics, supply chain management, organizational development, planning for improvements. The other journals published only one document related to the subject, as well as the authors that also have one publication each one making the field of the publication well dispersed.

The articles considered outliers, according to the number of citations extracted from the databases, are presented in Fig. 27.2. In bibliometric terms, the analysis of outliers can provide relevant information for the identification of very or little-cited works, where works with a high number of citations can be considered outliers [12].

The outliers are identified by calculating the interquartile range (IQR), which is obtained based on three quartiles—the first quartile (lower), the quartile intermediate (median), and the third (upper) quartile. The difference between the upper quartile and the lower quartile determines the interquartile range. With the interquartile interval, it is possible to find the upper and lower limits of the sample (e.g., see [13]. The results of the calculations are described below: First quartile (Q1) = 0; Median = 2; Third Quartile (Q3) = 7; IQR = 7; Upper limit = 18. In this case, the outliers are papers with the number of citations above the identified upper limit.

Morita et al. [14] propose an instrument to measure the perception of families regarding procedural aspects of palliative care in Japan about the perceived experience, levels of satisfaction, and the degree of expectation among other utilities to identify the need of improvements. Oloruntoba and Gray [15] were the first to use the term "customer" and "customer service" in the humanitarian context. The authors developed, based on the literature review, an understanding of the various beneficiary's perspectives required to assist the population affected by a disaster in

Fig. 27.2 Outliers papers

Authors		No. of citations
Morita T., et al.	(2004)	78
Oloruntoba, Richard; Gray, Richard	(2009)	53
Moe T.L., et al.	(2007)	45
Downey L.V., Zun L.S.	(2010)	32
Medina-Borja A., Triantis K.	(2007)	19
du Mortier S., Arpagaus M.	(2005)	17
Eisenman D., et al.	(2014)	15
Lucchi E.	(2012)	9
Schiffling S., Piecyk M.	(2014)	8
Flannery K.B., et al.	(2007)	8
Chilenski S.M., et al.	(2014)	7
Kigenyi O., et al.	(2013)	7
Haavisto I., Goentzel J.	(2015)	6
Leow J.J., et al.	(2012)	6
Pérouse de Montclos M.-A.	(2012)	6
Byabagambi J., et al.	(2015)	5
Kilic T., et al.	(2015)	5
Martins A.P.B., Monteiro C.A.	(2016)	4
Zotti M.E., et al.	(2015)	4
Gandure, Sithabiso; et al.	(2010)	4
Kwon H.-M., et al.	(2016)	3
Solheim E., Garratt A.M.	(2013)	2
Khazai B., et al.	(2018)	1
Nath R., et al.	(2017)	1
Rokaya D., et al.	(2017)	1
Stark L., et al.	(2015)	1
Yilmaz D.G., et al.	(2013)	1
Nxumalo K.K., Antwi M.A.	(2013)	1
Westhoff W.W., et al.	(2008)	1
Gouws N.B.	(1990)	1
Gutierrez-Montes I., et al.	(2018)	0
Ozen M., Krishnamurthy A.	(2018)	0
Wijegunarathna E.E., et al.	(2018)	0
Amir Zal W.A.	(2017)	0
Dapaah A.D., et al.	(2017)	0
Maji S., et al.	(2016)	0
Oo S.S., et al.	(2016)	0
Piyasil V., et al.	(2014)	0
Charoenkalunyuta C.M., et al.	(2011)	0
Vermeulen J., et al.	(2011)	0
Zhou L., Li R.	(2010)	0
Mangoud A.M.	(1996)	0
Chabalala H.P.	(1995)	0
Yan Zhang-hui	(2009)	0

the development of humanitarian chains, providing assistance and satisfaction to all those involved. Moe et al., [16] adapted the balanced scorecard (BSC) approach to projects related to natural disaster management, maximizing the desired outcomes of the projects and establishing performance measures in four areas: donor perspective; the target beneficiary perspective; the perspective of the internal process; and learning and innovation perspectives. Downey and Zun [17] evaluated hospital patient satisfaction as an essential indicator for reducing people's suffering. Medina-Borja and Triantis [18] presented a conceptual framework for designing and implementing

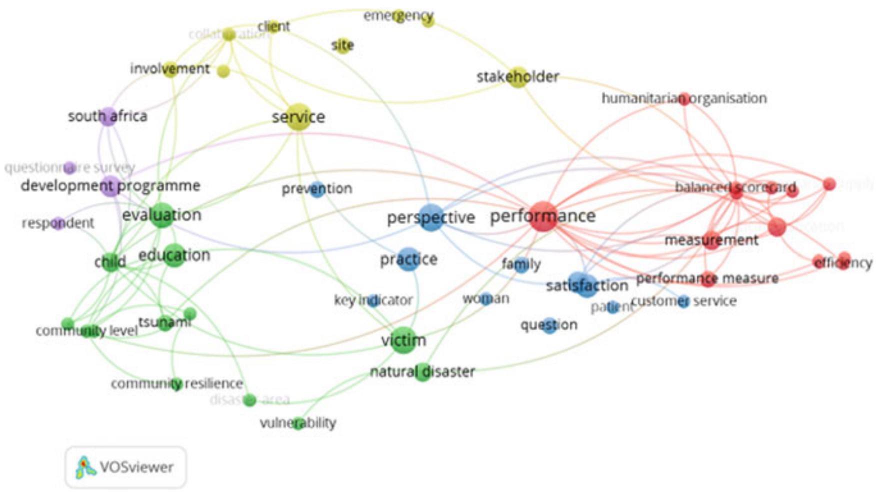

Fig. 27.3 Keywords map

Table 27.1 Keywords clusters

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Balanced scorecard	Child	Customer service	Client	Development programme
BSC	Community level	Family	Collaboration	Questionnaire survey
Customer	Community organization	Key indicator	Community participation	Respondent
Efficiency	Community resilience	Measure	Emergency	South Africa
Humanitarian context	Comparasion group	Patient	Involvement	
Humanitarian logistic	Disaster area	Perspective	Quality improvement	
Humanitarian organization	Education	Practice	Service	
Humanitarian supply chain	Evaluation	Prevention	Site	
Measurement	Natural disaster	Question	Stakeholder	
Performance	Outcome indicator	Satisfaction		
Performance measure	Tsunami	Woman		
Pratical implication	Victim			
	Vulnerability			

VOSviewer

a performance measurement system which addresses four main dimensions: revenue generation, capacity building, customer satisfaction and efficient results, which can be used in non-profit organizations, mainly humanitarian organizations.

For the analysis of keywords, a co-occurrence map (Fig. 27.3) is created using the VOSviewer software. VOSviewer is used for the analysis of bibliometric networks and can be used to create maps of publications, authors, periodicals, keywords based on a co-occurrence network [19]. The map shows connections between similar terms, where the size of the circles means the number of occurrences of the term and the degree of relation is represented by the proximity between the terms [19].

The words were collected through the title, abstract, and keywords of the documents, which were exported in the binary search option, indicating or not the presence of a term, where the frequency of occurrence of this term is not considered.

Keywords can also be grouped into clusters (Table 27.1). It is noted that in all groups, there is an integration of terms related to the theme of this study: humanitarian logistics, quality evaluation, and beneficiary perspective.

27.4 Conclusion

This aim of this paper is achieved by the identification of the current state of the art related to performance indicators in operations from the beneficiary's perspective. Based on the SLR procedures, we analyze 44 documents obtained in the Scopus and Web of Science databases, according to bibliometric aspects regarding the year, journals, authors, papers more cited, and correlation of keywords.

The results reveal that the topic of performance indicators in humanitarian operations has been debated for some time and, as of 2011, the number of publications on the subject has increased. We notice that the topic is covered by different journals and authors, making the theme dispersed in the academic field. The keyword analysis identified variations in the terms used by the papers when it comes to measuring performance in humanitarian operations from the perspective of the beneficiary.

Taking into account the outliers documents, we conclude that the discussion has been considered relevant by developing structured models [18] or the adaptation of widely known frameworks for disaster management [16], and other more general aspects about the beneficiaries' perspective, such as the construction of instruments to identify the level of satisfaction with the services rendered [14, 15, 17] can be observed.

We suggest for future research to incorporate existing studies in other databases and also other sources of gray literature. Also, future research may address the content analysis of the selected articles, identifying, for example, the most commonly used techniques for assessing performance in humanitarian organizations or the most common indicators.

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Chapter 28
Risk Assessment Applying Logistic Variables at Urban Scale: Case of Gamarra (Peru)

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Abstract This study evaluates the risks that could result in a disaster in Gamarra (Peru). The baseline focuses on the last mile logistics characteristics such as population density, commercial activities, and infrastructures in square kilometers. Vulnerability of buildings and pedestrian's speed are also considered. The results show a risk map to help decision makers.

Keywords Risk assessment · Last mile · Logistics · Hazard area

28.1 Introduction

Cities are artificial environments created, developed, and defined by human beings with a combination of the social environment and the natural environment, under varied density patterns [1] as the number of stores per km^2, the length of loading and unloading areas, number of deliveries per hour, and average number of vehicles and disruptions per hour [2]. In parallel, there is a natural environment made up of all those living and non-living beings that inhabit the planet interacting in different ways with humans. Both environments are in a permanent relationship, balance and imbalance, competing for the use of resources generated in both environments [1].

During the last decades, the urban population has grown significantly, and in 1960, it represented 33.62% and it has increased to 54.82% in the year 2017 [3, 4] while the rural population has had a decrease of 66.38–45.17 in 2017 66.38% until 45.17% in 2017 [3, 4]; Likewise, an urban population of 68% is estimated in the year 2050 [5]. Rural populations are characterized by low population density, limited access to basic services and can be understood as vulnerable socio-ecological systems [6, 7].

The urban and rural populations are degrading the environment by the use of space and are also generating imbalances, causing, in turn, events such as air and

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water pollution, deforestation, and the alteration of riverbeds and seas, which have an impact on society [1]. As part of this process of change, several natural phenomena are generated, such as rains, temperature increase, melting glaciers, among others, and urban areas such as traffic, transportation, and pollution.

The disasters are sudden or foreseeable calamitous events that transform the functioning of a community and cause human, material, economic, or environmental losses, overflowing the capacity to face the situation with their own resources. They can be of two types: natural and man-made; natural disasters are those catastrophic events caused by the nature or natural processes of the earth, and its severity is measured in loss of life, economic loss, and the capacity of the population to recover; In turn, natural disasters are classified into five subgroups: biological, geophysical, meteorological, hydrological, and climatological, which cover disasters that include earthquakes, droughts, floods, forest fires, among others. On the other hand, anthropogenic disasters are those generated by the action of man. These are classified into three subgroups: industrial accidents, transport accidents, and various; within these, there are a variety of types of disasters such as explosions, fires, oil spills, radiation, air accidents, among others, caused by certain human activities [8].

The risk of a disaster is the combination of severity and frequency of hazards, the number of people and assets exposed to the hazard, and their vulnerability to being harmed (Risk $=$ Hazard $\times$ Exposure $\times$ Vulnerability) [9]. Some authors define the developed stages of disaster risk management such as mitigation, preparedness, response, and recovery [10–15] from the analysis of hazards, risks, and future trends. The main purpose is to understand the risk of a disaster, strengthen its governance, and increase preparedness to give an effective response.

Hazard is defined as a human phenomenon or activity that can cause loss of life, damage or other health impacts, damage to property, loss of facilities and services, social and economic interruptions, or environmental damage [8]. Vulnerability is the diminished capacity of a person or a group of people to anticipate, face, and resist the effects of a natural hazard or it is caused by the actions of man. Reducing vulnerability requires strengthening the capacity for social recovery and the ability to minimize the degree of loss [16]. On the other hand, exposure is the degree of influence of danger [8], and its level varies according to its social group, sex, ethnic origin or another entity, age, and other factors [16].

There are studies and diverse tools used to identify and quantify a hazard, the exposure and the vulnerability in which people from certain areas find themselves. The study of pedestrian mobility is used to determine the danger of the inhabitants through indicators such as the average speed of the pedestrian and the number of disruptions. A study to measure the level of exposure is the Last Mile [17, 18] which proposes a framework to develop urban logistics tools and metrics. This framework addresses the definition of geographic scale, centrality, and logistics-oriented metrics in one square kilometer (km^2) as an appropriate size for characterizing a subarea in the city with shop inventory, roads and regulations, delivery operations, disruptions, and traffic. In the same way, there are tools to quantify the degree of vulnerability in which the population of certain areas is located; for example, the study of seismic vulnerability of the city hall of La Victoria, which was used in this study to identify critical structures, their status and location.

In Peru, about 80% of the population lives in urban areas, Lima concentrates 32% of the population and 45% of the country's internal product [19]. This study focuses on Gamarra, located in the district of La Victoria; dangerous area due to its urban characteristics, its large commercial proportion and the density of people during a common day. According to the Instituto Nacional de Estadística e Informática (INEI), there are more than 31,737 establishments, 71,484 people who work and offer a high number of services, supplies and other products related to the textile, clothing and fashion industry at an international and national level, and other economic activities that are growing around it. Net sales in 2016 were USD 2005 million and the expected daily visit of consumers was between 300,000 and 500,000 people [20]. The number of people could indicate a high density in the area, which generates threats, vulnerabilities, and scenarios of an adverse event or danger.

Disasters are a social construction, and the community resilience is a key factor to overcome adversity [21]. This paper is the basis for establishing future humanitarian logistics action plans, starting from establishing social commitments in schools, churches, warehouses, and government spaces to engage the most vulnerable zones in the study area.

28.2 Methodology

The methodology for analyzing the disaster risk index was determined considering the danger, exposure, and vulnerability.

The hazard was determined with the study of pedestrian mobility, to define the average speed at which a pedestrian moves and its disruptions. The velocities were recorded and in parallel, the disruptions and their types were recorded as well (these were determined by a previous observation).

The last mile study was used to evaluate the exposure. The first step was to delimit the km^2 of interest; the area selected as the object of study included 70 blocks limited by Av. México and Av. Isabel Católica to the south, Av. Aviación to the east, Av. 28 de Julio to the north and Jr. La Mar and Av. Parinacochas to the west; then, the data were collected through five forms: store inventory, roads and regulations, traffic counting, delivery follow-up, and traffic disruptions.

With the purpose of developing this work, different visits were made to public entities who are in charge of preventing and responding to disasters: Civil Defense (INDECI) and Risk Management of La Victoria City Hall, where it was possible to obtain the study on the state of Infrastructure in each block (Study of seismic vulnerability). In Table 28.1, the evaluation criteria of each block can be observed.

The exposure of people and infrastructure to a hazard means the level of vulnerability; this is why five variables cover three main aspects: the number of affected people, ease of escape, and the state of infrastructure (Table 28.2).

Table 28.1 Evaluation criteria for buildings per block of the MLV

Predominant Material	Quality of conservation	Antiquity From	Antiquity To	Floors From	Floors To	Vulnerability category	Level of vulnerability
Concrete	Very good	1	10	1	2	Low	1
Brick	Good	11	30	1	2	Medium	2
Brick	Regular	31	50	3	4	High	3
Brick	Regular	31	50	5	6	High	3
Brick	Regular	31	50	7	more	Very high	4
Adobe	Bad	31	50	1	2	Very high	4
Wood	Bad	51	more	1	2	Very high	4
Carboard/ Straw	Very bad	51	more	1	2	Very high	4

Source Study of seismic vulnerability of the City Hall of La Victoria

Table 28.2 Selected variables description

Variable	Description	Source	Associated concept
Pedestrian average speed	It allows to know the speed of a pedestrian in km/h when moving along the paths of each block	Pedestrian mobility	Hazard
Density per block	It allows to know the number of stores in an area of 100 m^2 inside a block.	Last mile: shop inventory	Exposure
Pedestrians per hour	It allows to know the average number of pedestrians walking through a block in the range of one hour	Last mile: traffic count	Exposure
Traffic signage and number of lanes	It allows to know if the block has traffic signals and how many lanes for cars exist	Last mile: roads and regulations	Exposure
Estate of constructions	It allows to know the infrastructure quality rating in each block	Seismic vulnerability MLV	Vulnerability

Source Own development

28.3 Results

Given the variables, each studio provides data that are qualified according to an established criterion (Table 28.3), resulting in a specific score that goes from 1 to 4. To obtain every block index, each variable result was weighted considering the same weight (20%).

Since the methodology is applied to Gamarra, a range of specific numerical data will be considered to qualify the results of each variable, and it will be able to interpret them in an appropriate way to the actual context. First, store density variable: the average area for a store in Gamarra is 20 m^2, according to the field collection category shop inventory from the last mile studio, it means that there should be five stores every 100 m^2 as the average amount. If there were more stores, then it is qualified with a lower score. Second, pedestrian per hour: as the results in a block are an average, the minimum and maximum data recorded were taken and divided into equitable quartiles. The more people transiting through the street, the less evaluation score it has as a consideration of possible affection if a disaster takes place. Third, traffic signage: a specific punctuation was given as the result of the combination of two relevant factors: the number of lanes in the street as a way of scape and if there is adequate traffic signage that leads transit. Fourth, pedestrian mobility: free transit speed is 4.6 km/h. To obtain the evaluation range, the minimum and maximum data recorded were taken and weighted in quartiles. Fifth, estate of constructions: The criteria of the City Hall of La Victoria were considered to evaluate the level of vulnerability based on predominant material, the quality of conservation, the age, and the number of floors in each block.

As an example of the calculation of the index, the result of each variable in block 50 can be shown as follows (see Table 28.4).

The 70 blocks have their results of variables as the example shows on Table 28.4; then we proceed to weight the results in a representative number to evaluate the risk in each block (Fig. 28.1). According to the result of the index of each block, it has been categorized into four levels of risk: optimal, adequate, precautionary, and inadequate.

The risk levels are fractions of the range constituted from the minimum to the maximum possible result of the index. The best possible rating is 4 and the worst possible 1. An equitable range was considered for each fraction, given the range of

Table 28.3 Evaluation criteria

Store Density		Pedestrian per Hour		Traffic signage		Pedestrian mobility		Estate of constructions	Category	Score
From	To	From	To	From	To	From	To	Level		
0	<5	0	<2000	>=300	∞	>=3.94	∞	1	Optimum	4
>=5	< 10	>=2000	<4000	>=200	<300	>=3.28	<3.94	2	Adequate	3
>=10	<15	>=4000	<6500	>=100	<200	>=2.62	<3.28	3	Caution	2
>=15	∞	>=6000	∞	0	<100	0	<2.62	4	Inadequate	1

Source Own development

Table 28.4 Variables results in block 50

Block ID	Store density	Pedestrians per hour	Traffic signage and number of lanes	Pedestrian mobility: average speed	Estate of constructions
50b	4.07	4128	171	2.37	4

Source Own development

Fig. 28.1 Map of results of the risk assessment index in each block *Source* Own development

values [6, 11]. There are three units available for four risk levels, that is, a higher risk level is considered every 0.75 units (3/4 = 0.75). The values of the upper limits of the division [1; 1.75; 2.5; 3.25; 4] are rounded (see Table 28.5).

Table 28.5 Levels of risk according to index results

Risk Level	Lower limit	Upper limit	Color
Optimum	> 3.3	<= 4	
Suitable	> 2.5	<= 3.3	
Caution	> 1.8	<= 2.5	
Inadequate	>= 1	<= 1.8	

Source Own development

The optimal level of risk means that at least two of the five variables obtained an optimum rating, and the rest are adequate as a minimum, that is, density levels of stores and pedestrians, signs, speed of people transiting, and the quality of infrastructure of the block are in an acceptable state before an adverse event. Blocks with this rating are located on the west side of km^2.

The blocks of the northeast and central east reached the precaution or inadequate level of risk and the blocks distributed from the south to the central part of km^2 have an adequate level of risk. This part of the studied area is considered as the center of the commercial emporium, characterized by its galleries, street trading, and a large number of people transiting.

According to the qualification criteria, in this zone, the blocks present a high level of store density, on average more than 10 stores per 100 m^2. This means a smaller size to transit than recommended for the customers and sellers' safety. Pedestrians walk at a speed less than 3.28 km/h, compared to the free transit speed of 4.6 km/h due to road disruptions.

In terms of infrastructure, the results suggest that there are no traffic signs, and the City Hall of La Victoria considered the buildings as highly vulnerable. According to the study of vulnerability, buildings are older than 30 years; they are in a regular state of conservation and have, at least, three floors or more on average.

28.4 Conclusions and Recommendations

The literature suggests that the current tools used to assess disaster risks are based on historical, socio-economic, demographic, institutional, and geographic information systems. However, logistical data have not been considered for that purpose. The population density, levels of commercial activity, and road infrastructure capacity are urban characteristics that have a higher impact on the logistics flow of a city and the studios selected. This study provides relevant variables to develop the risk assessment that serves to characterize the study area, in order to assess the level of risk associated with each block.

The main contribution of this research is the characterization of the studied area through the evaluation of risk level with logistic variables in each block in order to prevent disasters. With this methodology, it is possible to go from urban logistics to humanitarian logistics through an adequate evaluation of risk.

The results of the procedure confirm that Gamarra is an area of great population density, covering up to 24 times more the number of establishments in a square kilometer (km^2) than in other city halls such as Jesús María, Lince, or La Molina. The area presents a high level of danger due to the reduced space they have for pedestrians to transit on, less than recommended for the safety of customers and vendors. In addition, there is evidence of absence of traffic signs and a high density of stores and pedestrians, which means a high level of exposure; also, the City Hall of La Victoria considered the infrastructure of the area as highly vulnerable. Therefore, the risk of danger in the area is high and it is advisable to take measures to increase the safety of pedestrians passing through the area.

For recommendations on public policies, it is important to mention the context of the studied area and the authorities that govern it. However, there was also a lack of relevant additional studies and execution of projects related to risk prevention and communication to the population. In this sense, it is recommended to consider the logistic data collected in this work to know the urban behavior of the area and to identify the main difficulties. According to the results, the most relevant variable is the speed of a pedestrian in an area with disruptions. This represents a challenge for the authorities in this high-density area with a high-potential human loss.

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Chapter 29
Crisis Management Assumptions and Manager Resilience

Paulo Yazigi Sabbag

Abstract Assumptions associated with the concept of a crisis and crisis management reveal the fact that managing crises is broader than managing risks. Emotions count. The resilience style of crisis managers provides inferences for redefining the phases of crisis management: prevention, de-escalation, intervention, and recovery.

Keywords Crisis · Risk · Resilience · Scale

29.1 Introduction

The variety of crisis situations in society, organizations, and individuals obscures the concept of a crisis and therefore affects the structure and practices of crisis management. The problem examined here is how the structuring of phases affects the performance of crisis management.

First, the concept of a crisis is disputed. Since resilience refers to the capacity to bounce back from great adversity, it is both a relevant and respected factor in this context. A cluster analysis is presented here derived from the Brazilian ERS scale for resilience in adults. Discussing the assumptions inherent in the concept of a crisis and crisis management enables us to infer the best structuring of the phases of crisis management through a discussion of the impacts of the practices associated with them.

29.2 Theoretical Domain

Crises exist in political and social environments as well as organizational, medical, and psychological environments. This concept has been used for millennia all over the world. Given that it has such breadth, variety and a wealth of applications, different

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contemporary definitions of a crisis coexist. Most of the scientific literature does not even define a crisis, which further expands the variety of applications of this concept.

In ancient Greek, *krisis* signified *a decision or decisive point* in the progression of diseases as well as *a turning point*, Wiktionary informs us (https://en.wiktionary.org/wiki/crisis, accessed on September 2, 2018). Other meanings: *an abrupt change* in a military context; *an unstable situation* requiring a decision in medicine; *a traumatic change* in psychology; and *a peak of conflict* in the theater. This same dictionary explains the graphic for the term *crisis* in Chinese: In terms of *kanji*, it is made up of two ideograms: *wei–danger* and *ji–crucial point*, a point at which something happens, erroneously defined as an *opportunity*. In both Greek and Chinese, crisis refers to a *decisive point of change*.

Roux-Dufort [18] warns: If a crisis were an event, facing crises would be the "management of exceptions." This author supports the notion that a crisis is a process that begins well before an event, which passes through various stages and provokes change even after the crisis has ended. He warns of disruptive crises, situations whose onset results in change, which justifies the notion of a "turning point."

Kouzmin [6] suggests three conditions which are present in crises: "a severe threat, a high degree of uncertainty, and the need for prompt, yet critical and potentially irreversible decisions." He also relates crisis management to resilience when he states that "in crisis situations, organizations will attempt to learn and adjust to return to the 'original' state of operations" (op. cit., p. 155).

Among the types of crises, the seminal classification of Lerbinger [7] is adapted here and updated to the present time:

- Natural disasters or "acts of God": earthquakes, tsunamis, hurricanes, volcanic eruptions, storms, and floods;
- Emergencies: accidents; fires, explosions, catastrophes, and civil defense cases;
- Force majeure: wars, strikes, slowdowns, vandalism, union lawsuits, and market crashes;
- Technological crises: human, operational and technological failure; cybercrimes; work accidents with victims; unforeseen interference; collapse and structural fatigue; and contamination and environmental disasters;
- Crimes: adulteration of products; leaking of confidential information; violation of digital systems; social and work violence, coercion, kidnapping; and terrorism;
- Social incidents: confrontation, slander, rumors, fake news, consumer rights, defects and recalls, lethal epidemics, discrimination, harassment, and prejudice;
- Economic and managerial crises: hostile takeovers, changing business leaders, financial collapse, errors in business decisions, management conflicts, "white-collar" crimes, ethical violations, mass layoffs, and brand adulteration;
- Existential crises: burnout; psychological disturbances; and critical illnesses.

Waller et al. [22] define an organizational crisis as "a low-probability, high impact event that threatens the viability of the organization and is characterized by ambiguity of cause, effect, and means of resolution as well as by a belief that decisions must be made swiftly." The authors state that "most crisis situations are emotional events that can dramatically affect team cognition, communication and coordination efforts," and adopt five phases for managing crises: signal detection, preparation/prevention, containing/damage control, business recovery, and learning, as Mitroff [11, 12] poses.

Resilience is the capacity to face great adversity [14]. It is the capacity to recover (its etymological root in Latin is *resilio*, which means "to go back" or metaphorically recover) and in certain cases the capacity to overcome. A working definition of resilience is "individual or organizational sources of strength that make it possible to face and even learn from adversity and challenges" [19].

The meaning of resilience demonstrates its affinity with crisis management: Managing crises is making decisions and driving change to overcome and recover. However, few authors associate these two concepts. In 2008, the World Economic Forum published a report entitled "Building Resilience to Natural Disasters: A Framework for Private Sector Engagement" in which the concept of resilience appears just as a footnote, and the resilience of individuals in relation to disasters is not even mentioned [25].

29.3 Discussion

Analyzing the classification of crises presented above, it may be noted that those involved in managing them may identify them as risks and therefore practice risk management. If the sources of risks and crises are the same, what distinguishes them? It is erroneous to assume that crises have a greater impact than risks: There are catastrophic risks and crises that pass quickly. We may observe that crises are characterized by unstable situations, abrupt evolution and growing impacts which can affect the emotions of those affected. A crisis is defined when there is a feeling of a loss of control and an urgency to act. If every crisis involves heightened emotions and biases in terms of perception, the resilience of the affected individuals should always be considered.

We need to examine some assumptions that have become common wisdom regarding crises, to better manage and later create a working definition of crises.

Crises can be chronic and recurrent is a common belief. In medicine, a critical state is associated with an acute and not a chronic situation. It is possible that crisis intervention continues over a period, making it seem chronic, even though it is not. Crises are always acute, due to the rapid acceleration of events, but they can be recurrent. For example, if the fundamentals of an economy are not good, economic crises can occur one after another.

Crises involve threats and opportunities is another common piece of wisdom. Crises threaten societies, organizations, and individuals. However, they are accelerated events that dictate points of change, and they create an urgent need to make decisions and confront the situation. Depending on the way in which a crisis is faced, the change caused by the crisis can become an opportunity. Studying the crisis caused by Katrina in the USA, Waters reveals that "some women experienced the hurricane as a positive force, leading them to break the hold of friends and family interfering with their education and social mobility" [24, p. 758].

Crises are unpredictable, undetectable, sudden, and accidental is another commonly held belief. Within the classification above, there are various examples of accidental, fortuitous crises or acts of God or force majeure. In these instances, crises are difficult to detect, which is why the acceleration of events appears to be so "sudden." However, considering crises to be unpredictable incites an attitude that disdains any steps to prevent crises which would be negligent.

Crises only involve objective issues is a piece of common wisdom in the technical sphere. We cannot limit ourselves to objectivity when we are dealing with crises whose evolution and impacts are imponderable. In fact, rationality is limited before and during a crisis. In crisis management, one must consider the subjectivity of perceptions and emotional impacts caused by those who are involved and affected. For example, any crisis is acute when a loss of confidence takes place. Inflated and contagious emotions [9] dictate whether the occurrence of risk will end up turning into a crisis.

In managing crises, managing risk is enough. The management of risks makes it possible to identify the sources of a crisis, even when they are improbable, and makes it possible to evaluate its probability, impact, and difficulty of detection, which will enable the creation of anticipated and contingency responses [15]. However, risk management rarely affects the emotional and psychosocial conditions of those affected, which is where crisis management gains another dimension and roles.

Crises strengthen individuals, organizations, and societies. This common belief is much more "wishful thinking" than a frequent outcome. It has to do with resilience: Only those with high resilience can face crises in a functional manner and by thriving from them [19].

Based on this reflection on assumptions, the following working definition may be adopted: "a crisis is an accelerated sequence of events which causes a loss of control, heightened emotions and the perception of growing undesirable consequences." This definition is broad enough for societal, organizational, and individual crises as well as similar practices in all fields of application. With this definition, we can infer that the resilience of individuals and organizations is the key issue in terms of the effectiveness of crisis management.

The ERS scale for resilience in adults has been validated by using the item response theory [20]. Ranging from a score of 1–100, it classifies individuals as having high, medium, or low resilience. After its validation, the same sample of 1503 observations was used for exploratory factor analysis, which revealed nine factors that make up resilience along with their respective sub-scores. Table 29.1 contrasts individuals with elevated and reduced resilience for each of the nine factors, in terms of scale questions.

Cluster analysis was performed on the same sample. It is a descriptive statistical technique used to identify groups among similar individuals [17]. It may be used to identify groups of individuals with similar styles of resilience, which may be useful in interpreting a sample's means and standard deviations, which is why it is often used in marketing [16]. The problem with this technique is that there it has neither consistent guides nor established techniques. The present study uses the K-means

Table 29.1 Behavior associated with the extremes of high and low resilience in individuals

High resilience	Factor	Low resilience
Believe that they control their lives and have trust in their abilities; focused	Self-efficacy/self-belief	Insecure; belief in destiny; low self-esteem; and need for self-affirmation
Practical and resolute; have the capacity to experiment	Problem solving	Get tangled in problems; tend to remain paralyzed
Reasonable emotions, without extremes; remain calm and serene	Temperance	Unstable, avoid change, revolt against situations, extreme reactions
Accept themselves and others; have compassion for those affected	Empathy	Intolerant; prejudiced, insensitive
Likely to act; guided by purpose; existential courage	Proactiveness	Reactive, not protagonists, difficulty in dealing with failure
Seek support and help, present emotional and social intelligence	Social skills	Remain isolated, feel humiliated in asking for help, lack the ability to adapt
Persevere, can stand difficult conditions for long periods of time, determined	Tenacity	Give up easily, tend to view themselves as victims
Hopeful, even in difficult times, positive	Learned optimism	Skeptical, unbelieving, negative thoughts, and emotions dominate
Open minded, switch tactics until they work	Mental flexibility	Stubbornly insist on tactics that do not work, stubborn

technique, which makes it possible to form four groups, whose average scores are presented in Table 29.2.

Interpreting Table 29.2, note that the factors are presented in decreasing order of their weights in composing the overall resilience score. Cluster A consists of individuals with elevated resilience: the overall average score is 81.9, which is greater than the score of 77 adopted to classify those with elevated resilience, and all the sub-scores are greater than the sample averages. Cluster D consists of individuals with reduced resilience: The overall average is 59.1 which is less than 66, the minimum score adopted to represent modified resilience; all the sub-scores are less than the sample averages.

The problem with cluster analysis's use of averages is that an individual in Cluster D does not always have a score of less than 66: There are cases of individuals with moderate resilience, but which are in Cluster D and so on for the other clusters—which are due to the long tail of the frequency histogram. However, since the clusters define different styles of resilience, they make it easier to interpret styles in the face of crises.

A surprise occurred in interpreting Clusters B and C, both with overall average scores classified as moderate resilience. The inference arose when analyzing the demographic data presented in Table 29.3. The differences are in gender and educa-

Table 29.2 Cluster analysis of the ERS scale for resilience in individuals

Cluster	Total	A	B	C	D
	Avg	Avg	Avg	Avg	Avg
Observations	**1503**	**495**	**389**	**371**	**248**
F1_WEIGHT—self-efficacy and self-confidence	70.9	77.2	70.0	72.8	57.0
F2_WEIGHT—problem solving	76.9	89.5	*80.7*	66.6	61.4
F3_WEIGHT—temperance	63.7	79.5	*70.4*	49.1	43.8
F4_WEIGHT—empathy	70.6	80.9	54.7	*80.1*	60.9
F5_WEIGHT—proactiveness	75.6	85.1	69.0	*79.8*	60.7
F6_WEIGHT—social skills	80.0	87.6	71.4	*85.0*	71.1
F7_WEIGHT—tenacity	75.5	82.8	68.8	*80.7*	63.7
F8_WEIGHT—learned optimism	81.3	90.6	76.8	83.3	67.0
F9_WEIGHT—mental flexibility	58.4	63.8	56.0	60.1	48.5
Overall resilience score	**72.5**	**81.9**	**69.0**	**72.7**	**59.1**
Standard deviation	9.23	4.55	4.53	4.43	6.07

Table 29.3 Demographic factors in relative clusters for the ERS scale

Cluster		Total (%)	A (%)	B (%)	C (%)	D (%)
Q4—education	Total	100.0	100.0	100.0	100.0	100.0
	Exact sciences	23.7	25.3	30.9	18.0	17.8
	Human sciences	17.4	18.9	11.9	19.7	19.4
	Biological sciences	8.2	5.3	8.8	9.8	10.9
	Social sciences	48.9	48.5	46.9	50.8	50.2
	Arts	1.7	2.0	1.5	1.6	1.6
Q5—sex	Total	100.0	100.0	100.0	100.0	100.0
	Female	51.7	46.7	43.2	62.9	58.3
	Male	48.3	53.3	56.8	37.1	41.7

tion. Cluster C is 62.9% female and has more individuals who have studied human sciences and fewer who have studied exact sciences than the other clusters. Cluster B is 56.8% male with a higher proportion of individuals who have studied exact sciences than the other clusters.

Comparing the Cluster B and C sub-scores relative to the overall average, the difference is notable. Cluster B has higher sub-scores (in italics in Table 29.2) in *Problem Solving* and *Temperance* (factors which have a low average in Cluster C)—which represents the technical profile, or shall we say "male" archetype in the style of moderate resilience. Cluster C, somewhat more functional than B, presents higher sub-scores in *empathy*, *proactiveness*, *social skills*, and *tenacity* (factors which have a low average in Cluster B)—which represents a more human profile, or shall we say "female" archetype in the style of moderate resilience.

If crises represent the intensification of the occurrence of risks, resilience, for both those involved in crisis management as well as those affected by (or perceived to be affected) by the crisis, influence these processes. The working definition adopted here for crisis management is "coping with situations perceived to be crises or critical, by mitigating damage and optimizing the recovery of individuals, organizations, society and the environment."

There are two hidden assumptions here: first, the difficulty of detecting when an occurrence of risk will turn into a crisis; second, the difficulty in defining when crisis management ends. To detect the onset of crises, the solution is to evaluate their emotional impact on those affected, and this is associated with temperance and therefore resilience. To determine when crisis management ends, it needs to evaluate the duration of post-crisis actions to support the affected, which also depends on their degree of resilience.

The redefinition of a crisis and crisis management has an important consequence: The definition of the phases involved in crisis management. Fink [2] borrows terms from medicine to design four phases of crisis management: the prodromal phase (a group of non-specific symptoms), the acute phase, the chronic phase, and the crisis resolution phase.

The preparation to face crises is "prevention," the first phase of the process. Many authors disdain the de-escalation phase, which is necessary to reduce negative emotions and make it possible to retake control of the situation; this deceleration is the second phase. As soon as possible, we proceed to the "intervention" stage to mitigate damage and engineer the recovery of the organizations involved. The overcoming of the crisis and the return to relatively normal operations does not end the work of those involved in crisis management: The post-crisis "recovery" phase is essential given the need to recover and even increase the resilience of those affected by the crisis.

Since we do not know beforehand how a crisis will grow and what its impacts will be, the prevention phase is designed to optimize the resilience of individuals, organizations, and environments. It is essential to practice risk management during this phase [15]. Gowan et al. [3] suggest the evaluation of organizational resilience—and also the individual's resilience. Norms and procedures must be created, and people need to be trained in the systems that go into action when a crisis develops, educating the people who will be involved (as occurs with a fire brigade). The focus should be on management and above all communication systems: WEF [25] recommends diversifying channels of communication. Proximity and good relationships between communities are also essential, according to Hale et al. [4]. Media training to leaders is also as important as establishing the function of spokesperson for institutional communication. Various plans make up this phase: damage containment, business recovery, crisis governance, and the crisis learning mechanism (suggested by [12]). Much emphasis is attributed to sign detection systems, including human sensors and the diversification of the technologies used [12, 25]. To Mitroff and Linstone [13], the support of an outside consulting firm is necessary. The WEF [25] suggests the creation of new insurance products to prevent the financial impacts of crises.

After perceiving that risk has become a crisis, the de-escalation phase seeks to decelerate its speed and retake control of the situation. The governance of crises requires a readiness to put risk contingency plans into action [15]. A crisis committee, a war room and a central command for operations are all recommended. Care should be taken given the usual biases in terms of decision making in the face of risk and to avoid groupthink [5, 6]. All the plans produced previously can guide the course of action. Mitroff [12] recommends conflict management, usual among stakeholders during this phase. One cannot give equal attention to all stakeholders, and it is necessary to select those considered critical and develop specific strategies for them. Fink [2] points out the need to isolate the crisis, avoiding contagion. Since the escalation of a crisis leads to heightened emotions, transparency and abundant communication will avoid a loss of confidence. Sapriel [21] recommends reputation management, while Fink [2] talks about how to the handle hostile press. All emergency measures occur during this phase.

Retaking control of the situation is initiated during the intervention phase of the crisis, whose focus is reducing damage to the environment, society, organizations, and individuals. This phase concludes when the governance that existed before the crisis is reestablished. Mitroff and Linstone [13] suggest avoiding attributing blame because this is a proactive stage. Hale et al. [4] suggest that this is the time to reactivate systems of institutional communication, public relations, and internal communications. Since this is a more laborious phase, it usually involves a greater number of organizations and people. WEF [25] recommends involving the community in the effort to face the crisis, which would occur during this phase. It also suggests that the business should channel its input into national disaster platforms and strategies linked to a high-level government process or office when the crisis affects the environment and society.

The final recovery phase seeks to increase the resilience of the individuals and organizations affected as well as society. Echterling [1] recommends collecting statements and constructing narratives, among other techniques, to collect the lessons learned. According to Mitroff [12], this phase should be dedicated to reexamining systems and processes, including making crisis audits. The fundamental point during this phase is offering psychological support for those who could develop PTSD—post-traumatic stress disorder [8, 10, 23, 26]. In addition to these recommendations, this is fertile ground for making an educational effort to increase the resilience of those affected because it will reduce their vulnerability and accelerate their recuperation.

29.4 Conclusion

The styles of resilience make it possible to infer their capacities as crisis managers. The prevention phase requires people who for the most part have elevated or moderate resilience (Clusters A, B, or C). Do not exclude those with reduced resilience (Cluster D): The prevention of crises is an exercise in improving self-efficacy, resoluteness, and proactiveness. Mixing these styles reduces the probability of planning preventive measures only from the point of view of someone with elevated resilience.

The better the prevention efforts, the more effective the operation will be in ending a crisis. Fear will harm this process, affecting above all those with reduced resilience. Those with elevated resilience (Cluster A) may commit acts of heroism (through an excess of self-confidence) which may lead to greater damage and more victims. This justifies the need for a centralized command of operations for isolating and ending a crisis. Temperance, resoluteness, and proactiveness during this phase are all essential, which thus confirms the importance of leaders from Clusters A and B.

The intervention phase of a crisis is the one in which technical knowledge, organization, and methodical work are required. Seeking to find individuals to blame, however, lowers the resilience of many of those involved, harms relationships, and creates a commotion along with secondary risks. Regarding resilience, learned optimism, mental flexibility, and tenacity are desirable qualities for leaders during this process (Clusters A and C).

During the recovery phase, empathy, social skills, and mental flexibility are indispensable. There needs to be a clear separation between those who re-examine and improve processes from those who provide support to those affected—these are almost opposite skills: the technical side and the human side. However, the focus should be on the resilience of those affected. Those with reduced resilience require support and time to recover. It is common for many of them to seek substances that will diminish their consciousness (alcohol and drugs) to ease their suffering. Others will make hasty and radical decisions. Others may develop grave illnesses. Those with moderate resilience tend to recover over a reasonable period. As changes occur, they will tend to display less resistance to their implementation. Those with elevated resilience, if properly mapped, tend to become agents of change. Therefore, all this stimulus is valuable: They recover their optimism, and they are protagonists and opinion makers. Thus, the resilience of individuals occupies a central role in terms of crisis management.

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Chapter 30
Brazilian Navy Operations in Response to Two Disasters in Haiti: A Comparative Case Study

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Abstract This research aims to analyze comparatively the responses to the earthquake (2010) and the hurricane Mathew (2016) occurred in Haiti according to the perspective of the Brazilian Navy operations. The results reveal an improvement in the hurricane response that can be associated with preventive and planned collaborative strategies.

Keywords Case study · Disaster response · Haiti

30.1 Introduction

A disaster can be defined as a severe disruption of the functioning of a community or society at any scale due to critical events that result in conditions of exposure, vulnerability, and incapacity, leading to human, material, economic, and social losses and impacts [24]. For Altay and Green [3], the management of disaster can be divided into the following phases: mitigation, preparation, response, and reconstruction. Among them, the response stands out in the research because it is the most dependent on logistics and support in the supply chain [2]. In this phase, one of the main challenges is the coordination between different actors [18]. Leiras et al. [19] also report that the large number and diversity of stakeholders with different organizational cultures and structures make it difficult to reach a productive relationship between them; they also highlighted the need for research on interactions between stakeholders in disaster and humanitarian operations (DHO) considering their perspectives and the need for more applied research.

Based on a systematic literature review of Humanitarian Supply Chain Management papers up to 2017, Behl and Dutta [5] observe some research gaps regarding

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methods and topics. Among them, the authors mentioned the need of empirical validation of theories, including longitudinal data and analysis of the stakeholder's needs and their degree of preparedness so that they achieve better collaborations and partnerships [5].

The present work brings a Stakeholder Theory embedded approach to comparatively analyze the responses to the earthquake disaster (2010) and the disaster with Hurricane Matthew (2016), both occurring in Haiti, according to the perspective of the Brazilian Navy—which address the research gaps raised by Behl and Dutta [5]. Concerning Stakeholder Theory, several authors discuss the relevance of the military for the disaster response operations. Auerbach et al. [1], for example, address the civil–military collaboration during the earthquake response to the success of medical operations. Cardoso et al. [7] also report military actions in response to the hurricane in their research on military support of the Brazilian Navy (BN) provided to the United Nations during the operations. Moreover, the collaboration of the military with other stakeholders is of paramount importance in maintaining disaster response operations and serving the beneficiaries, since the military provides security, transportation, logistics, emergency supplies, among others, having extensive involvement during humanitarian aid [8].

Besides the empirical validation, the selected case study considers longitudinal data of two remarkable disasters. The first struck Haiti in 2010, an earthquake that generated an extremely high number of victims (2.8 million people affected, 222,570 deaths and 300,572 injured), damage (more than 97,000 homes destroyed and other 188,000 damaged) [9], involvement of several stakeholders from various countries (2000 organizations and agencies operating in Haiti) [4], making it the most significant global humanitarian response. By 2016, the country was still vulnerable when it was hit by the Hurricane Matthew, causing massive flooding, landslides, and destruction of a large amount of infrastructure and victims (about 1.4 million people in need of immediate humanitarian assistance, 546 deaths and more than 175,500 people in shelters) [27]. Therefore, such comparison allows cross-analysis of the cases, identifying similarities and differences between the sources of evidence, which also contributes to addressing the research gaps noted by Behl and Dutta [5].

After this introduction, the paper presents the theoretical reference for the research. Section 30.3 addresses the methodology considered. Next, Sect. 30.4 discusses the comparative analysis of the two disasters that affected Haiti. Last, we present the research conclusions.

30.2 Theoretical Reference

The Stakeholder Theory proposed by Freeman [13] defines stakeholders as "all groups or individuals that affect or are affected by the business" and considers the relationships among the stakeholders as the central object concerning dyadic connections. Besides the direct interactions, there are other complex relationships cited by other authors [14, 23] and less simplistic definitions in which the concept of stakeholder and their relationships expands the opportunity to understand the organizational problems and overcome them through integration and responsibility for each decision-making. This theory has a significant influence on organizational performance management, with some frameworks developed considering the characteristics of all stakeholders involved in a specific organization. Lima et al. [20] explain that the frameworks for performance management have emerged along the years, aggregating new perspectives, and the Performance Prism developed by Neely et al. [21] is the most recent among the existing frameworks. This framework is structured by the identification of stakeholders, their wants and needs, strategy, processes, and capabilities, which are still challenging elements faced in the disaster response.

Inspired by the work of Neely et al. [22], Fontainha [11, 12] developed an integrated framework to discuss the strategy of collaborations in the disaster response, illustrated in Fig. 30.1. This framework addresses four dimensions: identification of the stakeholders, their wants and needs, the processes to be executed by them in response to disasters, and collaborative strategies for inter-organizational interactions. The dimension of collaborative strategies is the central focus in the framework while the other three mentioned dimensions support this discussion.

In the stakeholder dimension, the framework identifies the stakeholders. Some works describe the stakeholders in the academic literature, for example, the one by Kovács and Spens [18] that defines seven different actors. More recently, Fontainha et al. [10] developed a systematic literature review and identified 10 main stakeholders in DHO divided into three groups: public (legislative and regulatory, government, and military), private (media, direct supplier, and private sector) and people (international aid network, national aid network, and donor), in which the beneficiary is the primary stakeholder, detached from the others.

Fig. 30.1 The integrated framework for collaborative strategy in disaster response. *Source* Based on Fontainha [11, 12]

Regarding the wants and needs dimension, the framework discusses what is satisfaction for the stakeholders in complex relationships and whether or not the stakeholder's wants and needs are met. In terms of the military perspective, there is a discussion of recognition of the military's understanding of disasters and operational knowledge by other stakeholders [15] and the need for broadcasting news about the disaster by the media in order to have professional volunteers (local aid network) available to integrate the missions [16].

Regarding the process dimension, the framework discusses the activities that should be performed in the disaster response. The works of Blecken [6] and Fontainha et al. [11, 12] are the main contributions observed in the academic literature to this dimension. While Blecken [6] developed a reference task model addressing logistic activities performed by international humanitarian organizations, Fontainha et al. [11, 12] developed a reference process model compound of nine macroprocesses defined as a result of a systematic literature review, described as follows: "recognition of the occurrence of disaster," "assessment of the current situation," "search and rescue," "(R)establishing infrastructure in the response," "Resource request for the response," "Resource transport during the response," "Services to the population," "Demobilization of the operations," and "Response support operations."

Concerning the strategy dimension, the framework discusses the seven elements of the collaboration strategy identified by Jahre [17] in her systematic literature review (i.e., coordination; suppliers' relation; commercial–humanitarian cooperation; collaborative procurement; civil–military coordination; adaptability; and orchestrating networks).

Regarding the interaction among the dimensions, Fontainha [11, 12] explains that the combination of the stakeholder and the wants and need dimensions allows the identification of which needs must be met according to the identification of which stakeholders are involved in the disaster response. The combination of the wants and needs and the process dimensions allows a more objective understanding of stakeholders' wants and needs in the planning of disaster response operations according to a process perspective. The combination of the stakeholder and the process dimension allows the identification of which stakeholders are involved in each disaster response process. All of these dimensions and discussions are subsidiary in the debate of which and how the collaborative strategies are implemented in the disaster response.

30.3 Research Methodology

Due to the characteristics of the situation in Haiti, the research applies the case study as the method to compare the disaster response by the Brazilian Navy (BN). Voss et al. [25] define a case study as a unit of analysis where it is possible to study the same problem in different contexts of the same organization. Yin [26] reports that there are six steps to conduct the case study: plan, project, preparation, data collection, data analysis, and reporting. Section 30.1 describes the first step (plan) for the research indicating the adherence of the situation in Haiti and the case study.

The project stage composes the logic that connects the data collected and the research questions, as well as the discussion for single or multiple cases [26]. This work has a single-case study project, having the Brazilian Navy as a unit of analysis acting in the responses of two disasters in different contexts occurred in Haiti. In the preparation stage, the research encompasses the questions to gather empirical data to contrast with the findings discussed in the four dimensions of the framework for collaborative strategies (stakeholders, satisfaction, processes, and strategies).

The sources of evidence from this research are reports and interviews. Regarding the reports, the study considered four mission reports of the Marine Corps (MC) operations for the earthquake and seven reports for the Hurricane Matthew. Regarding the interviews, the analysis considered five semi-structured interviews with two interviewees effectively involved in the earthquake response and the other three involved in response to the hurricane disaster. These professionals occupied the following positions: Commander of the Operational Group of Marine Corps; Officer of Command and Control and Officer of Social Communication; Immediate of the Combat Services Support Component; and Commander of the Logistic Detachment. Voss et al. [25] highlight that in the data collection stage, there is the principle of triangulation, which consists in the use and combination of multiple sources of evidence, hence increasing the reliability of the data—which is the combination of the data gathered from the reports and the semi-structured interviews.

The data analysis applies the pattern matching technique, in which a fundamentally empirical standard is compared to the theoretical standard [26]. Therefore, an inter-case analysis was performed to analyze all the data together and compare them. Data frames were also elaborated for each dimension addressed in the framework, which contains a summary of information that confirms, complements, or contrasts the literature, resulting from each interview and verification of documents, allowing the triangulation of data. The last step, which consists of the reporting, is given in the full text of this paper.

30.4 Comparative Analysis of the Military's Response to Disasters in Haiti

Regarding the stakeholders observed in response to the earthquake and Hurricane Matthew, there is a slight evolution in the comparative analysis. In both disasters, there was no legislative and regulatory identification, which corroborates with the literature that indicates that such stakeholder could be discarded in the context of an underdeveloped country due to lack of financial stability to establish legislation about disaster response programs [10]. In contrast to the earthquake, the BN reported the interaction with the direct supplier in response to the hurricane, which benefits the BN operational capacity, and can be associated with improvements in the operation from 2010 to 2016. Besides, the BN had a weak interaction with the private sector, evidencing an opportunity for greater exploitation concerning this relationship. Also, despite the significant involvement of donors with other stakeholders (e.g., the international aid network, government, and beneficiaries), the BN did not interact with donors in either both disasters. To summarize, in terms of stakeholder dimension in the earthquake's response, the interaction of the military occurred with six other stakeholders: government, local aid network, international aid network, private sector, media, and beneficiary, while in the hurricane, the military interacted with all those mentioned in the earthquake and with direct supplier, additionally.

In the wants and needs dimension, regarding the BN, in both disasters, the interviewees considered that overall stakeholders recognized the military's understanding of disasters and operational knowledge, which reinforces the perspective pointed by Hall [15]. In the earthquake, the military did not use the media to mobilize professional volunteers to integrate the missions, contradicting the perception of complex relationship involving the military as pointed by Heyman et al. [16], but rather to communicate the progress of operations. On the other hand, in the hurricane, it was observed the attendance of the needs regarding the use of the Media to mobilize the local network and volunteers. Another perceived difference is the contribution of the interviewees in identifying additional needs not mentioned in the literature. Whereas in the case of the earthquake the interviewees did not identify additional needs, in the case of the hurricane the interviewees cited the need for coordination and greater communication between stakeholders. Regarding the satisfaction of other stakeholders on the topic of the performance of the military, in both disasters, the interviewees are unanimous in confirming the fulfillment of their wants and needs through the operational support of the BN.

Regarding the process dimension, in both disasters, the military executed all level 1 processes, but there is a difference in level 1 processes with more or less emphasis, that is, where the military acted more effectively or not. While in response to the earthquake, the processes with greater focus were "recognition of the occurrence of disaster," "assessment of the current situation, "search and rescue," and "demobilization of response," in the response of the hurricane, in addition to those already mentioned, processes had an overwhelming military involvement: "transport of resources during response" and "response support operations". Moreover, in response to the hurricane, the BN performed fewer macroprocesses than in response to the earthquake. One of the factors reported by the BN that could actively explain this difference is that the earthquake is an unpredictable disaster, and the hurricane is a predicted disaster; hence, lots of the processes performed in response to the hurricane had been planned. This decrease in macroprocesses performed in 2016 compared to 2010 does not show an involution of this dimension and may even characterize better planning and organization in response, as well as learning from previous experiences or more integration of stakeholders.

Toward the central dimension of the framework, the collaboration strategies in both moments remained practically the same, except by the inclusion of the relationship with suppliers in 2016. In summary, in the earthquake's response, four collaboration strategies were identified: coordination (by command and by standard), civil–military coordination, orchestral networks, and adaptability, while in the hurricane's response it was additionally perceived the suppliers' relation strategy. Furthermore, the military's strategic role in the earthquake had more reactive characteristics without anticipation in extreme situations, as opposed to the response to the hurricane that presented a higher capacity for planning and anticipation.

Regarding the integrated framework, the analysis reveals that in the integration between the dimensions "stakeholders" and "wants and needs" the BN had a strong degree of interaction with the international aid network, government, and beneficiary in the earthquake response. In the hurricane response, besides these three stakeholders mentioned in the previous disaster response, the BN also had a strong degree of intensity in the interaction with media and local aid network. Concerning the government, there is an increase in the perception of the interaction with the BN in 2016, which may suggest a greater political structuring over the years in the country. Also, the direct supplier in the hurricane appears with a considerable increase in the interaction level with the BN, as well as the local aid network also presented strong interaction with BN. In the hurricane, there was also a slight increase in BN interactions with the media, the private sector, and the international relief network, showing that it had a greater interaction with these stakeholders in response to the hurricane than in the earthquake. The analysis of the integration between the dimensions "processes" and "wants and needs," in both disasters, reveals that the BN considered the wants and needs of the stakeholders in the execution of the processes. Regarding the analysis of the combined dimensions of "stakeholders" and "processes," in most of the processes, there was involvement of the government, beneficiary, and international aid network in both disasters. Regarding the dimension of collaborative strategies, they remained practically the same in the two moments, with the addition of the relationship with suppliers in 2016.

It is noteworthy that the military has internal doctrines that support disaster response planning. One of the doctrines reported by the interviewees is the interagency approach, which is considered an effective strategy for achieving collaboration with other stakeholders. One of the significant differences between the two disasters is related to the non-predictability of the earthquake in 2010 in contrast to the predictability of the Hurricane Matthew in 2016. Thus, the strategies in response to the hurricane were focused on planning while in response to the earthquake were reactive. That focus justifies the observations of the collaborative strategy involving the "supplier's relation" in BN operations in the hurricane response and not in the earthquake response, mostly because this strategy is based on pre-positioning resources, for example, something decided at the planning stage. Hence, the findings suggest that, despite the different characteristics of the disasters, the response to the hurricane was better than the response to the earthquake, precisely because of the higher intensity in the interactions with other stakeholders, which resulted in more needs met within the disaster response processes.

30.5 Conclusions

The present research applied the framework developed by Fontainha [11, 12] based on the Stakeholder Theory to comparatively analyze the responses to the disasters of the earthquake (2010) and Hurricane Mathew (2016) occurred in Haiti according to the perspective of Brazilian Navy. The research provided academic and managerial contributions. In the first perspective, this research contributed to filling a gap in the literature on the interactions among stakeholders in DHO, as the case study confirms and contrast some insights discussed in theory. In the managerial aspect, the BN and the military in general could rely on this research to promote improvements in its operations, since the integrated framework allows the exploitation of how to plan and perform collaborative strategies, revealing which stakeholders depends on the BN and the military and how their wants and needs are associated with the disaster response processes. Additionally, different stakeholders could use the results of this study to pursue learning and collaboration with the military, and also discuss the framework proposed by Fontainha [11, 12] according to their perspectives. Thus, it is suggested as future research the inclusion of perspective from other stakeholders engaged in both disaster responses towards the verification of whether the different aspects resemble, complement, or contradict the findings discussed in the present work that focused solely on the BN perspective.

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Chapter 31
Simulation and Analysis of Different Designs of Escape Areas with the Insertion of Obstacles

Manuela Marques Lalane Nappi, Ivana Righetto Moser and João Carlos Souza

Abstract Starting from Social Forces models, the homogenization of variables and fixed parameters, different architectural solutions were simulated and compared for emergency emptying of areas with large public. The results show that small adjustments in the input data generate divergent responses, indicating that the effectiveness of evacuations depends on multiple variables.

Keywords Evacuation · Social force model · Design solutions

31.1 Introduction

Collective phenomena observed in pedestrian crowds have attracted the interest of a growing number of scientists [10], making that disasters involving crowds come out as an important research area, along with the simulation of pedestrian flows. These disasters are triggered, especially when observed crowd stampede, creating situations where the risk of death is established, as pointed out by Shukla [18]. For the author, the architectural design of the spaces exerts great influence in the processes of evacuation. At the same way, Illera et al. [12] emphasize that the increasing number of disasters reported in large mass events raises the question of preventive measures related to the project, pointing out the need to rethink security concepts to include new ways of optimizing buildings and sites for large events.

It is fact, according to Illera et al. [12], that evacuation planning is not yet a well-established field of research in architecture. However, since panic and stress occur in built spaces, a natural field of action for architects, the authors discuss the responsibility of these professionals to consider the results of simulations in the design process, making the building safer. In this sense, knowing the main factors that cause disasters in crowds, it is relevant to the understanding of how facilities for pedestrian movement can be designed, aiming at maximizing the efficiency of

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evacuation flows and the safety level. With this objective, a review of outstanding works developed in the area was performed [2, 3, 10, 17, 16, 19] which pointed out disparities between the simulations proposed in each of them, making it difficult to compare results.

We attempted to contribute to the state of the art by homogenizing variables and fixed parameters, repeating each proposition of the above-mentioned authors in a single simulation model, based on Social Forces. This proposal aims to find more assertive answers regarding the two issues that were considered most relevant in the literature consulted: the interference of obstacles near the exits, in normal and evacuation situations, and the influence of the parameter nervousness in the pedestrians' flow during an emergency evacuation. In order to do so, a computer simulator was used, more specifically the PTV Viswalk module of the Vissim PTV software, which allows the use of the Social Force approach. From this approach, pedestrians can walk independently of their destination, without a predefined network model for their trajectories.

After performing the architectural and behavioral surveys adopted in the simulations proposed by the aforementioned authors, adaptations and adjustments were considered necessary to minimize the number of parameters to be calibrated, seeking the robustness of the simulations, analyses and results. Among the fixed parameters are: the dimensions of the simulated environments and the density of the crowd. As the main variable is the walking speed, responsible for introducing the parameter of nervousness, one of the focuses of analysis proposed in this research.

31.2 Pedestrian Simulation and the Social Force Model

According to Duives et al. [1], current pedestrian simulation models are used to predict where, when, and why dangerous movements occur in high-density crowds. However, according to Moussaïd et al. [15], even modeling approaches considered to be successful are still not consistently presented in relation to empirical observations and are often considered difficult to calibrate. Thus, the work developed by Duives et al. [1] seeks to evaluate the simulation models of existing pedestrians regarding the phenomena of known crowds, verifying if they can be used to simulate high-density crowds and indicating possible existing gaps.

Among the many simulation models for pedestrian movement modeling, Duives et al. [1] reviewed a wide spectrum available for the field of research and analysis, providing an overview of each of them: Cellular Automata, Social Force models, Activity Choice models, Velocity-Based models, Behavioral models, Network models, Continuum models, and Hybrid models. The results of the review carried out by the authors indicate that only three models are able to reproduce a large set of crowd movement phenomena: the Cellular Automata, which implement long-range interactions, the Social Force models and Nomad, based on activities. Thus, according to Duives et al. [1], these models can now be indicated as the best models of crowd simulation, from the perspective of phenomena.

For Duives et al. [1], the current field of pedestrian simulation points to some large areas of application. One of them refers to the research about the crowd movement, and the models described in the works of Helbing et al. [7] and Hoogendoorn and Bovy [11] have managed to simulate most of them. Duives et al. [1] recommend, therefore, the Social Force models and Activity Choice models, respectively, for pedestrian crowd movement research.

The model proposed by Helbing and Molnar [8] and Helbing et al. [5, 6, 4] is a continuous, microscopic model whose deterministic interactions are based on social force. The concept of the model is grounded on the assumption that changes in pedestrian movement are guided by fields of social force. Briefly, it is based on overlapping effects of attraction and repulsion, which are responsible for determining the behavior of individuals. The Social Force model applies optimized behavioral strategies, i.e., that the pedestrians have learned from experience. Although it is a microscopic model, its movements are guided partly by the macroscopic behavior of the crowd and less by personal characteristics [1]. According to Shukla [18], this type of modeling has been used effectively for pedestrian simulations in normal and panic situations.

31.3 Obstacle Interference

For Moussaïd et al. [15], the increase in the frequency and proportions of mass events has made mass disasters and the simulation of pedestrian flows becomes important and emerging areas of research. Thus, recent collective phenomena observed in pedestrian crowds have attracted the interest of a growing number of scientists. For Shukla [18], pedestrian stampede is a disastrous behavior and is usually triggered in situations where the risk of death is established, such as fire in crowded corridors, or when there is a rush to reach large-scale events. According to the author, the architectural design of the spaces exerts great influence in the processes of evacuation.

As signaled by Helbing et al. [5], in panic situations, the outflows can be significantly improved by the insertion of columns, preferably of circular section, in an asymmetrical way in front of the exits. According to Helbing et al. [10], this strategy can prevent the accumulation of fatal pressures in the exit areas and, consequently, reduce the number of injuries. The asymmetrical positioning of the columns, according to the authors, helps to avoid the balance of forces and the blockage coming from them.

Several important studies in the international literature present simulation results that try to evaluate different architectural conformations in the simulation of pedestrian movement, particularly when dealing with high densities. Table 31.1 presents a summary of the main scenarios analyzed by the authors that ground this work. It is noteworthy that all of them were analyzed from Social Force models, except for Yanagisawa et al. [19], whose results are derived from real simulations with a group of 50 women. The original result of each of the scenarios is presented in the form of people flow (persons/second), along with the results of this paper, in the Results and Discussion section.

Considering the importance of each of the works analyzed and listed in Table 31.1, as well as the disparities between the proposed simulations, we sought to contribute to the state of the art from the homogenization of variables and fixed parameters, repeating each proposition in a single simulation model, based on Social Forces. The purpose of this study is to find more assertive answers regarding two questions that were considered more relevant in the literature: the interference of obstacles near the exits in normal and evacuation situations and the influence of the parameter nervousness in the pedestrian flow during an emergency evacuation.

31.4 Research Method

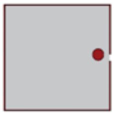
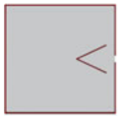
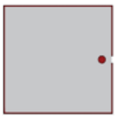
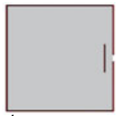
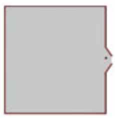
The selection of the scenarios presented in Table 31.1 was based on the analysis of the evacuation flows resulting from each original simulation and the most promising results found by the respective authors were adopted for this paper. Then, the fixed and variable parameters to be used in all the simulations were established, adapting the original scenarios to meet the following adjustments: rooms with dimensions of 15 m $\times$ 15 m and 1.0-m wide exits. In the case of the SE1 and SE2 scenarios, two lateral triangular areas of each were suppressed, so that they corresponded to the original propositions. In addition to the two fixed parameters mentioned, a population of 200 people was determined in each scenario.

The speed imputed in each of the two sets of simulations therefore determine the only variable parameter of this work, namely: 1.32 m/s, which corresponds to a normal walking speed inside a crowd [4]; and 2.5 m/s, which corresponds to the walking speed of people in a hurry (greater than 1.5 m/s), introducing the parameter called nervousness to the simulations. This parameter, affirm Helbing et al. [10], the transition between rational behavior and panic behavior, influencing oscillatory flows, desired speeds and imitative or pastoring behaviors. For Frank and Dorso [3], we cite for comparative purposes, the speed of 6.0 m/s represents a panic race. The simulations were carried out in the PTV Viswalk module of the Vissim PTV software, which allows the use of the Social Force approach. From this approach, pedestrians can walk independently of their destination, without a predefined network model for their trajectories.

Figure 31.1 illustrates a simulation of the REF (reference) and HE1 scenarios, between 6 and 7 s after the start of the evacuation. It is seen that the desired speed increase results in a faster agglomeration near the exit, being that for both speeds, it is possible to observe the formation of arcs.

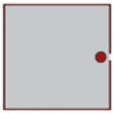
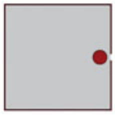
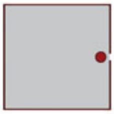
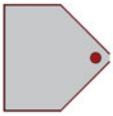
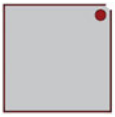
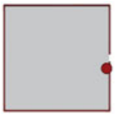
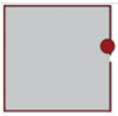
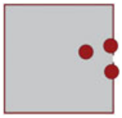
For the determination of the total evacuation time of the scenarios, the static simulation model was used. By not causing a change in the state of the model, the time is not considered a variable of the system [14]. To determine the results accurately, the mean values of the desired measurements were calculated.

Table 31.1 Relation of simulated scenarios

Author(s) and original data	Applied scenarios			
Helbing et al. [9, 10] no. of people: 200; dimensions: 15 m x 15 m; exit: 1.0-m wide; v = 1.5 m/s; obstacle´s dimensions graphically obtained	REF 	HE1 		
Escobar and De La Rosa [2] No. of people: 200; dimensions: 15 m x 15 m; exit: 1.0-m wide; v = not specified; obstacle's dimensions graphically obtained	REF 	ER1 	ER2 	ER3 
Frank and Dorso [3] No. of people: 200 (the results refer to the evacuation data of the first 160 people); dimensions: 20 m x 20 m; exit: 1.2-m wide; L = 1.2 m (door width); v = 1.5 m/s	REF 	FD1  Ø = L $d^a = \sqrt{3}L/2$	FD2  $e^b = 0.1$ L $d^a = \sqrt{3}L/2$	FD3  $e^b = 0.1$ L $d^a = 1.1$ L
Yanagisawa et al. [19] No. of people: 50 (real simulation); dimensions: not informed; exit: 0.5-m wide; v = not informed	YE1 	YE2  Ø = 0.20 m $d^a = 0.75$		

(continued)

Table 31.1 (continued)

Shiwakoti and Sarvi [16] No. of people: 200 (the results refer to the evacuation data of the first 50 people); dimensions: 15 m x 15 m; exit: 1-m wide; $v = 5$ m/s	REF 	SS1  Ø = 1.5 m d^a = 0.5	SS2 	SS3  Ø = 1.5 m d^a = 0.7 m
Shiwakoti et al. [17] No. of people: 200 (the results refer to the evacuation data of the first 50 people); dimensions: 15 m x 15 m; exit: 1-m wide; $v = 5$ m/s	SE1 	SE2  Ø =1.5 m d^a = 1.2 m	REF 	SE3  Ø =2 m d^a = 0.5 m
Jiang et al. [13] No. of people: 80; dimensions: 10 m x 10 m; exit: 1-m wide; v = panic evacuation; obstacle's dimensions graphically obtained	REF 	JE1  Ø = 0.75 m	JE2  Ø = 0.75 m	JE3  Ø = 1.0 m

[a]Distance from obstacle to exit
[b]Thickness of obstacle

(a) ds = 1.32 m/s (b) ds = 2.5 m/s

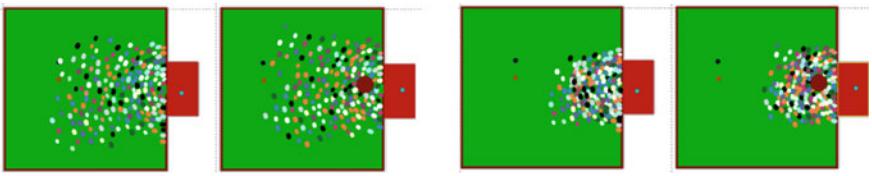


Fig. 31.1 Simulation of scenarios REF (without obstacle) and HE1 (with obstacle)

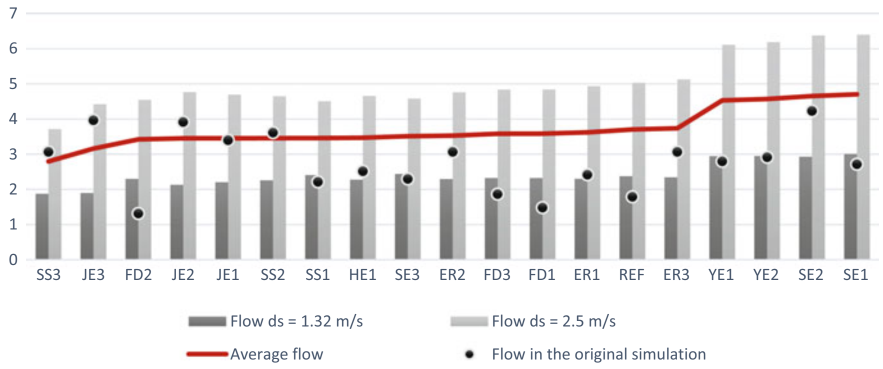
In the sequence, the results of all the simulated scenarios will be presented and discussed, comparing them with their original results. For that, the users' flow of the environment (persons/second) was determined for each of the scenarios, considering the mean evacuation time after ten simulations. The time taken to calculate the mean was the last person to leave the environment.

31.5 Results and Discussion

Graph 31.1 presents the results obtained for each of the simulated scenarios, from the determination of the total users' flow (persons/second). The dark bars show the flow of people to the desired speed ds = 1.32 m/s; the light bars present the flow at the desired speed ds = 2.50 m/s, when introduced the nervousness parameter; the red line represents the average obtained for the two speeds; and the dark points represent the original results of each of the works, prior to the standardization of the fixed parameters mentioned above.

It is seen, in Graph 31.1, that the different architectural solutions that were compared after the homogenization of fixed and variable parameters present results that approximate the originals, specifically when compared to a single simulated speed or your average. However, it is noteworthy that, for the two simulated speeds, only four scenarios presented better results than the unobstructed scenario (REF). This fact differs from the original studies, in which almost 90% of the solutions were more effective than the reference scenario (REF). Thus, the results indicate that small adjustments in the input data generate highly divergent responses, suggesting that the effectiveness of simulated evacuations depends on multiple variables.

Figure 31.2 presents the scenarios that generated the most effective responses in the comparisons made, they are: YE1, YE2, SE2, and SE1. Screen capture was obtained within 5–6 s of the start of evacuation. A notable feature in such scenarios



Graph 31.1 Users flow (persons/second) in all simulated scenarios

(a) Scenarios YE1 (left) and YE2 (right). (b) Scenarios SE1 (left) and SE2 (right).

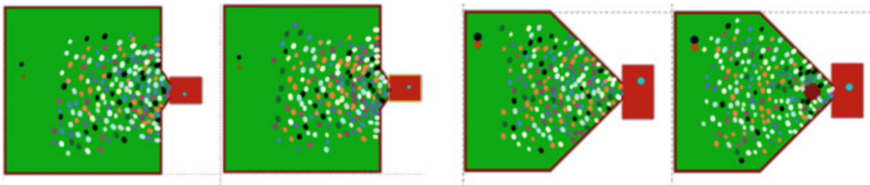


Fig. 31.2 Scenarios that presented greater users flow in the simulations

is the presence of the funnel form preceding the neck, represented by the 1.0-m wide exit. It should be highlighted that these were the only scenarios that presented visibly larger flows than the reference scenario (REF—with exit in the center of the wall and without obstacles) as well as the only scenarios that present the funnel format among the scenarios analyzed.

Regarding the introduction of the nervousness parameter, with the desired speed (ds) increasing to 2.5 m/s, its influence on pedestrian flow was restricted to the total evacuation time, which fell, on average, by half. Other differences were not observed.

31.6 Final Considerations

The simulation of crowds' movement to maximize evacuation flow efficiency and people safety is the subject of relevant publications, especially international ones. In addition to this discussion, there is a need to understand how pedestrian installations can be designed to eliminate or mitigate the risks inherent in human behavior in emergency and panic situations. And we must still consider the transposition of this understanding, based on computational simulation, into the language of architects and planners. For, although it is not well established as a field of architecture research, evacuation planning cannot be separated from the architect's action, which generates the spaces where human relations are established and behaviors derived due to adverse situations, including panic.

It was presented in this work an architectural survey of solutions that had as objective to smooth the flow of pedestrians from the proper insertion of obstacles. Based on this survey, it was suggested to compare the propositions that stood out in each one of the studied researches, making it necessary to promote adaptations and adjustments that minimized the number of parameters to be calibrated, looking for the robustness of the simulations, analyses, and results. The parameters fixed were the dimensions of the simulated environments and the number of people evacuated and the variable parameter was the walking speed, responsible for introducing the nervousness, one of the focuses of analysis proposed by this research.

The results obtained were divergent from the original propositions and did not indicate the presence of obstacles as a facilitator of the evacuation flow. It is believed that this is due to adjustments in the input data, performed to achieve the homogenization of the analyzed scenarios, which ended up generating disparate responses. In this sense, it is plausible to sustain that the effectiveness of simulated evacuations depends on multiple variables, indicating that an obstacle, in an isolated way, cannot guarantee better flows or greater chances of survival. And, although there is interference from architectural elements and the design of escape areas and evacuation routes in the outflow of pedestrians, they should be considered in consonance with other issues, including behavioral ones.

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Chapter 32
Computational Simulation Applied to Evacuation of Wounded, Bodies and Collection of Debris in Disaster Zones

Carlos Alberto González Camargo

Abstract The objective of this work is to demonstrate how to increase productivity in the evacuation of wounded, bodies and debris collection in the disaster zone using scenarios built in computational software which would increase the possibility of saving more human lives and recovering the areas in less time.

Keywords Humanitarian logistics · Disaster zones · Logistics simulation

32.1 Introduction

The Council of Supply Chain Management Professionals explains as logistics involves a series of key activities and processes that must be completed in an efficient and timely manner [9]. The logistics in a firm has inbound logistics and outbound logistics, and transportation and inventory control are the two activities most important. But, is the same in humanitarian logistics or can be different?

Humanitarian logistics is an interesting research topic, and in fact in last five years, there has been an increase in the disasters around the world. Between the years 2012 and 2017, disasters causing death to 72,543 persons and damages for U$536.9 billion [8]. During the first semester of 2017, preliminary data shows that 149 disasters occurred in 73 countries. The impact of which resulted in 3162 deaths, affected more than 80 million people, and caused more than US$32.4 billion [8]. In Americas continent, the number of natural disasters was 32 in 2017, resulted in 654 deaths, total affected 7,639,426, and caused more than U$8.7 billion. The motivation to write this paper is to simulate operations logistics in case of disasters to provide efficient solutions. In this sense, we can think in the humanitarian logistics and the principal aspects.

We can differentiate the logistics in a firm of the humanitarian logistics. The first includes materials' suppliers, manufacturers, transportation, distributors, and custom service. The second includes equipment and machines rescue suppliers, rescue per-

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sonal, drugs and food suppliers, wounded and debris transportation and the persons and infrastructure inventory. The justification for this job is base in this question: What happens if the level service is not good in a firm? The result can be customer lost. In humanitarian logistics, if any member fails to perform, the result can be lost lives. This is the importance of this topic.

In this sense, the goal of this research is to demonstrate the possibility of humanitarian logistics simulation and the best option to rescue persons, bodies and debris. In this research four scenarios were built in computational software and the yields in terms of the evacuation of wounded and debris collection were compared. This process could be carried out faster if it is simulated, which would increase the possibility of saving more human lives and recovering the areas in less time.

32.2 Literature Review

In recent years, humanitarian logistics has taken a big boost as a study area because of the increased frequency of natural disasters worldwide [15]. The use of discrete-event simulation (DES) and system dynamics (SD) are now instances to solve problems in humanitarian logistics. In this case, the problem of the logistics performance, when the disaster occurs, is possible to solve using simulation with different scenarios.

Thompson [16] reviewed the state of disaster logistics among Caribbean small island developing states that are Caribbean Community (CARICOM) members, and, based on those findings proposed a coherent logistics framework that could influence the development of a robust system that can effectively respond to disasters in the region. Hadiguna et al. [10], purpose a decision support systems assess the feasibility of public facilities during an evacuation after a disaster has occurred. The model is a decision support system to assess the extent to which public facilities can be used as evacuation centres for the victims of an earthquake and/or tsunami. The results from this study confirm that this system can provide critical and timely insights into complex evacuation scenarios.

Liberatore et al. [12] speak about a model for the joint optimization of recovery operations and distribution of emergency goods in humanitarian logistics. They propose and solve the problem of planning for the recovery of damaged elements of the distribution network, so that the consequent distribution planning would benefit the most. They apply the model, called RecHADS, to a case study based on the 2010 Haiti earthquake. They also show empirically the importance of coordinating recovery and distribution operations optimization. Bernardini et al. [2, 3] wrote about simulation models for evaluating evacuation and risk-reduction strategies.

Caunhye et al. [7] wrote a literature review about optimization models utilized in emergency logistics in pre-disaster operations. Shao et al. [14] wrote about simulation multi level to emergency facilities. The description contents three parts: facility location, relief distribution and casualty transportation, and other operations. Brailsford et al. [5] wrote about discrete-event simulation and system dynamics for management decisions making; this is important because finally this job want to take a decision about the evacuation of wounded, bodies and collection of debris. Cao and He [6] analysed the modelling material supply in emergent disasters using parameters and an optimization model, using agent based for material convergence in humanitarian logistics. The cyclone risk, wind, and flood have been modelled [11]. The simulation has emerged as a popular decision support in the domains of manufacturing and services industries. In this study, the authors present the advantages of the simulation in improving the health care services, and modelling is presented along with a comparison between the most two popular simulation software in the market nowadays: ARENA and SIMIO [13]. Bernardini et al. [2, 3] wrote about evacuation in the urban scenario and human behaviour.

Afshar and Haghani [1] developed a comprehensive model that describes the integrated logistics operations in response to natural disasters. The mathematical model controls the flow of several relief commodities from the sources through the supply chain and until they are delivered to the hands of recipients. Boonmee et al. [4] wrote about the facility location problem in the humanitarian logistical case. They analysed the facility location type, data modelling type, disaster type, decisions, objectives, constraints, and solution methods will be evaluated and real-world applications and case studies to examine the pre- and post-disaster situations with respect to facility location.

32.3 Methods and Procedures

The following is the result of an investigation, quantitative, descriptive, and analytical approach, whose objective is to increase productivity in the evacuation of wounded, bodies and debris collection, in the disaster zone. The methodology that was carried out began with the search in the literature on modelling and simulation of the evacuation of wounded in the disaster zone, which allowed to know the state of the investigation in this subject. It was possible to show that process simulation has been used mostly for industrial processes, services, and logistics, always seeking to improve some aspect in particular.

The proposed model allows improving productivity in the affected areas. The productivity in this case is the number of wounded, bodies or debris rescues in one hour. Subsequently, two images of disaster areas were selected and computational simulation scenarios of the process of wound evacuation and debris collection were carried out, using a computational system. The case study focuses on two zones, the first an area devastated by the recent hurricane Irma and the second an area affected by the earthquake in Mexico. The construction and configuration of scenarios were made using Flexsim and really photos of Mexico and Dominican Republic any days after of disaster occurred. You can generate a lot of scenarios simulations, improvementing the performance for rescue of persons. You can change the localization of the machines of rescue and key points of evacuation increasing the number of persons rescue.

This exercise seeks to support decision-making related to the best routes, means of transportation and people, to carry out the evacuation of individuals and collection of debris. The case was applied considering Poisson distribution, because the number of wounded, bodies and debris has been down up in the time after of the event.

32.4 Experimental/Numerical Setting

The computational model was implemented in Flexsim simulation software. This process was conceived with different elements as processor, transporter, persons, and trucks. The design used a digital photo, connections between elements, time configuration, and statistics. The principal variables are time and number of rescue persons. The definition of variables, parameters, and performance measures is the most important in this exercise. The case was applied considering Poisson distribution, because the number of wounded, bodies and debris has been down up in the time after of the event.

The Poisson function is defined by:

$$X - P$$
$$F(k) = P(X = k) = e^{-\lambda} \cdots \lambda k/k! \cdots k>=0$$
$$E(X) = \mathrm{Var}\,(X) = \lambda$$

In this model, $\lambda$was 0.8.

The analysis of information was made with the option statistics of Flexsim, allowing measure the productivity in the evacuation of wounded, bodies and debris collection per hour, changing the localization of collection points. The statistic distribution selected was the Poisson distribution. The time of simulation was one hour for everyone case, 3600 s. The cases were two disaster zones, the first a place in Mexico and the second Dominican Republic.

32.5 Results and Discussion

The results obtained show that, by making decisions from the simulation, higher productivity can be obtained, in this case understood as the evacuation of wounded, bodies and debris collection per hour. This exercise contributes to the topic of research in humanitarian logistics, because usually this type of models made with software is used in production companies or in pre-disaster operations. On the other hand, it is related to technology applied to the health and welfare of society, considering that it is carried out for the recovery of devastated areas, where people have been victims of a natural phenomenon. Subsequently, scenarios aimed at achieving evacuation and debris collection are simulated more quickly. Finally, an analysis of the benefits of the modelling proposal is made.

The presented model has been successfully used to demonstrate the need to solve this problem. Indicators of productivity in humanitarian logistics are considered in this paper. The author formed a model to increase the service level in the disaster zone.

Figure 32.1 allows seeing the image of Dominican Republic and the first scenario. The red circle is the place where the debris is initially localized by a person. The transporter goes and picks up the charge and moves to the green circle. The initial productivity was 76 box by hour.

The problem was the accumulation of box in the collection point number one because while the operator productivity is 96 box, the transporter only was 76. The improvement of the system was to move the point collection to the red zone two, then the operator and transporter productivity is 73 box and the accumulation is zero. See Fig. 32.2.

Figure 32.3 allows seeing the image of Dominican Republic and the evacuation of wounded and bodies after of Irma's hurricane. The red circle is the initial collection point. The transporter goes and picks up the person and moves to the yellow zone. The productivity initial was 26 wounded by hour and was the same for operator and transport. However, the first day, the rescue operation is fast, and the collection point is good to fast rescue, but the third day the transport goes near to the wounded and de-collection point is not necessary. This is the explanation about the Poisson distribution. The rescue, the third day is slow and the conditions in the scenario are different, the productivity was seven wounded by hour.

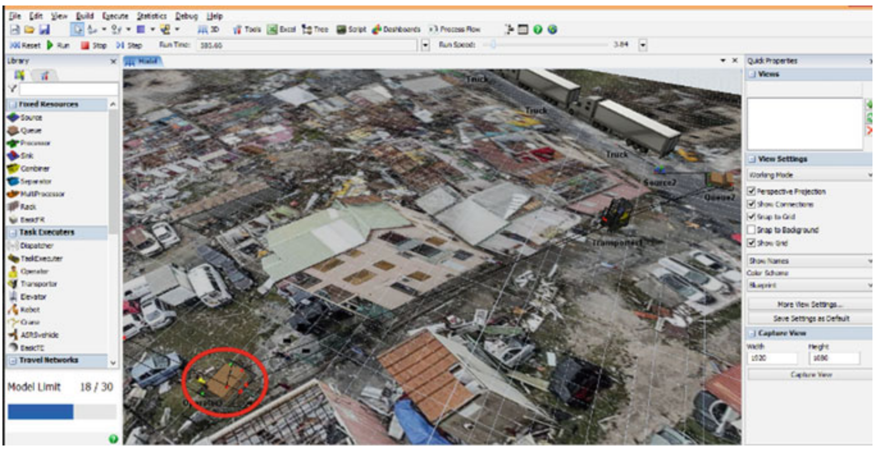

Fig. 32.1 Earthquake's Mexico. Simulation of the evacuation of wounded, bodies and collection of debris

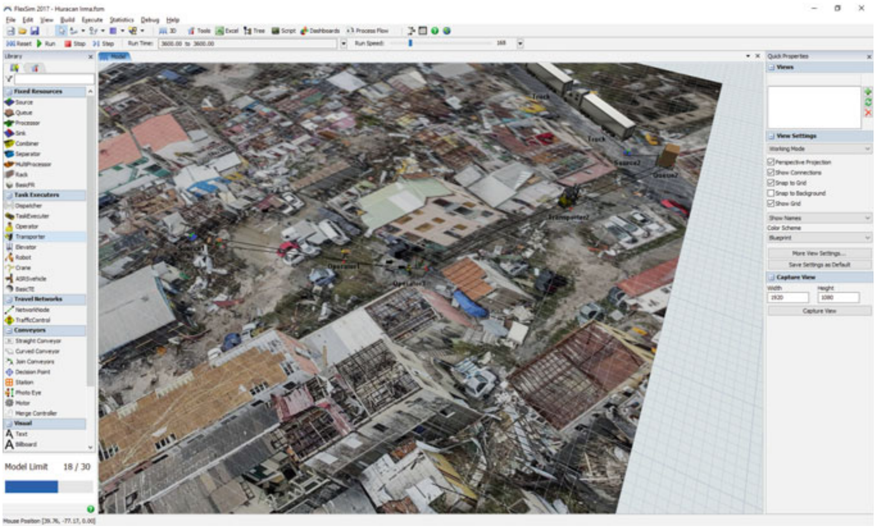

Fig. 32.2 Earthquake's Mexico. Second scenario

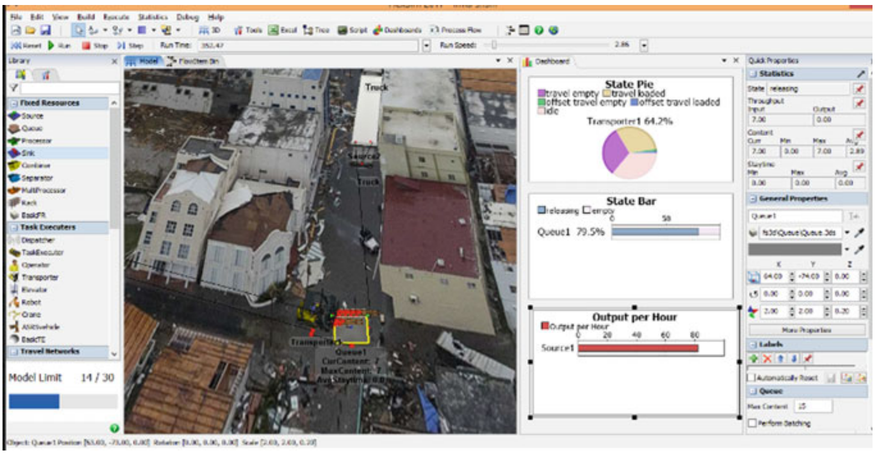

Fig. 32.3 Irma's Hurricane. Simulation of evacuation of wounded, bodies and collection of debris

32.6 Conclusions and Future Research

The modelling of the evacuation of wounded, bodies and debris in disaster zones is a topic interesting in humanitarian logistics. Indeed, the use of tools, methodologies, and techniques for managing disasters situations is a good option to improve the attention to the persons.

The main findings show the opportunity to planning the activities in the most appropriate way after a natural phenomenon occurs in an area, since in general the evacuation of wounded and removal of debris begin without any planning. When the phenomenon occurs, the wounded and bodies are rescued fast, but three days after, to rescue is slow. Then the service level to rescue initially is high, after is slow. This process could be carried out faster if it is simulated, which would increase the possibility of saving more human lives and recovering the areas in less time.

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Chapter 33
Collective Phenomena in Pedestrian Crowds and Computational Simulation of Design Solutions

Manuela Marques Lalane Nappi, Ivana Righetto Moser and João Carlos Souza

Abstract We discuss various phenomena of crowd dynamics and pedestrian evacuation in places with a large public. From the simulations of flows, we analyze the design solutions that promote the stabilization of walking paths in opposite directions, the induction and stabilization of flows at intersections, and the improvement of flows in bottlenecks.

Keywords Pedestrian crowd dynamics · Improved design elements · Computer simulation

33.1 Introduction

Increasing the frequency and proportions of mass events has made mass disasters, and simulations of pedestrian flows become important and emerging areas of research [14]. A crowd, according to Helbing and Johansson [6], occurs from the agglomeration of many people in the same area and at the same time, and their density must be presumed to be high enough to cause continuous interactions or reactions in other individuals. Duives et al. [2] affirm that the greater the density, the greater the problem of coordination, since a large number of people tend to dispute some small gaps.

Understanding the crowd behavior during collective displacements is at the heart of pedestrian traffic engineering, according to Helbing et al. [8] and Shiwakoti et al. [16, 17]. And an overview of the collective phenomena observed in pedestrian crowds includes concepts related to the formation of corridor pathways and oscillations in bottlenecks in normal situations, as well as different types of blocked states produced by panic situations [3]. In this sense, the authors distinguish pedestrian dynamics between normal situations and situations of panic and argue that, although the characteristic problems of each of these situations are investigated by different scientific communities, they can be treated consistently by the same model.

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For Shiwakoti and Sarvi [18], the most critical reason to study the collective dynamics of pedestrians in emergency situations is the lack of complementary data to develop and validate an explanatory model. The lack of knowledge about the impact of the built environment and its geometric characteristics on the crowd dynamics is also linked to the difficulties in finding empirical data on the basis of which different aspects of human behavior can be examined [15]. According to Moussaïd et al. [14], many models of pedestrian behavior have been proposed in order to explain the laws underlying the crowd dynamics. Among them, approaches that are based on physics are quite common, such as models of fluid dynamics and social force, both inspired by Newtonian mechanics.

This work discusses several phenomena of crowd dynamics, in normal and extreme situations, characterized by high densities or panic. From simulations based on the social force model, we analyze the flow of pedestrians in different design solutions, which aim to: (i) promote the stabilization of walking paths in opposite directions; (ii) induce the stabilization of flows at intersections; and (iii) smooth bottleneck flows with the adoption of the funnel shape. The results, especially the qualitative ones, point out that it is possible to achieve more efficient flows through the insertion of obstacles or the adoption of ways that induce the walking path of pedestrians in a crowd.

33.2 Concept of Social Force and Computational Simulation

The social force model proposed by Helbing et al. [9–11] and Helbing and Molnar [4] is based on the method of modeling fluid crowds. It is a continuous, microscopic model whose deterministic interactions are based on force. The concept of the model is grounded on the assumption that changes in pedestrian movement are guided by fields of social force. Briefly, it is based on the overlapping effects of attraction and repulsion, which are responsible for determining the behavior of individuals.

According to Helbing et al. [11], the social force model is able to reproduce self-organizing phenomena in crowds of pedestrians, which have been neglected for a long time but essential for determining the degree of efficiency (average speed in relation to desired speed) of optimized and potential flow sources of obstructions. Thus, the use of this model aims to develop design elements that increase the efficiency and safety of pedestrian facilities. Currently, although the experimental base has improved due to the availability of video technology, the development of image analysis software and infrared detectors, quantitative experimental studies are still scarce [11].

Helbing and Johansson [6] state that collective behavior can be translated into complex phenomena represented by self-organized patterns of movement. These patterns demonstrate, according to the authors, that an efficient and intelligent collective dynamic can be based on simple and local interactions. They warn that, under extreme conditions, such coordination may fail and give rise to critical conditions in crowds. For them, understanding these conditions may have significant implications for the optimization of pedestrian mechanisms, particularly for evacuation situations.

Helbing et al. [11] consider in their model that each pedestrian wants to walk with an individual desired speed in the direction of their next destination. In normal situations, the desired speed is approximately Gaussian. Its average value is 1.3 m/s, or less, with a standard deviation of approximately 0.3 m/s. When it is necessary to compensate for delays, the authors point out that the desired speed is often increased in the course of time. The time-dependent parameter reflects nervousness or impatience. When taken together, long waiting periods decrease the actual speed in relation to the desired speed. Such a mechanism, according to Helbing et al. [11], can lead to aggressive behavior as well as generate high pressures in the crowd. Helbing et al. [10] estimate that high pressures may be accompanied by the occurrence of clogging and crushing effects.

For Helbing et al. [11], once calibrated with empirical data of pedestrian flows, the corresponding computational simulations produce realistic results, even when considering new geometries and situations. Therefore, the social force model has predictive value, allowing the investigation of new scenarios, for which the use of experiments would become expensive, difficult to perform or dangerous [11]. This predictive value, according to the authors, is particularly important for the planning and optimization of escape routes.

33.3 Crowd Dynamics

Even if one considers its simplifications, the social force model of pedestrian dynamics describes several phenomena in a realistic way and clarifies self-organized spatio-temporal patterns that are neither planned nor prescribed or organized by external agents [6]. Examples of self-organization phenomena studied in normal situations are: (i) lane formation; (ii) oscillations of flows in bottlenecks; (iii) stripe formation at intersections [6]. Under extreme conditions characterized by high densities or panic, according to the authors, coordination may cease to exist and give rise to effects such as: (iv) freezing-by-heating; (v) faster-is-slower effects; (vi) stop-and-go waves; (vii) crowd turbulence. Each of them will be discussed below:

(i) According to Helbing and Johansson [6], the most relevant factor in the phenomenon of lane formation can be defined by the greater relative pedestrians' speed walking in opposite directions. Comparing them to people who follow each other, pedestrians in opposite motion have more frequent interactions until they separate in different paths, moving away every time another pedestrian is found. The resulting collective motion pattern tends to minimize the frequency and strength of avoidance maneuvers whenever oscillations are weak [3].

(ii) In bottlenecks, it is common to observe oscillatory changes in the direction of bidirectional flows of moderate density [6]. The authors interpret the oscillatory pattern as a phenomenon of self-organization capable of reducing the effects of friction and delays. Studies have shown that when a pedestrian is able to pass through a narrowing passage, other pedestrians with the same walking direction can easily follow him. In this way, the pressure to wait and push becomes smaller than on the other side of the bottleneck, increasing the chance of occupying it. This causes a deadlock situation, which is followed by the change in direction of passage [7].

(iii) For Helbing et al. [11], intersections of pedestrian flows are one of the biggest problems related to crowd dynamics and are practically inevitable. Helbing and Johansson [6] affirm that self-organized patterns of movement were found in situations where flows intersected in only two directions, with the formation of stripes. This configuration makes it possible for two flows to penetrate one another without pedestrians needing to stop, which minimizes obstructive interactions and maximizes average pedestrian speeds.

(iv) In cases of extreme densities, Helbing et al. [11] argue that orderly path formation may fail due to overtaking maneuvers in large disturbances or multitudes of nervous pedestrians. Helbing et al. [8] observed that these pathways are destroyed by the increase of the oscillation force, analogous to the increase in temperature in a fluid. The authors, however, have realized that instead of the direct transition from the fluid state to the gaseous (disordered) state, there is a solid intermediate state. This state is characterized by a blocking or freezing situation. Hence, we call this transition the paradoxical term of freezing-by-heating. Helbing and Johansson [6] point out that, contrary to the simulations; real crowds usually solve the resulting impasses by rotating bodies (or shoulders), allowing people to leave the blocked areas.

(v) Helbing et al. [3] state that the simulated flow of an environment is well coordinated and regular as long as the desired speeds are normal. According to the authors, for desired speeds of more than 1.5 m/s, which the authors refer to as "hurried people," there is an irregular succession of arch-like blockings of the exit and avalanche-like bunches of leaving pedestrians, when the arches break. According to Helbing and Johansson [6], the greater the difference between the arrival flow and the departure flow, the greater the likelihood of critical situations occurring, especially if people are trying to achieve a strongly desired goal or trying to escape a source of danger. In these situations, they say that high density causes problems of coordination, when several people start competing for the same few gaps. This can cause interactions of bodies and friction effects, capable of delaying the movement of the crowd or evacuation, hence the term fast-is-slower effect. This term reflects the observation that some processes take more time when they are executed at high speed [6].

(vi) Intermittent flows, or stop-and-go waves, characterize the inconstant outflow from a bottleneck, which is interrupted. Recent empirical studies of the flows of pilgrims in the Mecca region of Saudi Arabia, on January 12, 2006, have shown pronounced stop-and-go waves, which were observed in the entrance area of a 44-meter-wide bridge [6]. Helbing et al. [5] concluded that in high-density congestion, the resolution of obstructions at the output causes a shock wave that moves upstream. At the front of this wave, the density is low and people can leave the congestion. That is, if the density in front of the congestion is small enough, people will move forward to fill this low-density area. Thus, there will be alternating phases of resolution and filling of gaps near the exit, which leads to the alternating propagation of the congestion front [6].

(vii) When analyzing the videos of January 12, 2006, referring to the pilgrimage mentioned previously, the authors recorded the moment when the stop-and-go waves started. On the same day, when the density of the crowd reached even higher values, it was possible to observe a sudden transition of stop-and-go waves to irregular flows, as shown Helbing and Johansson [6]. These flows began to be characterized by random displacements, unintentional and in various directions, pushing people who could not stop even if they found other fallen people in front of them. The result of all this movement and its transitions was one of the biggest disasters in the world involving crowds [6]. The authors refer to this flow as crowd turbulence.

33.4 Improved Project Solutions

According to Helbing et al. [11], designing facilities for pedestrians represents an art that requires efficient flows, especially in the case of a large public meeting. Illera et al. [12] report their concern with the fact that although there has been research on pedestrian dynamics for a long time, preventive measures have not yet been detected in relation to constructions and organizations that bring crowds together. As pointed out by Illera et al. [12], standards and regulations prescribe design measures to ensure the safety of persons entering and exiting buildings. However, such security is restricted to measurable metrics such as escape route distances and doors widths. Qualitative design criteria, related to elements of architectural composition, according to the authors, are rarely formulated.

For Duives et al. [2], assessing the safety of events that gather pedestrians' crowds has proven to be a difficult task. In addition to different layouts of infrastructures, pedestrian movements also present different events. In this sense, Burd et al. [1] state that research on pedestrian dynamics is able to predict that small architectural features of the surroundings can have great effects on crowd behavior as well as pedestrian flow. For Helbing and Johansson [6], one of the main goals during mass events should be to prevent extreme densities. They are, according to the authors, what cause bottleneck congestion as a consequence of the breakdown of free flows and the ratio of increasing degrees of compression. By achieving a certain critical density, the potential for high pressures in the crowd is increased, especially when people are impatient due to long delays or panic [6].

The following simple examples of how to improve some standard elements in pedestrian facilities have been discussed in Helbing et al. [3]: (i) In high pedestrian densities, even walking paths tend to disturb each other when impatient pedestrians try to use any space for overtaking, leading to subsequent obstructions in the opposite direction of walking. Thus, the roads can be stabilized by a series of trees or columns dividing the opposite directions of walks, whose effect resembles a wall; (ii) the flow in the bottlenecks can be improved by a funnel-shaped design, although this format has less space for walking; and (iii) when different flows intersect, there may be oscillatory changes in the walking direction and periods of paralysis between them. Helbing et al. [11] indicate that an obstacle in the middle of an intersection tends to improve the efficiency of the movement, even if it reduces the area available for pedestrians. The explanation for this fact lies in the spatial separation of different directions of flow, so that only two directions can be intercepted in a single location.

According to Helbing et al. [3], the complex interaction between various types of flows can lead to completely unexpected results. These results are attributed to the nonlinearity of pedestrian dynamics. This means that planning for pedestrian facilities from conventional methods cannot always avoid major congestion, severe and catastrophic obstructions and blockages, especially when dealing with emergency situations. On the other hand, Helbing et al. [11] say that when working with a skillful pedestrian flow optimization, one can increase the efficiency and safety of these facilities, particularly when one makes use of the phenomena of self-organization. The authors also indicate that this increase in efficiency may be accompanied by compensating costs and even space reduction.

33.5 Research Method

The proposal of this paper is limited to simulating the three examples explained above, suggested in Helbing et al. [3], to improve some standard features in pedestrian facilities. These are: (i) insertion of obstacles to the stabilization of walking paths in opposite directions; (ii) adoption of the funnel shape to improve bottleneck pedestrian flow; and (iii) insertion of an obstacle in the center of an intersection to improve the efficiency of pedestrian movement (Fig. 33.1). In order to do so, we adopted the PTV Vissim software, its PTV Viswalk module, which allows the use of the social force approach. From this approach, pedestrians can walk independently of their destination, without a predefined network model for their trajectories. The speed imputed in each of the propositions was 1.32 m/s, which corresponds to a normal

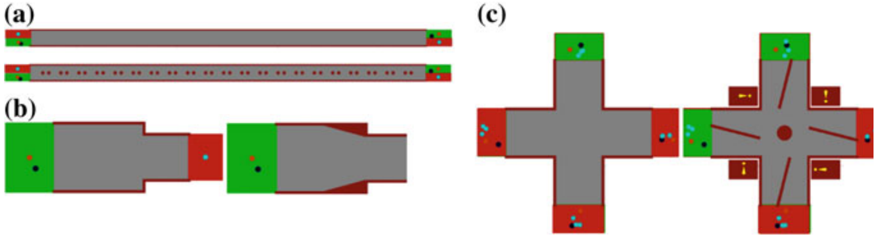


Fig. 33.1 Simulation of design solutions for the improvement of pedestrian flows

walking speed inside a crowd [11]. Due to the stochastic nature of the simulation model adopted in this work, random fluctuations occur influencing the results in each simulation performed. A stochastic simulation model, according to Lima et al. [13], has a random component, which is not controlled by the researcher.

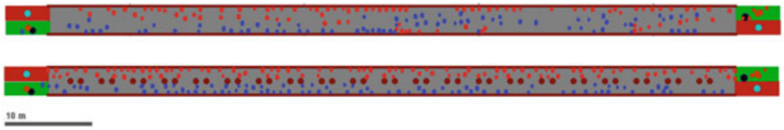
In Fig. 33.1, it is possible to observe the six design solutions simulated in this paper: (a) stabilization of walking paths with the insertion of obstacles (below) and conventional (above), where obstacles are represented by solid circles in brown color; (b) smoothing bottleneck flows with the funnel shape (right) and conventional (left); (c) induction of flow stabilization at intersections with the insertion of obstacles (right) and conventional (left), where obstacles are represented by solid brown circles and diagonal bars that induce the path to be followed by pedestrians, and yellow exclamation points represent elements of attraction, such as posters. Each of the six design solutions was simulated during the time of 300 s, during which the pedestrian flows were analyzed visually (qualitative analysis) and quantitative data were extracted that will be presented in the sequence.

33.6 Results and Discussions

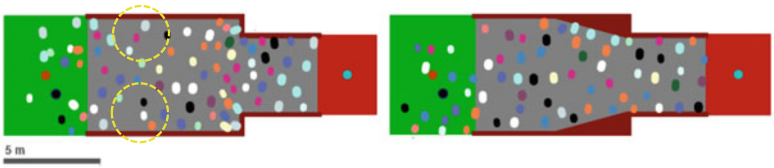
The qualitative analysis (Fig. 33.2) showed that the insertion of obstacles and the adoption of the funnel shape brought gains for the organization of the pedestrian flow in all situations analyzed. Stabilization of walking paths (Fig. 33.2a) proved to be faster in the proposition that included obstacles separating flows, although allowing the passage of pedestrians between them. With respect to the smoothing of flows in bottlenecks (Fig. 33.2b), it was also observed that the adoption of the funnel shape avoided the agglomerations that can be visualized in the conventional solution (left), highlighted in yellow, promoting a more continuous flow. Similarly, in the propositions aiming to stabilize the flow of pedestrians at intersections (Fig. 33.2c), the insertion of obstacles promoted a flow with less amount of avoidance maneuvers, as can be observed in the conventional proposition (left), with highlighted in yellow.

The quantitative analysis, presented in Table 33.1, shows that there were no significant changes between the conventional and obstacle propositions, when the data obtained after 300 s of simulation were compared. Some considerations, however, are necessary: (i) In the proposals for the analysis of the formation of walking ways, the conventional scenario was more efficient than the scenario with obstacles; (ii) in the propositions whose objective was to evaluate bottlenecks and intersections, both were more efficient after the insertion of driving obstacles and flow; (iii) the flows were calculated based on the number of pedestrians who entered the network in each simulated proposition, including those who did not complete the course at the end of the simulated 300 s.

(a) stabilization of walking paths with the insertion of obstacles (below).



(b) smoothing of bottleneck flows with the adoption of the funnel shape (right).



(c) induction of the stabilization of flows at intersections with the insertion of obstacles (right).

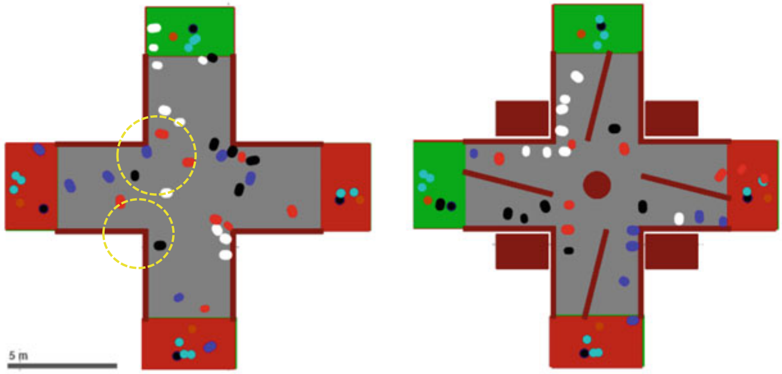


Fig. 33.2 Qualitative comparison between simulated design solutions

33.7 Final Considerations

Considering the relevance of understanding the consequences of collective movements considered complex, especially in the design phase of architectural spaces intended for large audiences, modeling based on social forces has been effectively used for pedestrian simulations in normal and panic situations. However, few studies have focused on understanding the impact of the built environment and its geometric characteristics on crowd dynamics. Thus, it was the intention of this research, besides discussing several phenomena of the crowd dynamics in normal and extreme situations, to analyze the flow of pedestrians from different design solutions. The qualitative and quantitative results indicate that it is possible to obtain more efficient flows with the insertion of obstacles or with the adoption of architectural forms that induce the walking path of pedestrians in a crowd. Since they do not represent an exhaustive approach, the simulations analyzed here require further studies to confirm the observed trend.

Table 33.1 Quantitative results of analyzed propositions

	Walking paths		Bottlenecks		Intersection	
	Conventional	W/obstacles	Conventional	W/obstacles	Conventional	W/obstacles
Efficiency[a] (%)	85.17	79.45	68.39	70.85	80.47	84.12
Flow (persons/s)	2.21	2.49	4.39	4.27	2.79	2.72

[a]Relation between the average speed and the desired average speed

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Chapter 34
Mapping of Humanitarian Operations Literature: A Bibliometric Approach

Rodolfo Modrigais Strauss Nunes and Susana Carla Farias Pereira

Abstract The purpose is to present a literature review of humanitarian operations/supply chain/logistic based on bibliometric methods for mapping this field of research. Software was used to construct maps and bibliometric networks. The science mapping approach is useful for providing quick identification of main research topics and clusters.

Keywords Science mapping · Humanitarian operations · Humanitarian supply chain

34.1 Introduction

The increase in the frequency and magnitude of natural disasters in recent years has caused an increase in the interest of the academic community of operations management by the theme, allowing the emergence of the field of study of humanitarian operations.

Thus, this article will seek to understand the intellectual structure of this field through extensive bibliographical research, using bibliometric methods and science mapping.

The remaining article is organized as follows. Section 34.2 presents the methodology used. Next, Sect. 34.3 presents the results and interpretations of the mapping. Finally, Sect. 34.4 presents the conclusions.

34.2 Methodology

This paper uses bibliometric methods through the science mapping approach. The bibliometric methods have two principal uses: performance analysis and science

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mapping [14, 62]. While the performance analysis seeks to assess the performance of publications in a research area, the science mapping aims to reveal the dynamics and structure of scientific fields. According to Zupic and Cater [62], this information on structure and development is useful when the researcher's goal is to review a specific line of research.

In order to construct the maps of the scientific field under study, the bibliometric techniques of co-citation and bibliographic coupling were used. Co-citation analysis is understood as the frequency with which two units are quoted together, indicating similarity between them [51]. The bibliographic coupling uses the number of references shared by two articles as a measure of the similarity between them, i.e., the more the bibliographies of two articles overlap, the stronger its connection [62]. Figure 34.1 shows how the citations relate to documents of these bibliometric techniques.

For each of these bibliometric techniques we used the workflow recommended by Zupic and Cater [62] for conducting science mapping studies in management and organization, composed of five steps: first, design research by defining the research question and choosing appropriate bibliometric methods to answer the question; second, compilation of bibliometric data by selecting the database, filtering the set of documents and exporting the data from the selected database; third, analysis through the application of bibliometric software (statistical software can also be used in conjunction to identify subgroups documents that represent research specialties); fourth, visualization step by choosing the preferred visualization method and selecting the appropriate software to implement the visualization; and fifth, stage of interpretation and analysis of results.

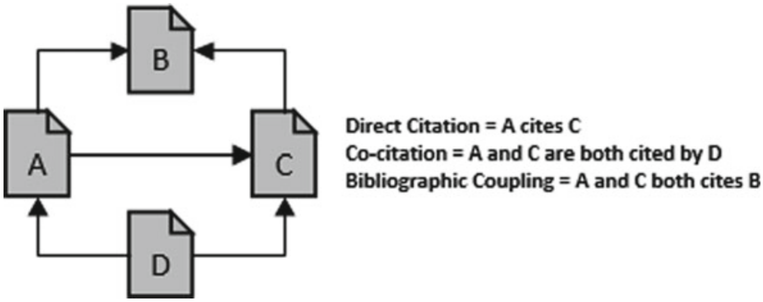

Fig. 34.1 Bibliometric techniques (*Source* Adapted from [40])

34.3 Mapping

34.3.1 Research Design

The objective is to carry out a complete mapping of the humanitarian operations area, including studies about humanitarian operations (HO), humanitarian supply chain (HSC), and humanitarian logistic (HL), through the search for the answer of the following guiding questions.

- *Q1: What is the intellectual structure of the humanitarian operations literature?*

The co-citation analysis was used to answer this question and the result is a map of the main works grouped (clusters), each corresponding to a domain of knowledge that reflects the intellectual structure of the field.

- *Q2: What is the intellectual structure of recent/emerging literature on humanitarian operations?*

The bibliographic coupling analysis was used to answer this question and the result is a map of the main works grouped (clusters), each corresponding to a domain of knowledge that represents the emerging intellectual structure in the field (trends in the area).

34.3.2 Compilation of Bibliometric Data

The database selected for this work was the Web of Science (WOS), since it is considered one of the most important bibliographic bases and the most used in bibliometric management research [14, 62].

The keywords used for the advanced WOS search were "humanitarian operation*", "humanitarian logistic*," "humanitarian supply chain*," "humanitarian supply chain management," "disaster operation*," "disaster relief," "humanitarian network*," and "relief chain*", using the language "English" and document type "article or revision" as filters. Returned as a result of the search a total of 1047 documents, which underwent a full reading of their titles as a first filtering, which resulted in the exclusion of 291 articles. As a second filter, summaries of the remaining 756 articles were read to ensure that they were relevant to the subject sought, resulting in the exclusion of 161 articles. It is important to emphasize that the contexts were analyzed to identify if they really addressed HO/HL/HSC, being observed in several cases, that although they used research environments involving disasters or humanitarian aid, they approached subjects of sociology, medicine, journalism, among others.

Thus, the final database for the development of this article had 595 articles. It is important to note that, specifically for the use of the bibliographic coupling technique, the base was reduced to the time limit from 2016 to 2018, which resulted in 326 papers (more than half of the total) since according to Zupic and Cater [62] the bibliographic coupling looks for trends in a field of study and should have a time horizon of maximum of five years.

34.3.3 Analysis, Visualization, and Interpretation

The bibliometric software chosen for the analysis step was VOSviewer. The use of this software allows a complete analysis based on science mapping.

To answer question 1, the database extracted from WOS was loaded into the VOSviewer software, selecting the "co-citation" analysis type and the "cited references" analysis unit. As it is the construction of a map/network, the amount of elements that will appear in its composition is fundamental because it will determine its intelligibility, i.e., a map that contains the element in excess is not intelligible.

Thus, the authors performed several tests in the software and concluded that, for the option selected, the ideal number was 37 elements, using the minimum citation number filter of a reference cited with a value of 40. The software generated as a result the network shown in Fig. 34.2, and the algorithm divided the elements into three clusters.

As the co-citation technique retrieves the references cited by the authors of the database articles, we obtain as a result of the seminal articles of the field of study. Therefore, a new search was made on WOS and Google Scholar to download and read these documents. After the reading, it was possible to name the clusters, as shown in Table 34.1.

The red cluster contains seminal articles that address supply chain management (SCM) issues in the context of humanitarian operations, being more focused on theoretical approaches in the field of operations management. In the map, it is possible

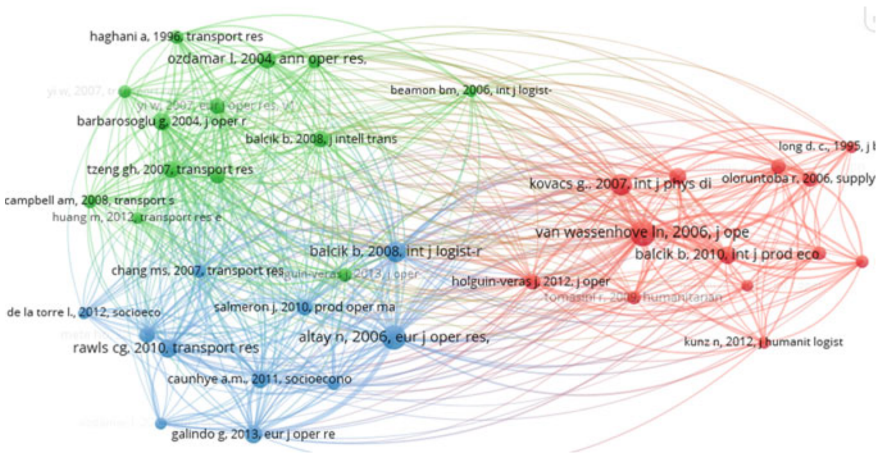

Fig. 34.2 Co-citation analysis of humanitarian operations

Table 34.1 Clusters of humanitarian operations—co-citation analysis

Color	Cited references	Main subjects	Suggested label
Red	Balcik et al. [6], Beamon and Balcik [10], Holguín-Veras et al. [23]; Kovács and Spens [27, 28], Kunz and Reiner [29], Long and Wood [30], Oloruntoba and Gray [35], Pettit and Beresford [41], Thomas and Kopczak [53], Tomasini and Van Wassenhove [55, 56], Van Wassenhove [58]	Characteristics of HL; cross-learning with SCM; performance; efficiency; coordination and collaboration; critical success factors; information and knowledge management; agility; strategies; planning and execution	Humanitarian supply chain management
Green	Balcik et al. [5], Barbarosoglu et al. [7], Barbarosoglu and Arda [8], Beamon and Kotleba [9], Campbell et al. [11], Haghani and Oh [22], Holguín-Veras et al. [24], Huang et al. [26], Ozdamar et al. [36], Sheu [50], Tzeng et al. [57], Yi and Kumar [59], Yi and Ozdamar [60]	Distribution optimization; stocking and transportation operations; routing; unusual constraints; delivery strategies; performance metrics; efficiency and equity; design of delivery systems; coordination of logistic; mathematical modeling	Optimization of logistics distribution in humanitarian operations
Blue	Altay and Green [3], Balcik and Beamon [4], Caunhye et al. [12], Chang et al. [13], De la Torre et al. [15], Duran et al. [17], Galindo and Batta [19], Mete and Zabinsky [31], Ozdamar and Ertem [37], Rawls and Turnquist [45], Salmeron and Apte [49]	Disaster management and operations; facility location; humanitarian networks; inventory pre-positioning; GIS-based disaster management systems; scenario planning; mathematical modeling; vehicle routing; planning and disaster response	Disasters operations management and planning

to perceive that the circle and the label of representation of each document are proportional to the importance of the work. The most important articles of this cluster, which present a more centralized position and more links, are Van Wassenhove [58] and Kovács and Spens [27], with link strength calculated by the software of 184 and 131, respectively.

With an operational research approach, the green cluster presents works aimed at solving problems with the objective of optimizing the physical distribution in humanitarian operations. The articles in this cluster make extensive use of mathematical modeling with the computational application. In the map it is possible to verify that the articles of greater prominence are Ozdamar et al. [36] and Barbarosoglu and Arda [8], with link strength of 92 and 87, respectively.

Finally, the blue cluster focuses on theoretical studies of literature review in OR/MS in the context of disaster management and development of preventive mathematical models based on a strategy of pre-positioning of facilities and planning in disaster response. The articles of Altay and Green [3] and Balcik and Beamon [4], with link strength of 172 and 125, respectively, are highlighted in the cluster.

In order to answer question 2, the restricted database for the years 2016–2018 was loaded into the VOSviewer software, the "bibliographic coupling" analysis type was selected and the "documents" analysis unit was marked. After some tests in the software, it was concluded that the ideal size of units to allow the understanding of the map/network corresponded to 21 components, using for this the filter of the minimum number of citations of a document equivalent to 9. The map/network representing the emerging works and the trends of the field of research is visualized in Fig. 34.3, which is represented in the form of heat map, that is, the closer to red color the most important is the item (the importance of the element is also proportional to the size and visibility of the letters that identify it).

The documents resulting from the bibliographic coupling analysis are all scientific articles and were already part of the database selected and used. Thus, the articles were read in full to allow the analysis of the emerging intellectual structure in the field of humanitarian operations. Table 34.2 shows the composition of the clusters formed by the software and the main subjects addressed by the articles (in the table

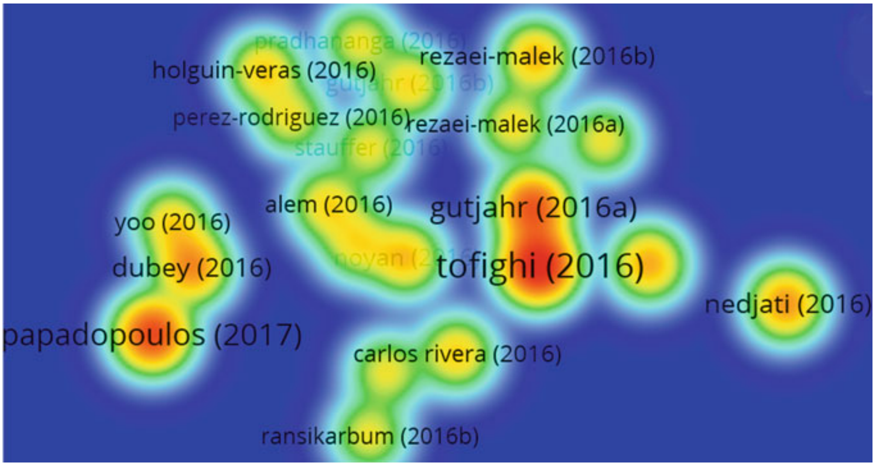

Fig. 34.3 Bibliographic coupling analysis of humanitarian operations. Gutjahr and Nolz [20], Gutjahr and Dzubur [21], Holguín-Veras et al. [25], Noyan et al. [34], Pérez-Rodríguez and Holguín-Veras [39], Pradhananga et al. [42], Stauffer et al. [52], Ahmadi-Javid et al. [1], Fahimnia et al. [18], Nedjati et al. [33], Rezaei-Malek et al. [46], Rezaei-Malek et al. [47], Tofighi et al. [54], Alem et al. [2], Dubey and Gunasekaran [16], Moreno et al. [32], Papadopoulos et al. [38], Yoo et al. [61], Rivera et al. [48], Ransikarbum and Mason [43], Ransikarbum and Mason [44]

Table 34.2 Clusters of humanitarian operations—bibliographic coupling analysis

No.	Document	Main subjects	Suggested label
1	Gutjahr and Nolz [20], Gutjahr and Dzubur [21], Holguín-Veras et al. [25], Noyan et al. [34], Pérez-Rodríguez and Holguín-Veras [39], Pradhananga et al. [42], Stauffer et al. [52]	Multicriteria optimization methods; multiple objectives; facility location; optimization of decision levels; deprivation cost functions; econometrics; distribution network design; welfare economics and social costs; optimization models to analyze disaster cycle management	Optimization of humanitarian logistics and the social cost
2	Ahmadi-Javid et al. [1], Fahimnia et al. [18], Nedjati et al. [33], Rezaei-Malek et al. [46], Rezaei-Malek et al. [47], Tofighi et al. [54]	Healthcare facility (HCF) location; stochastic bi-objective supply chain design; blood supply network; autonomous small unmanned aerial vehicle (UAV); relief pre-positioning; optimum location–allocation and distribution plan	Modeling in HSC and integration of new technologies
3	Alem et al. [2], Dubey and Gunasekaran [16], Moreno et al. [32], Papadopoulos et al. [38], Yoo et al. [61]	Sustainable humanitarian supply chain (SHSC); HSC: agility, adaptability and alignment; resilience in HSC; big data; public–private partnership; social media; information diffusion theory	Resilience and social media in HSC modeling
4	Rivera et al. [48], Ransikarbum and Mason [43], Ransikarbum and Mason [44]	Decision-making strategies; multiple objective programming; optimization HSC; strategic supply distribution; disruption management; experiments	Modeling in HSC using experiments and scenarios

a co-relation was made between the citations and the simplified label that appears on the map).

It was possible to visualize that all the emerging works presented by the bibliographic coupling analysis have a quantitative approach, being the majority of the field of operational research. This helps understand the evolutionary path of this field of research and its trends for future research.

34.4 Conclusions

This article contributed to understand the intellectual structure of the field of humanitarian operations, identifying first its fundamental basis and subsequently the emerging knowledge trends.

Although there were several literature reviews in this field of study, there was no bibliometric study with a science mapping approach. Therefore, this work contributes to an unpublished proposal.

The seminal works of the field of study were mapped, as well as the emerging works in importance at the present time, serving as a base for researchers and students to develop other researches in the area.

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Chapter 35
Application of a Disaster Economic Assessment Framework Through an Illustrative Example

Daniel Eckhardt and Adriana Leiras

Abstract This paper provides an illustrative example of the application of a unified disaster economic assessment framework. The results aim to highlight the primary targets of the proposed framework as its replicability, usability, comparison, capability and generality (applicability to different disaster types).

Keywords Economic assessment · Disasters · Natural hazard · Framework

35.1 Introduction

According to Guha-Sapir et al. [8], the worldwide estimates of natural disaster economic damages in 2016 were US$ 154 billion, 12% above the 2006–2015 annual average. It is estimated that in the next 50 years natural and human-made disasters will increase fivefold in number and severity—both in rural and in urban areas, because of factors such as population increase and land occupation, associated with the historical process of urbanization and industrialization [12]. Several episodes of high magnitude have demonstrated the vulnerability of modern society (earthquakes in Haiti and Chile in 2010; Fukushima nuclear accident in 2011), therefore evidencing the need for differentiated management for these events.

Disasters are divided into sudden onset (earthquakes, tsunamis, terrorist attacks) and slow onset (hungry, poverty or extreme drought) and are characterized by four main phases: mitigation, preparation, response and rehabilitation or reconstruction [14]. These phases are divided into pre-disaster and post-disaster stages, where the first is responsible for: (i) mitigation, encompassed activities, projects or actions aimed at preventing or reducing the impacts of a disaster, and (ii) preparation that involves the possible activities to be performed for a response

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before the disaster occurs [5, 14]. The post-disaster stage is composed by (i) response and reactive phase, given that entities, government and population act directly to save lives and preserve the human and financial resources of the affected region, and (ii) reconstruction that focuses on the financial, social and patrimonial restoration of the affected region [5, 14].

It is a common understanding in the literature that there is no way of neutralizing all negative impacts resulted from disasters, but efforts can be made to reduce their impacts [11]. One of these actions is related to provide a disaster economic assessment to quantify, qualify and support the event phases (mitigation, preparation, response and recovery). One of the primary sources of uncertainty in the estimation of the costs of natural hazards is the lack of enough, comparable and reliable data [10].

According to UNISDR - United Nations International Strategy for Disaster Reduction [13], one of Sendai's framework recommendation is to promote real-time access to reliable data and use information and communications technology innovations to enhance measurement tools and the collection, analysis and dissemination of disaster data. Following this statement, based on a systematic literature review of disaster economic assessment methodologies, Eckhardt et al. [7] proposed a modular, replicable and user-friendly framework capable of providing an economic assessment of different disaster types.

This paper provides an illustrative example of the framework proposed by Eckhardt et al. [7], with an application in a disaster in the mountain region of Rio de Janeiro in 2011. Through this application, we aim to validate some characteristics of the proposed framework, such as replicability (can be used by different users), modularity (to evaluate only specific and pre-defined costs), usability and generality (applicability to different disaster types).

This research is based on secondary sources, as peer-reviewed papers and gray literature (assessment reports and congress papers), related to the 2011's disaster in Rio de Janeiro. The information collected about the disaster in the mountain region of Rio de Janeiro in 2011 was, then, classified according to the economic assessment framework proposed by Eckhardt et al. [7].

The structure of this paper is as follows: Sect. 35.1 gives an overview of disasters. Section 35.2 presents the economic assessment framework proposed by Eckhardt et al. [7]. Section 35.3 details the illustrative example. Section 35.4 presents the research conclusions.

35.2 Economic Assessment Framework

Based on a systematic literature review, Eckhardt et al. [7] proposed a framework (as present in Fig. 35.1) to assess the economic costs of a disaster based on six major stages: (1) pre-event; (2) disaster event; (3) scope; (4) post-event; (5) coordination; and (6) technical data source. According to the authors, the four first stages are considered cyclic (one stage feeds the other), whereas coordination and technical data source are timeless supporting stages for all elements of the framework.

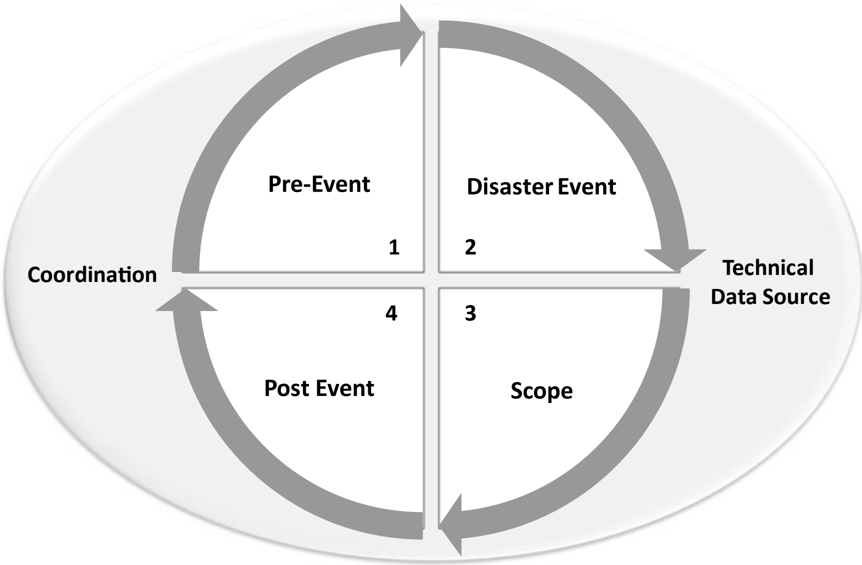

Fig. 35.1 Economic assessment framework. *Source* adapted Eckhardt et al. [7]

The pre-event stage is characterized by pre-disaster activities such as definition of the nomenclatures and units to be used; definition of resilience indicators; definition of indicators to be used during the assessment (number of deaths, number of injured people, number of residential units destroyed); and authorization and access to the necessary data (census, financial, socioeconomic information).

The disaster event stage aims to characterize and scale the impacts caused by the disaster. Disaster characteristics are understood as type (earthquake, flood, strong winds, drought); intensity scale; affected region; duration; and start date. The initial information usually defines the impacts after the occurrence of the event, such as the number of impacted people; confirmation of the affected regions; derivation of other disasters (e.g., an earthquake can generate tsunami); and initial damage estimates (e.g., the percentage of residential units destroyed).

According to Eckhardt et al. [7], the scope stage is considered the most complex one since it defines the scope to be carried out through the entire assessment cycle. This phase defines the costs to be evaluated, the reports, the type of evaluation (measuring positive impacts, potential impacts or only back to normality), the covered disaster phases, assessment priorities and sectors. According to ECLAC—Economic Commission for Latin America and the Caribbean [3]—there are three main sectors to be evaluated in this stage: social sectors (housing, education, health); productive sectors (agriculture, livestock, fishery, mining, industry, trade, tourism); and infrastructure sectors (water and sanitation, electricity, transport and communications). In addition, for each sector, the decision-makers should define which costs will be evaluated: direct costs (damages to property), business interruption costs (local interruption of economic processes), indirect costs (induced losses in local or regional levels), intangible costs (damages to goods and services which are not measurable) and risk mitigation costs (risk reduction costs).

The last stage of the internal cycle of the framework, post-event, is responsible for the publication of the performed assessment. At this stage, decision-makers should document lessons learned and if necessary define new indicators for future evaluations (feed the pre-event stage).

In order to support the execution of the internal cycle stages, the coordination stage is designed to define the assessment stakeholders; to create a communication plan; to list, mitigate and prioritize risks and issue; to define quality metrics; and to define the assessment budget. Finally, the technical data source (TDS) stage aims to create all infrastructures to operate the framework, for instance, the creation of a centralized database, definition of software and tools to be used, listing of methods according to the defined scope.

35.3 Illustrative Example

According to Bandeira et al. [1], the natural disaster that occurred in 2011 in 20 cities in Rio de Janeiro is considered the biggest natural disaster in Brazil, where 916 people died, and 90,000 were directly affected. The causes of this storm, described by the authors, were: geology of the region, irregular occupation (on slopes and alluvial plains) and intense precipitation (in periods of 15 min).

The phase of response to this disaster showed several problems, described by Bandeira et al. [1], such as: (i) logistics problems due to highways and interrupted roads; (ii) low level of planning and efficiency in the use of available resources (e.g., helicopters stopped in the field); (iii) lack of aid kits (doctors, food and water); (iv) removal of deaths; and (v) problems in distributing aid (for instance, no planning for allocation of medical kits and medications). Besides these problems, Costa et al. [2] have identified: (vi) lack of information on the actual size of the disaster; (vii) looting and insecurity in some affected places; (iv) lack of adequate transportation; (x) difficulties in using the available communication system due to the topography of the region; and (xi) poor quality of maps available.

Through the framework proposed by Eckhardt et al. [7], this study focuses on two major impacted sectors, housing and tourism. The first directly affected the local population; the second, directly and indirectly, impacted the economy, since most of the gross domestic product (GDP) of the region's municipalities is generated by tourism.

The overall input information to the framework was based on post-disaster data sources (assessments, case studies and methodologies). For indicators and resilience scores, two sources were selected, World Bank [16] that describes the Post-Disaster Needs and Assessment (PDNA) methodology, and ECLAC [3] that describes the Damage and Loss Assessment (DaLA) methodology. For disaster parameters and overall information (size, type, impacts), three sources were selected, the World

Bank [15] that applied DaLA, Bandeira et al. [1] that present a case study and ENAP—National School of Public Administration [4] —that tries to find answers to the disaster.

Table 35.1 shows the result of the internal cycle of the proposed framework. The first stage of the framework, pre-event, is defined before the disaster occurs. For this stage, we used the information presented in the World Bank [16] in order to define the indicators to be measured. The authors proposed the International System of Units as adopted by Brazil since 1962 [9]. The resilience score is based on the ECLAC [3].

The technical data source stage aims to support the operation of the stages present in the internal cycle of the framework. In this illustrative example, we can cite the use of a central Excel database for compiling and storing the data. The evaluation methods (e.g., repair/replacement, econometric, input–output) were obtained from Eckhardt et al. [6] and Meyer et al. [10]. The framework allows and highlights the use of sophisticated tools and methods, such as stage–damage curves (SDCs). However, since it is an illustrative example that occurred in 2011, such complexity would need to obtain the necessary information in the pre-event phase (for instance, the definition of river level and velocity indicators) and, consequently, would not make possible the framework operation. On the other hand, the framework is flexible in allowing the use of less complicated tools according to the result defined and expected in the scope stage. The coordination stage was not validated in this example since it is based on secondary data sources, and it had an academic purpose (stakeholders from the academy) and carried out a long time after the disaster.

35.4 Conclusions

This study sought, through an illustrative example, to analyze the economic assessment framework for disasters proposed by Eckhardt et al. [7]. The example showed the modularity of the related framework, where the scope was clearly defined and published through the following elements: sectors to be evaluated (tourism and housing), type of costs (direct and indirect), phase (response and recovery), methods (repair/replacement and econometrics).

The replicability of the framework can be done by a process to store the data and their respective data sources. However, the need for a detailed methodology (including processes and flows) is transparent to guarantee the expected result regarding replicability. Once applied to a different type of disaster from the earthquake example presented by Eckhardt et al. [7], the proposed framework shows that it can be applied to different sudden onset disaster types. On the other hand, it is necessary for additional applications in a slow onset disaster such as drought and hunger.

The technical data source stage needs additional efforts to map the methods to be used in the different assessment costs, and according to the scope defined it can also be enhanced with an execution duration of each type of method and cost according to the disaster scale. Finally, the coordination stage seems to be adequate and well

Table 35.1 Economic assessment framework applied to housing and tourism sectors

	Description	Housing	Tourism	Reference
Pre-event	Pre-define measurable indicators	• Number of residential units affected divided by: (i) location (rural, industrial, commercial); (ii) construction type (wood, concrete); (iii) year of construction; and (iv) damage level • Number of people impacted divided by (i) death, (ii) injured, (iii) homeless • Average quantity of people per family • Average temporary shelter needs • Total cost to repair or replace • Total cost for social rent • Definition of house sizes • Total furniture cost	• Number of historic buildings affected by (i) year of construction and (ii) type • Number of hotels and restaurants affected by: (i) location; (ii) construction type; and (iii) activity type • Revenue loss	World Bank [16], ECLAC [3]
	Define units and nomenclature standards	International System of Units and Brazilian reais currency Nomenclature: Not applied		–

(continued)

Table 35.1 (continued)

	Description	Housing	Tourism	Reference
	Provide data authorization and accessibility	• Population census • Household survey • Affected area maps • Finance reports • Poverty maps • Construction materials used in the affected areas • Typical household goods and equipment • Average monthly rentals • Construction costs for each house type	• Total number of tourists by: (i) visitation place/location; (ii) month; and (iii) special dates • Average reais spent by each tourist per day • Total revenue by tourism place	Adapted ECLAC [3]
	Resilience score	• Construction capacity per month • Time to release financial resources	• Construction capacity per month • Time to release financial resources	Adapted ECLAC [3]
	Description	Housing	Tourism	Source
Impacts	Disaster specification	• Disaster type: floods and landslides • Date: January 10–12, 2011 • Duration: 3 days • Most critical cities affected: Nova Friburgo, Teresópolis, Petrópolis, Sumidouro, São José do Vale do Rio Preto, Bom Jardim e Areal • Number of deaths: 916 • Number of impacted people: 90,000 • Number of homeless people: 35,000 • Several cultural heritages destroyed: Friburgo Downtown Church + Chair Lift and Petrópolis (Vale do Cuiabá region was destroyed) • Hotels and marketplaces were • In the seven municipalities, 6.13% of the properties were impacted, and 3.34% were destroyed		Bandeira et al. [1], World Bank [15], ENAP [4]
	Impact analysis			

(continued)

Table 35.1 (continued)

	Description	Housing	Tourism	Source
Scope	Define which disaster phases will be covered	Response and recovery	Recovery	–
	Decide whether to count 'potential' or 'back to normality' costs in the assessment	Back to normality costs	Potential	–
	Define the costs to be evaluated	Direct costs	Indirect costs	–
	Define which sectors will be covered	Housing and human settlements	Tourism	–
	Measure the positive aspects of the disaster	No	Yes	–
	Define overall priorities per disaster phases	No	No	
	Define deliverables (full and partial reports)	Total direct costs by house type	Total indirect costs by total loss revenue.	–
	Check for previous disaster assessments	Not applicable	Not applicable	–
Post-event	Reports	Results of this research	Results of this research	–
	Lessons and learn	Results of this research	Results of this research	
	Report publication	Not applicable	Not applicable	–

referenced, but a future work, based on a real-time disaster application, is needed to prove its effectiveness.

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Chapter 36
Disaster Debris: Fire in the Largo do Paissandú-SP, 2018

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Abstract This study presents the management of over 5000 tons of debris generated in the fire in Largo do Paissandú, São Paulo/Brazil, 2018. The process lasted 12 days and the debris was sent to a construction and demolition landfill without prior segregation, not abiding by the best practices in disaster waste recovery.

Keywords Disaster · Disaster waste management · Humanitarian logistics · Donation

36.1 Introduction

The complex interaction between climate change, increasing urbanization, and codependence on critical infrastructures (telecommunications, water, electricity, sewage, etc.) poses great challenges to current engineering in the context of the disaster management. In this sense, academic and practitioner efforts are being increasingly mobilized for developing appropriate knowledge and tools for disaster management and for reducing economic and social impacts arising from them. Some types of disasters, depending on social and environmental conditions, are predictable and recurrent, such as drought, floods, and landslides. However, when a society fails in regulating activities, in accommodating interests, or in the acceptance and peaceful coexistence between groups [1] demonstrating this through the absence of efficient social and governmental structures for controlling and monitoring activities which

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could jeopardize the integrity of citizens, technological disasters such as urban fires, explosions, collapse of buildings, and dam ruptures also become predictable.

The issue is highlighted due to the sharp increase in the number of people affected by natural disasters (floods, hurricanes, earthquakes, tsunamis); man-made disasters (conflicts, terrorist attacks, and wars); and the growing economic losses, especially in hydrological disasters, have demanded greater efforts by states and humanitarian aid organizations [8]. Forecasts predict that, over the next 50 years, natural and anthropogenic disasters will increase fivefold in number and in severity [21, 22]. This framework makes disaster preparedness and response measures necessary. The uncertain nature of such events, in addition to the large number of casualties, makes humanitarian operations a critical aspect of disaster management and relief operations and is one of the key aspects to achieving improvements in cost, time, and quality [2]. The agile and efficient mobilization of resources is essential to assist people in situations of vulnerability due to disasters. Inefficient resource management can jeopardize emergency response besides increasing victim suffering [10].

In Brazil, disaster management poses major challenges to public managers, non-governmental organizations, and private companies. While natural disasters usually derive from climatic events with the possibility of identifying patterns, limitations in public policies, lack of education and training, non-regular occupations, and cultural differences in the country contribute to the complexity of the issue.

In this sense, logistic characteristics in humanitarian operations present great challenges in the development of strategies that can take into account these specificities. Thus, it is important to consider aspects such as the description and structuring of humanitarian assistance channels, the network configuration for emergencies, inventory control and its relationship with the high degree of customization, uncertainty of demand and removal of disasters waste, both for the return of the affected site to its normality, as well as to enable access to the rescue and supply teams.

Leiras et al. [12] evaluated international publications and detected the lack of studies on humanitarian operations in Brazil. Another aspect also little explored in the disaster literature in Brazil [9] is waste management during and after the disaster, whether they result from the disaster itself or are generated by the affected population or even result from the disposable donations.

Several factors can contribute to the occurrence and intensification of the impacts of these events, such as: lack of land use planning and occupation; fragile local governance; vulnerability and the natural or built environment; deficiency in the supervision of standards and codes; unsafe construction patterns, deterioration or lack of infrastructure, among others. An example is the fire and collapse of the Wilton Paes de Almeida building, in Largo do Paissandu, São Paulo City-SP, which occurred on May 1, 2018.

Based on the information provided by governmental and non-governmental organizations, this work aims to report and to evaluate media records in addition to "in loco" observations of the researchers of the Paissandu fire response operation, especially focusing the activities of humanitarian assistance and the management of solid waste generated by the collapse.

36.2 Method

The present study adopted the format of a case study to report the fire and collapse of the Wilton Paes de Almeida building in Largo do Paissandu. Gonçalves [7] emphasizes the importance of recording humanitarian operations and lessons learned so that the teams responsible for the response operation do not commit any misunderstandings of previous disasters. Disaster site visits were carried out for photographic registration and follow-up of the first response actions. Interviews were carried out Municipal and State Civil Defense and Sao Paulo city Fire Brigade agents. In addition, Municipal Assistance and Social Development Secretariat (SMADS—acronym in Portuguese), Brazilian Red Cross–Sao Paulo Branch (CVB-SP—the acronym in Portuguese), and Municipal Authority of Urban Cleaning (AMLURB—the acronym in Portuguese) employees were interviewed. It was also used media reports, the Red Cross activity report for May 2018 and data and documents made available by the agencies contacted.

36.3 Disaster Waste Management

Solid waste management, even in normal situations, is a complex process that requires the joint action of different actors. In disasters, these processes become even more complex since new actors are added and the role played by each is not clearly defined.

In a normal situation, the knowledge of the origins, quantities, and characteristics of the waste generated in a community is the basis for efficient management. In some disasters, the waste generated in a single event is equivalent to 5–15 times the annual waste generation of the affected community [5]. In these situations, it is necessary to deal with abnormal amounts of debris and waste and due to the circumstances, it is impossible to apply the methods usually employed in waste management [6].

After a disaster, there are variations in waste, which considerably affect management activities: large numbers of food and water containers provided by relief teams, increased quantities of building debris and demolition, health and medical service material, waste-containing human remains, waste with historical value and bulky waste.

Disaster management in a more planned way began to be recognized in 1995, following the publication of the United States Environmental Protection Agency (EPA) document entitled Planning for Disaster Debris. The document was updated in 2008 and was called Planning for Natural Disaster Debris Guidance. Debris is the waste stream resulting from a natural disaster and often includes building materials, sediments, vegetative debris, personal property, and other materials [4, 23]. According to this document, a disaster management plan should include planning activities, support activities, and proper waste management. The activities related to each phase are listed below:

- Planning activities: (i) establishing a team responsible for the plan, (ii) defining a plan update schedule;
- Support activities: (i) identifying most probable debris types and its forecast; (ii) listing applicable legislation and regulations; (iii) inventory of actual capacity of waste depots; (iv) monitoring mechanisms; (v) pre-selecting temporary sites for waste storage; (vi) identifying equipment, administrative, and contractual needs; developing a communication plan; (vii) creating a disaster waste prevention strategy;
- Waste management: (i) creating a waste-removal strategy; (ii) preparing recommendations for identifying and handling harmful materials; (iii) determining the destination for each type of debris, such as: recycling, power generation, final disposition, and burning options.

Although the document is specific about debris, its guidance can be extended to disaster management in a broader way. Considering the activities listed, it is necessary to consider disaster management as a function of humanitarian logistics [13]. However, disaster management is a subject not yet explored, neglected in humanitarian logistics studies and research. Particularly, there is a gap in the development of methodologies associated with locating final or temporary deposits of disaster waste.

The availability of temporary deposit sites for disaster wastes is a paramount for the environmentally sound management of waste, enabling its segregation and recycling, as well as allowing a prompt removal of residues that hinder the recovery and reconstruction process [4, 5, 14]. The selection of these sites should include, besides economic and logistic aspects, socio-environmental criteria, such as distance from homes and water bodies, including groundwater [23].

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36.4 Disaster Waste Management in São Paulo

Disaster waste management is still an issue to be addressed in Brazil. The National Solid Waste Policy (PNRS, the acronym in Portuguese), sanctioned in 2010 by Law n^{o}. 12,305, emphasizes that municipalities must contemplate all types of waste generated in their Integrated Solid Waste Management Plans (PGIRS, the acronym in Portuguese). However, in its Article 19, Section IV, which deals with the minimum content of the PGIRS, there is no mention of the management of solid waste originated in disaster situations (BRASIL [3]). The existence of municipal plans for the management of solid waste does not guarantee that actions for the management of waste generated in disasters are contemplated, as is the case with the municipal solid waste plan of the municipality of São Paulo.

The solid waste management of the city of São Paulo is centralized in the City Hall, through the AMLURB, which also regulates the concession of services provided by private companies. The Municipal Law nº 13.478 of 2002 defined the services of urban cleaning and urban solid waste management [16]. This law divided the services into divisible ones; those relating to the collection, transportation, treatment, and final disposal of municipal solid waste; and indivisible services, those related to sweeping and urban cleaning.

The municipality PGIRS does not contemplate specific actions for managing disaster wastes. Much of the waste generated in the municipality, as in the case of floods, is considered bulky waste, within the scope of indivisible services. These residues consist of materials not removed by the routine collection of household solid waste, such as furniture, mattresses and old appliances, large containers and pieces of wood, vegetable waste from the maintenance of public or private green areas, among others [17]. Hence, the waste generated in disasters that fall under this category is collected by the regular system of bulk waste collection, without a differentiated quantification of these residues.

Construction and demolition waste (C&D) is also commonly generated in disasters. In the city of São Paulo, the population can discard up to 1 m^3 of these wastes in Ecopontos (voluntary delivery points) for free. These wastes and those disposed of irregularly in the city, are collected by service providers to Amlurb.

Thus, in the municipality of São Paulo, a large part of the waste generated in disasters is collected along with the regular system of bulk waste collection and/or C&D, with no specific guidelines or regular and routine quantification of waste from disasters.

36.5 The Fire in the Largo do Paissandu

At 1:30 AM, on May 1, 2018, a short circuit caused by the excess of household appliances connected to a single-power outlet caused an explosion on the fifth floor of the Wilton Paes de Almeida building, located in Largo do Paissandu, in downtown São Paulo city, causing a fire of great proportions. The fire quickly spread through the other floors, and around 2:50 AM, the building collapsed. The fire also hit a Lutheran church and other neighboring buildings. The disaster killed seven people who could be identified, and two persons were reported missing [19].

The occupation was non-regular. The building dwellers belonged to the Movimento Luta por Moradia Digna (Fight for Dignified Housing Movement) and were in the process of repossession by the owners. There is disagreement regarding the total number of people affected by the disaster. While the media [24] present 146 families and 372 people living in the building, Civil Defense data [18] show records for humanitarian assistance of 203 families, with 471 adults and 41 children.

The response to the disaster required the joint action of different municipal agencies, such as the Regional Municipal Government of Sé (responsible for the urban maintenance, Fire Department, Municipal and State Civil Defense, Municipal Assistance and Social Development Secretariat, Housing Secretariat, Health Secretariat, AMLURB, among others). Each of the agencies received an assignment, and the response coordination was assigned to the Fire Department. In order to have an integrated action of different actors, the State Civil Defense Coordination [18] and the Government Secretariat of the city of São Paulo were also involved.

The humanitarian response activity began at 10 AM on May 1. At 1:00 PM, donations began to arrive at the site [15]. The Brazilian Red Cross, São Paulo Branch (CVB-SP) was designated by the city hall as the focal point for receiving donations. The difficulties reported by the interviewees included the presence of different actors, which, albeit necessary, hampered a more effective integrated action, and the situation of social vulnerability to the families affected by the disaster.

36.6 Management of Solid Waste from the Largo do Paissandu Fire

In the case presented, the removal of the waste generated was essential for the action of the fire department. Since it was a fire followed by collapse, the disaster generated a significant amount of debris, as shown in Fig. 36.1. Due to the quantity and peculiarities of the case, these wastes demanded a logistics of differentiated collection, the wastes being quantified throughout the process.

For conducting the waste collection service, the City hall activated the AMLURB. The collection of the waste was carried out by a company hired to provide public janitorial services to the northwest region of the municipality of São Paulo (regions: Center, North, and west). In the contract, there is a clause allowing the collection of waste in emergency operations.

The collection service started on the day of the collapse and finished after 12 days. 557,755 tons of waste were collected, a quantity 7.8 times as high as the daily average of waste C&D collected in 2016, by the municipal public service, according to data from the National Sanitation Information System [20]. The wastes were sent to the

Fig. 36.1 Record of the debris generated in the event. Date: May 1, 2018. *Source* The authors' Collection

C&D waste landfill. The amount sent to the landfill exceeded the capacity stipulated in the contract.

The collected wastes were sent to the landfill without previous segregation. In disasters, response actions must be rapid and, therefore, may not conform to the hierarchy recommended in the international guidelines for solid waste management (prevention and reduction; reuse; recycling; recovery of waste and final disposal) [11]. However, as presented earlier, some countries have guidelines that determine temporary storage sites for the waste generated in disasters and recovery alternatives, such as recycling [4, 5, 14].

Besides the waste derived directly from the fire and collapse, disaster waste management should consider the waste generated in the response phase, such as those from donations to victims. In some cases, due to the general commotion of society and lack of planning, there is usually a large volume of donations, including unnecessary items, which are converted into solid waste after a screening process.

In the case presented, the CVB-SP carried out the management of donations the management. Approximately, 80% of the donations received were clothing for women, 15% for men, and 5% for children. After sorting, approximately 34% of the donations were discarded as waste or sent to institutions that reuse the tissue for other purposes. The percentage of donations discarded in the regular period is approximately 18%. Donations that occur as a result of a campaign with high publicity and/or disasters that cause high social commotion, as in the case presented, tend to have a higher percentage of discarding [15]. Still, according to reports, during a stay in the temporary shelter for the residents of the Wilson Paes de Almeida building, the donations were used for a short period and discarded, because there was no way to wash them in the place.

36.7 Conclusions: Lessons Learned, Gaps, and Future Challenges

The disaster of Largo do Paissandu and its consequences show that technological disasters, as well as natural disasters, can be predictable and recurrent in the absence of preventive actions. Aiming to prevent new events of a similar character, the Municipal Civil Defense carried out technical visits to irregular occupations in the Center of São Paulo.

Even though there is specific legislation for managing solid waste, there is a gap when these wastes are derived from disasters. There is no public policy for the prior definition of sites for this destination, or for the separation and classification of these wastes.

Regarding disposable donations and waste from shelters, these were treated as part of the urban cleaning and urban solid waste management services, and there is no specific policy for these materials. In a city, the size of São Paulo, such waste did not impact the routine of the public cleaning system, but in smaller cities, these materials can overload the system. Therefore, the case shows the importance of the existence of disaster management plans or of considering this type of waste in a differentiated way in the PGIRS.

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Part V
Logistics and Supply Chain Management

Chapter 37
Systematic Literature Reviews in Sustainable Supply Chain—SSC: A Tertiary Study

Bruno Duarte Azevedo, Rodrigo Goyannes Gusmão Caiado and Luiz Felipe Scavarda

Abstract Using the SR method, this paper cataloged 27 SSC LRs in order to identify the main topics, findings, and gaps for further researches. Despite the misunderstanding in the past, nowadays sustainability in SC is seen in a better way. However, some topics require more attention, especially the social ones.

Keywords Sustainability · SSCM · Management

37.1 Introduction

Over the past few years, sustainable supply chain management (SSCM) has become a topic of great importance to the practitioners and to the academics of the operations management (OM) community, which is reflected in the growing number of associated publications to the theme and by the several recent systematic reviews of the literature (e.g., Miemczyk et al. [1]; Touboulic and Walker [2]; Dubey et al. [3]).

SSCM is defined as "*the strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chains*" [4]. It is been considered as an advent of a new era that incorporates environmental performance, social performance, and economic contribution or what has been referred as an intersection of three spheres of sustainable development [5].

Environmental aspects of supply chain management (SCM) have been the leading focus of research [6]. In the beginning, sustainability initiatives focused on environmental issues only [7], limited to the field of green supply chain management—GrSCM, which consists in the action of integrating environmental concepts into SCM, starting from the design phase to managing the product after its life [8, 9]. However, as approached by Elkington [10], the concept of sustainability must meet the "triple bottom line" including social aspects on its analyses. This misunderstand-

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ing was particularly prevalent during the early conceptualizations of sustainability, what is a common phenomenon when a new paradigm emerges [6]. In its turn, SSCM is broader in its characterization, combining sustainability with efficient SCM, and being able to integrate the concept of GrSCM as a part of its field [11, 12].

SCM and sustainability are two important areas whose literatures have been increasingly explored in order to break down systematically and comprehensively its complexities, structures, processes, connections, and limitations [13], forging a more holistic and integrated view in both areas. Literature reviews (LRs) in SSCM are expanding and are progressively used to organize the literature. This context was the motivation to carry out a tertiary study in order to capture the current results of LRs in the SSCM. Tertiary literature review (TLR) synthesizes data and information in a particular subject [14, 15] and is particularly useful when several overlapping systematic reviews have been performed in a particular thematic area, to explore the consistency between the results of the individual analyzes [16].

Thus, this research aims to catalog the different SSCM LRs in order to identify the major topics covered, main findings, and gaps for further researches. It provides in a fair, rigorous, and open manner, a general understanding of SSCM research to academics and practitioners with synthesized knowledge regarding SSCM and serves as foundation for future works. Therefore, the sample was papers that highlight the integration of triple bottom line sustainability into SCM.

The next section of this paper describes the research methodology, and then, the results with the discussion are presented. The final section presents the author's main conclusions.

37.2 Research Methodology

The research is classified as exploratory and descriptive, with data collection from secondary sources (i.e., LRs) and qualitative approach through a thematic synthesis analysis to map the main areas of research and methodological procedures. This paper is based on assumptions of systematic reviews, such as to locate relevant existing studies based on prior formulated research questions, to have an explicit, reproducible strategy for screening and including studies, an appropriate analysis and synthesis of their respective contributions [17].

Based on the literature of SLRs [18, 19], this TLR composed of five steps: (1) *mapping research questions (RQs)*; (2) *setting search strings and databases*; (3) *determining inclusion/exclusion criteria*; (4) s*electing and evaluating studies* which includes: initial filtering by titles and keywords, secondary filtering by abstracts, applying *snowballing* and full-text content analysis; and (5) *reporting descriptive and thematic synthesis results*. The description of the first four steps is presented within this section while step 5 is reported in Sect. 37.3.

Based on the introduction, the following RQs are posed:

RQ1 What are the main research topics in SSC?

RQ2 What are the main findings obtained in critical literature on SSC?
RQ3 What are the gaps for further researches found out by the state of the art?

The keywords “supply chain,” “sustainability,” “green supply chain,” and “sustainable supply chain” were introduced using the Boolean logic “OR” associated with and “AND” with the main keywords related to literature reviews, which were pointed out by Thomé et al. [19] in their research protocol: “research synthesis,” “systematic review,” “evidence synthesis,” “research review,” “literature review,” “meta-analysis,” “meta-synthesis,” “mixed-method synthesis,” “narrative reviews,” “realist synthesis,” “meta-ethnography,” “state of the art,” “rapid review,” “critical review,” “expert review,” and “conceptual review,” complemented by the keywords “extensive review,” “structured review,” “integrative review,” and “integrative literature review.”

The search process used two search engines and indexing systems, i.e., Scopus (Elsevier) and ISI Web of Science (Thomson Reuters Scientific), both covering a significant amount of researchers in OM. Snowballing was conducted to go beyond the search keywords and database limitations, as recommended in [19]. The strings were continuously refined, resulting in 107 reviews found in Scopus and 125 in WoS.

The research combined the search keywords into title, abstract, or keywords, limited to papers published in peer-reviewed journals up to May 23, 2018. The inclusion/exclusion criteria followed [17] being related to knowledge area (environmental science, energy, engineering, business, management and accounting and chemical engineering), publication type (peer-reviewed academic journal and language (English)).

First, papers were refined by titles/keywords screening analysis and 106 records were excluded. Next, 126 articles were analyzed by abstracts, and 77 were excluded. Based on the full-text content analysis of 49 articles, a total of 24 reviews complied with the selection criteria. To ensure complete coverage, there was also an inclusion of three articles through snowballing, and thus, 27 reviews represent the bibliographic portfolio of this research.

After identifying the relevant articles, researchers discussed and created a database using Microsoft Excel worksheet. Articles were coded according to bibliographic characteristics of the source, type of study, and contextual dimensions like evaluated object, gaps, findings, topics addressed, sustainability dimensions.

In the next stage, there was a thematic synthesis analysis, in which individual articles were categorized and organized by concepts. In order to synthesize knowledge in a replicable and transparent way, the technique of content analysis was used, considered by Seuring and Gold [20] as an effective tool to analyze a bibliographic portfolio in a systematic and rule-governed way. The content analysis is based on the work of [21], through the following steps: (1) delimitation of the material to be analyzed; (2) descriptive analysis of formal characteristics: main journals and years of publication; (3) selection and construction of dimensions and analytical categories in an inductive way: thematic synthesis of content in four categories; (4) evaluation of the material according to the categories: summary of findings and gaps within these categories. As [22], an inductive approach was used to categorize knowledge from the literature, iteratively, testing and revising by the constant comparison between the categories and the information collected.

37.3 Results and Discussions

Observing the results, it is noticed that there is a great variety of authors approaching the subject (see Table 1 in Appendices). The majority of the publications came from journals that focus on sustainability such as Journal of Cleaner Production, Sustainability and Corporate Social Responsibility and Environmental Management. However, many articles were published in traditional OM journals such as Supply Chain Management: an International Journal, International Journal of Physical Distribution and Logistics Management, and International Journal of Production Economics. Confirming that SSCM is still a growing subject, it is interesting to notice that 19 of the 27 articles were published in the last five years (2014–2018), with the peak in 2017 (the TLR only cover the first 5 months of 2018).

In order to facilitate the understanding, the thematic synthesis results are shown in three different topics: SSCM research topics; main findings; and main gaps and implications for further researches.

Based on the inductive approach used by Seuring and Müller [12], the main research topics identified were grouped in: (1) dimensions of sustainability; (2) framework, models, and new definitions; (3) theories in SSCM; (4) managerial aspects aligned with SSCM. They are discussed next.

37.3.1 Dimension of Sustainability—Social Pillar

This research topic focuses on the holistic and integrated view of sustainability. One of the most recurrent issues is the gap around the social and human dimensions of sustainability [2, 13, 23–26]. There are two main reasons for this to happen: In the initial years of SSCM research, despite many managers have heard of the term sustainability, most supply chain personnel had very different viewpoints of what sustainability really is [4] and still not clear if it has changed. Second, given their more quantifiable characteristics, the prevalence of environmental and economic approaches to SCM seems to be correlated with the emphasis on performance. So, there is the need to develop key social performance metrics, with a methodology established for their assessment [27, 28], and also the need to address behavioral issues like human resource management and supply chain partner relationship management [7].

A better inclusion of the social pillar is needed [2, 23–26]. Key social performance metrics need to be identified, a methodology established for their assessment and the way to provide opportunities for impoverished communities explored [28]. To measure the triple bottom line, a logical step would be to develop scales the supporting facets of SSCM, and the relationships among resource dependence, external uncertainty, vertical coordination, imitability, and supply chain resiliency [4]. To achieve this, new business models should be developed which can evaluate non-economic values as equally as economic ones [27].

Mathematical modeling and multi-criteria decision-making tools have been extensively applied; however, the use of multi-criteria optimization as a methodology has been paid limited attention. Although a number of empirical studies have been conducted, more sophisticated statistical techniques and analyses may be used in the future [7]. In their article, Beske-Janssen et al. [29] indicate that studying the practical examples of major initiatives such as the Higg Index, developed by the sustainable apparel coalition which has been founded by leading apparel and textile companies, might provide interesting insights for the future development of measurement methods. Incorporation of sustainability reporting standard such as GRI is another fruitful research avenue that possesses the potential of contributing toward development and deployment of sustainability measurement standards for industries globally [30]. To investigate, for example, the relationship between company environmental and social performance versus economic performance, and the relationship between regulatory compliance and economic performance across members of a supply chain, Carter and Liane Easton [6], suggests that some data sources, such as Compustat, might be combined with other secondary data sources, such as the Wharton Research Data Service, the Dow Jones Sustainability Indexes, and the GRI.

37.3.2 Frameworks, Models, and New Definitions

This research topic proposes models, new roadmaps, frameworks, or guidelines to expand the definitions of SCM. As a strategy that will enable companies achieves SSCM [3], some authors included in their literature review the proposal of new frameworks and/or models and/or definitions for SSCM [2–5, 11, 12, 23, 27, 30–32]. These models/definitions capture all of the key characteristics of both business sustainability and SCM [11] and can be also a tool that will help organizations to: (i) diagnose their current situation through assigning importance factors to each of the drivers of SSCM and (ii) evaluate their SSCM strategy and these drivers to check whether there are factors where they need to be improved in order to achieve full realization of their strategy and hence competitive advantage [3].

Exploring the linkage among innovation, supply chain, and sustainability and identifying its characteristics, Gao et al. [32] propose a refined definition of sustainable supply chain innovation (SSCI). Arguing for "world-class SSCM (WCSSCM)," Dubey et al. [23] state that, "*as the majority of SSCM literature reviewed has attempted to use OR-based mathematical models or multi-criteria decision making tools, empirical research fails to capture some of the most important ethical dimensions and social issues.*" Establishing a synergistic relationship between the widely accepted principles of the international quality management standard ISO 9001:2015, key SCM principle of supply chain integration and the three pillars of sustainability, Bastas and Liyanage [30] presented a theoretical framework revealing the sustainable supply chain quality management (SSCQM).

However, although specific social risk management practices such as the SA8000 or code of conduct have been established, it appears that they are poorly used instrumentally rather than actually useful to employees. Since suppliers are forced to remain competitive and gain orders while simultaneously attempting to reduce costs, these specific practices can even cause pressure [24]. In this sense, once the traditional perspectives have been strongly influenced by neoclassical economics, the competitive paradigm seems to dominate the SSCM field. Sustainability issues may require a shift in mindsets and business models. This could allow transitioning to new conceptions of consumption and a firm's purpose as well as developing alternatives to the dominant discourse of growth [2].

It is also clear the need for more practical studies to test and/or validate the proposed models for SSCM [3–6, 24, 26, 31]. Some articles indicate the need for qualitative approaches such as ethnographies [6]. Others state that still exist some potential opportunities to quantitative study in SSCM and for modeling of real-life complex sustainable factors using dynamic programming, goal programming, etc. [5]. But in general, as the concept is still evolving, there is the need for both, qualitative and quantitative survey methods, especially at the supplier level located in developing countries [24, 31].

37.3.3 Theories in SSCM

This research topic focuses on the need for more theory building in SSCM. Resource-based view (RBV) and stakeholder theory are the most applied in SSCM [32]. However, some authors state that theory-building efforts in SSCM remain scarce, with the predominance of a few popular imported macro theories, having implications on the conceptualization of SSCM and the topics researched to date [2]. Systematic reviews portray that there is still much theoretical research and that few of these are validated through the use of statistical tools, mathematical modeling or at least an empirical study. This can occur because companies are not eager to share information related to the environmental and social dimensions unless it is made mandatory by regulatory authorities [31]. There are still few articles in the field using mixed-method approach or collection from multiple sources in order to generate a triangulation that answers research questions [5].

A theoretical background is often missing [3, 12, 33, 34], and survey research should follow taking up theoretic conceptualization of SSCM [35]. The richness of the settings for empirical studies needs to be exploited toward developing innovative theoretical ideas and the process of theory development in SSCM do not need to be restricted to the traditional deductive model involving the testing of hypotheses [2]. To Dubey et al. [3], there is a huge opportunity to examine current SSCM phenomena using integrated organizational theories. Following, from a theory development perspective, studies are mostly scattered and are far from reaching a theoretical consolidation [31].

37.3.4 Managerial Aspects Aligned with SSCM

This research topic uses modern methodologies and practices along the SSCM, contemporary strategies, or operations management. The first item that comes in this topic is the importance of information technology (IT). The reviews showed that IT systems have begun gaining attention from researchers and practitioners [7], supporting activities in the value chain such as technology development (e.g., relationships with universities to develop qualified supply chain managers) [4]. As [26], lean–sustainable, agile–sustainable, or even lean–agile–sustainable supply chain paradigms can be achieved by leveraging different integration categories and requires that new sustainable practices be implemented. However, in order to achieve sustainable results in the lean-agile SSC, distribution and logistics systems must be continually improved and information and communication technologies (ICTs) must be implemented to cooperatively integrate customers and suppliers [28]. Thus, the use of newer technologies and players would play a significant role for SSCM, as information systems bring benefits to organizations, suppliers, and customers, being considered an important tool for SSCM [25].

Another topic that comes in the managerial aspects of SSCM is the need for the use of indicators. Abbasi [27] states that "*free markets of open and dynamic supply chains should become fair, with globally agreed sustainability norms and minimum standards/requirements/rules*." In this sense, it is vital to have a set of standardized indicators that guide the agents of the chain and help in the measurement of sustainability. Global Reporting Initiative, GRI sustainability indicators, for example, which are developed through multi-stakeholder contributions, are a common approach that can help to structure the performance metrics, including a large part of the supply chain, and not only the first tier [29].

Last but not least, the relationship between assessment and collaboration of the actors of an SSCM needs further study [36]. Sustainability goals require close interaction between all firms involved to ensure simultaneously economic, environmental, and social performance on a product's total life cycle. Valuable and rare resources and capabilities emerging from supply-chain-wide collaboration are prone to become sources of sustained inter-firm competitive advantage [35]. In this sense, [7] state that researchers should focus on behavioral aspects like coordination, collaboration, and motivation of members in a supply chain. Big data analytics and data mining can be utilized to assess current practices in terms of their environmental impact, which could further lead to removal of inefficiencies and bottlenecks associated with supply chains.

37.4 Conclusions

The present work catalogs 27 LRs in SSCM with the objective of identifying the main topics addressed, main findings, and gaps for future research. Attesting the evolution of the theme in the recent years, several authors were found reviewing the literature and indicating new lines for further research. Despite the misunderstanding in the past, nowadays sustainability comes with a holistic perspective, including economics, environmental, and social issues as its pillars.

The main topics identified in the LRs were divided into: (1) dimensions of sustainability; (2) framework, models, and new definitions; (3) theories in SSCM; (4) managerial aspects aligned with SSCM. It became clear that a topic that will require more attention is the need to create standardized measurement/evaluation systems that are capable of understanding the three dimensions of SSC, especially the social ones. It is also important for the construction of multi-criteria optimization models that help model sustainable supply chains, considering various risks and even uncertainties. Furthermore, closed loop supply chain business models or frameworks are expected to be a better way to improve socio-eco-efficiency, reducing costs and environmental wastes (through reuse, recycling, and reduction of consumption—3Rs.), as well as increasing the value chain and stakeholders' participation.

Finally, although not mentioned in any of the articles, the authors understand that the fact that the industry is going through its fourth revolution can be a catalyst for SSCM. Given the increasing pressure for the continuous and synchronized updating of ICTs among SSCM members, in order to ensure greater integration along the chain and greater interoperability between systems, a suggestion for future work is to study the influences of Industry 4.0 technologies in the sustainable supply chain.

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Chapter 38
A Maturity Model for Manufacturing 4.0 in Emerging Countries

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Abstract Based on a systematic review and a focus group, this paper proposes a Manufacturing 4.0 maturity model in emerging countries to increase operational efficiency, improve the integration of physical and virtual structures and guide multiple stakeholders through a holistic view of the supply chain with social, environmental and economic implications.

Keywords Manufacturing 4.0 · Maturity model · Systematic literature review

38.1 Introduction

In recent years, some of the most advanced economies are making a global move to improve productivity and efficiency, as well as establish a dynamic and autonomous industrial production [1]. The fourth type of industrial revolution seeks to link modern information and communication technologies (ICT) initiatives in industrial systems, arousing the old computer-integrated manufacturing (CIM) idea into a new era [2]. This new scenario has been faced by countries such as Germany (Industrie 4.0), France (Nouvelle France Industrielle), the USA (Advanced Manufacturing Partnership) and Spain (Industry Connected 4.0), focusing on the improvement of communication among people, machines and resources to transform centralized processes of production control into a decentralized and autonomous model [3]. In this way, the German concept, Industry 4.0 (I4.0) can make a smart factory by applying advanced information and communication systems [4], being perceived as a strategy to achieve competitiveness in the future [5]. In this new era, digital technologies like cloud computing, big data, Internet of Things (IoT), wireless industrial network, cyber-physical systems—CPS, augmented reality, machine learning and

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cybersecurity are the main factors for the change of the manufacturing industry. The introduction of these technologies allowed companies to find solutions capable to transform the growing complexity in opportunities to ensure a sustainable competitiveness along with profitable growth [6]. However, the manufacturing industry still has few studies about the assessment or measurement of maturity of digitalization or I4.0 [6, 7] and even less regarding an emerging country. Although manufacturing systems and I4.0 technologies are complementary to each other, the literature that relates both remains scarce [8]. In this vein, this paper aims to critically review maturity models in I4.0 context in order to propose a maturity model (MM) to evaluate manufacturing 4.0. To do this, a systematic literature review (SLR) of the subjects under investigation was handled. This review explores the following questions:

- What are the reference maturity models/frameworks proposed on I4.0 era?
- What are the main attributes to evaluate the level of maturity of the manufacturing towards I4.0?'

Then, focus group interviews (FGIs) were applied at a technological institute in order to propose a maturity model for manufacturing 4.0 (3M4.0) in emerging countries, offering a holistic view of the supply chain with social, environmental and economic implications. In this sense, the proposition of a new model seeks to provide the manufacturing organizations a broad orientation, introducing a script to evaluate real situations, in order to control the progress and provide guidance for new improvement strategies.

38.2 Background

The three first industrial revolutions have brought mechanization, electricity and information technology (IT) for the human manufacture [9]. Since the first industrial revolution, the manufacturing sector has been testifying major changes in its original version, growing in every facets and acquiring more and more technologies [4]. The adoption of ICT into manufacturing industry started in the 1970s [5]. However, the main ideas of Industry 4.0 have been firstly published at the Hanover Fair followed by the formation of a working group chaired by Siegfried Dais (Robert Bosch GmbH) and Henning Kagermann from the German National Academy of Science and Engineering (Acatech) in 2011 [4] and have built the foundation for the Industry 4.0 manifesto published in 2013 by the Acatech [10]. Industry 4.0 embraces several technologies and associated paradigms, including radiofrequency identification (RFID), enterprise resource planning (ERP), Internet of Things (IoT), cloud-based manufacturing and social product development [11]. The cyber-physical systems (CPS) are considered the key technology for Industry 4.0 and their application in a smart factory is called cyber-physical production system (CPPS), in which industry 4.0 technologies can be clustered in data acquisition and data processing, machine-to-machine communication (M2 M) and human–machine interaction (HMI) [12]. The CPS are responsible for meeting the agile and dynamic production requirements and for improving the efficiency and effectiveness of the entire industry [11]. Today, new and disruptive business models are evolving around the elements of digitalization, and development geared towards Industry 4.0 has had a crucial influence and generated great opportunities in the manufacturing industry, relying on the establishment of smart factories, smart products and smart services incorporated in an internet of things and also called industrial internet [10]. Besides that the main features of Industry 4.0 are digitization, optimization, and customization of production; automation and adaptation; HMI; value-added services and businesses, and automatic data exchange and communication [11].

The goals of Industry 4.0 are to achieve a higher level of operational efficiency and productivity, as well as a higher level of automation [11]. For a successful implementation of Industry 4.0, the initial situation of industrial companies should be considered in a socio-technical view [12]. As Jayaram [8], the term Industry 4.0 consists of 'industries which are connected to the Internet for information sharing, production monitoring and industry management', including automation, industrial internet of things (IIoT), data sharing and cloud computing, percolating the concepts of *interoperability, transparency, technical guidance* and *independent choices*. As Stock and Seliger [10], the Acatech outlined the paradigm of I4.0 in the following dimensions: horizontal integration across the entire value creation network that describes the cross-company and company-internal intelligent cross-linking and digitalization of value creation modules throughout the value chain of a product life cycle; the end-to-end engineering across the entire product life cycle that describes the intelligent cross-linking and digitalization throughout all phases of a product life cycle and vertical integration and networked manufacturing systems that describes the intelligent cross-linking and digitalization within the different aggregation and hierarchical levels of a value creation module.

38.3 Methodology

This work has an exploratory and descriptive nature as it aimed at collecting the most relevant information available in the literature and it sought to reveal how information can be presented to society. The research strategy was adapted from Voss [13] with two aims: exploration and theory building. This study used a qualitative research method that was deployed in two stages. Stage one was a SLR of the maturity models proposed for Industry 4.0 era. This stage aimed to locate relevant existing studies based on prior formulated research questions, to evaluate and synthesize their respective contributions. This SLR consists of four consecutive phases: (1) formulating question(s) for the research; (2) selection and evaluation of studies; (3) analysis of the content of selected articles; and, (4) the description of results [14]. The identification of the keywords is extremely critical to a comprehensive and unbiased review. The search was limited to a set of keywords ('Industry 4.0', 'manufacturing technologies', 'information systems', 'Manufacturing 4.0', 'Maturity Model'), being conducted in the following databases: Scopus and ISI Web of

Science. The research had combined the search terms into title, abstract or keywords, limited to articles published in peer-reviewed journals and conference papers from acknowledge proceedings in English or Portuguese languages, which were available online until August 2018. Then, stage two provided a theoretical model by collecting rich qualitative data based on focus groups composed by two discussion rounds conducted from August 2018 to September 2018 with six experts (one mechanical engineer, one computer engineer, two professors of operations management and two production engineers) who are specialists in I4.0. FGIs aimed at discussing potential improvements in attributes and dimensions of I4.0 maturity models in order to increase added value of existing models for the creation of a proposed 3M4.0. The duration of each discussion round was about 60 to 90 min. The following four sessions were conducted for data collection: (1) overview of I4.0 maturity models, intended to share basic knowledge among participants; (2) brainstorming with experts about dimensions, attributes and levels for deployment of the proposed model, discussing key processes and technologies for its implementation; (3) zoom and filter session presenting the proposed model and evaluating theoretical and practical implications, including outcomes in environmental, social-technical, and economic dimensions; and (4) details on demand session, which was a description of the workflow of each dimension for application in future studies. At the end, a 'lesson-learned' workshop was held with all specialists to point out social, environmental and economic implications.

38.4 Results

This section points out the main I4.0 maturity models reviewed in literature and findings from an empirical study in Brazil. Table 38.1 shows the main proposed maturity models for evaluating I4.0 and their respective key attributes and levels.

As can be seen from Table 38.1, 19 maturity models/frameworks were found, most of them with more than three dimensions and three levels. It is noticed that most of the MMs available in the literature have European origin—predominantly German—and are idealized to evaluate the maturity level of manufacturing in developed countries. Thus, to develop a maturity model for emerging countries, one must take considerations the socio-economical differences regarding already economically consolidated countries and emerging countries.

Furthermore, FGI discussions showed that there was a consensus regarding the importance of the integration between human and technological factors across the supply chain and the operations within organizations. In this context, industrial experts point out that technologies and knowledge management are critical attributes. Experts also believe that advances in manufacturing enable decentralization in planning and control, customization of networks according to new business models and smart products and services. In this sense, just as it is relevant to have interoperability between systems, it is also essential that processes and members (downstream and upstream) be aligned, making supply chain management (SCM). Therefore, as I4.0

Table 38.1 I4.0 maturity models/frameworks

Model (source)	Attributes
The connected enterprise MM [17]	4 dimensions related to technological readiness. No further information is provided related to aspect dimensions and the creation process of them
IMPULS—I4.0 readiness [18]	6 dimensions: strategy and organization, smart factory, smart operations, smart products, data-driven services, and employees
A MM for I4.0 readiness [19]	8 dimensions: strategy, leadership, customer, products, operations, culture, people, governance, and technology
Empowered and implementation strategy for I4.0 [20]	No information provided regarding the MM
Industry 4.0/digital operations-self assessment [21]	6 dimensions: business models; product & service; portfolio market & customer access; value chains & processes; IT architecture; compliance, legal, risk, security & tax; and organization & culture
MM for industrial Internet [22]	The research is not completed yet. No information regarding the MM
SIMMI 4.0 [16]	3 dimensions: vertical integration, horizontal integration, cross-sectional, and technology criteria
A categorical framework of manufacturing for Industry 4.0 and beyond [9]	3 dimensions for the intelligence level: control, integration, and intelligence 3 dimensions for the automation level: machine, process, and factory
Stage process MM for I4.0 [23]	3 dimensions: envision, enable, and enact
SPICE-based I4.0—MM [15]	5 dimensions: asset management, data governance, application management, process transformation, and organizational alignment
DREAMY [6]	5 dimensions: design and engineering, production management, quality management, maintenance management and logistics management
Capability MM *Human* [24]	13 dimensions: acceptance and application of new techs and media, professional competence, learning competence, corporate strategy, human resources dev. strategy, organization and democratization, flexible working models, health and safety, information and communication, employer branding, change management, process orientation, and knowledge management

(continued)

Table 38.1 (continued)

Model (source)	Attributes
A MM for smart manufacturing workshop [25]	8 dimensions: unloading systems (ALU), levelled and balanced mixed flow production (LBM), parameters optimization system (POS), real-time monitoring system of production process (RMP), digital logistic tracking system (DLT), high-precision online testing and inspection system (HPD), automatic fault diagnosis and warning (AFD), and integrated information systems (IIS)
M2DDM [7]	3 dimensions: manufacturing Level, manufacturing control level, Enterprise Control Level
A digitalization MM [26]	3 stages: strategy, processes, and activities
The Logistics 4.0 MM [27]	3 aspects of logistics: management, flow of material, and flow of information
AMM [28]	***Strategy Axis***: business, technology and networking & integration strategy indicators ***Maturity Axis***: infrastructure for I4.0, analytical skills and absorptive capacity maturity indicators ***Performance Axis***: benefits (economical, social and environmental) of I4.0 adoption, Impact on efficiency performance indicators
MM for business model management in I4.0 [29]	9 dimensions: costumer segment, value proposition, channels, customer relationship, source of income, key resources, key activities, key partners, and cost structure
Evolutionary maturity based I4.0 Migration Model [30]	3 Dimensions: technology, organization and personnel

aims at added value improvement over the production operations, we assume, after discussion with industry experts, that four maturity levels would be adequate to help companies to assess the maturity of their operations management and SCM with regard to I4.0.

38.5 Discussion

In this section, to validate the necessary attributes and technologies to better assess the digitalization of manufacturing in emerging countries, theoretical and applied results were triangulated, thus providing a new maturity model for manufacturing 4.0 (Fig. 38.1).

Fig. 38.1 Maturity model for manufacturing 4.0 (3M4.0)

As Gökalp et al. [15], it is important to notice that successful transformations happen in levels. As shown in Fig. 38.1, 3M4.0 has four levels which are adopted from conceptual to self-optimized and the aspect attributes defined for each level are developed based on: SCM; technology; sales and operations management; knowledge, skills and attitude. The conceptual level represents manufacturing automation to identify problems, performance, bottlenecks, quality and safety of operations through technologies such as scanning, instrumentation and data analytics for an accurate diagnosis of workflows. The managed level refers to an organization that, in addition to automatically identifying the orchestration of its operation, performs a post-processing of data to identify a causal link between cause and effect, as well as suggesting operational improvements in future operations. The advanced level, however, calls for the use of data prediction, since it has a pragmatic interoperability and promotes automatic actions before a problem or bottleneck appears. Above all, the self-optimized level refers to an autonomous factory that makes decisions and adapts itself to the work processes necessary to an efficiency.

38.5.1 Social, Environmental and Economic Implications

The theoretical model advocates a socio-technical approach since it needs to collect tacit knowledge of the people, as well as, technological to train and equip factories in favour of digital transformation. People are catalysts of this process, so they must be trained and be able to deal with a new digital and technological scenario that demands changes in the organizational culture. Regarding the environmental implications, the maturity model aims to have more control over the entire process that allows sustainable practices to be achieved through waste reduction and recycling of obsolete products through sustainable additive manufacturing. The economic implication is clear and objective, since the maturity model provides a continuous and incremental improvement approach, allowing the conscious and gradual use of the information and communication technologies inherent in the precepts of I4.0.

38.6 Conclusions

The purpose of this study was to review the main I4.0 maturity models and—with the help of Industry 4.0' experts—to explore their main attributes in order to propose a MM for manufacturing 4.0. Through a systematic literature review, we could demonstrate that no maturity model currently exists that meets the needs of manufacturing 4.0 in terms of socio-technical skills, production operations management and SCM views, considering the context of an emergent country. As a result of the review, 19 MMs have been identified, and they are analysed by six experts to compare their characteristics in order to satisfy the need for a I4.0 maturity model for manufacturing. 3M4.0 is proposed in this study, and it has a holistic approach consisting of the assessment of SCM; technology; sales and operations management; and knowledge, skills and attitude. The 'lesson-learned' workshop with experts also allows for the introduction of a roadmap towards I4.0 implementation (Fig. 38.2). The four-step Roadmap towards Manufacturing 4.0 implementation is applicable for a set of four fields of actions (identifying, understanding, predicting and decentralizing).

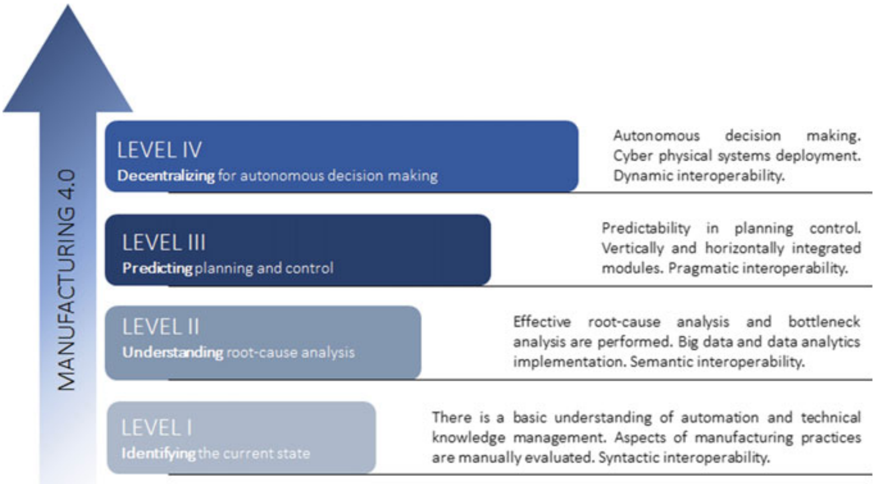

Fig. 38.2 Roadmap towards manufacturing 4.0

38.6.1 Limitations and Suggestions for Further Research

One limitation of the present work is that the perceptions of participants in the focus groups introduce subjectivity. In addition, the sample of experts was small and does not allow generalization of the results. However, the insights provided with this sample provide helpful insights to researchers on the evaluation of manufacturing 4.0. Besides that, within this paper, we present the first version of our maturity model for manufacturing 4.0. Therefore, as in Leyh et al. [16], 3M4.0' development is not yet fully complete and the next steps include: (1) conducting several expert interviews with a broader sample and model adjustments based on the experts suggestions if necessary (2nd iteration); (2) FGIs with different Brazilian companies to test the model's practicability (3rd iteration); and (3) surveys with companies to evaluate their performance in manufacturing 4.0 (4th iteration). As part of future work, it is planned to conduct multiple case studies in order to validate the usefulness and applicability of the proposed maturity model.

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Chapter 39
Forecasting Tanker Freight Rate

Rodrigo Ferreira Bertoloto and Fernando Luiz Cyrino Oliveira

Abstract The practiced freight rates have a great impact on the international trade of crude oil and oil products. This paper aims to verify the performance of dynamic regression models in short-term maritime freight forecasts in the spot market of a crude oil export route.

Keywords Freight rate · Tanker · Dynamic regression

39.1 Introduction

Maritime transport of crude oil and oil products is a key component of the petroleum industry's supply chain, integrating suppliers and customers located in different geographic regions. In 2017, 11,617 million tons of cargo was seaborne transported, of which 2,005 million tons of crude oil and 1092 million tons of oil products. The fleet of tankers corresponds to approximately 26% of the tonnage of the world fleet [3]. In this context, the freight rates practiced have a great impact on the international trade of these goods.

For some routes that comprise the main commercial flows of crude oil and oil products, consultancies and independent institutions disclose reference values of the spot market freight expressed in Worldscale rate.

The shipping market for oil tankers is basically based on two distinct mechanisms for agents interested in buying and selling transport. It is possible to contract transportation capacity through the modality of contract for a defined time, or period, called time charter party (TCP). Alternatively, it is possible to contract freight for

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a trip (voyage charter party), where contracting is given for a specific voyage from one point to another. This market is still known as spot freight market.

The freight of oil tankers in the spot market is usually traded using his own market's valuation unit, known as Worldscale [14].

Worldscale consists of standard flat rates (WS100) from any tanker port to any tanker port in the world. For each voyage is negotiated the percentage to be applied to the standard freight of the route. This percentage is the WS rate, which reflects the oil tankers' spot market.

The main objective of this paper is to verify the performance of time series models, through dynamic regression, in short-term maritime freight forecasts of the spot market for an oil export route from West of Africa to China.

The study also aims to compare the predictive capacity of these models with traditional methods widely discussed in the literature, such as exponential smoothing and ARIMA models.

Another objective of this study is to compare the forecasting performance of these models with the performance of a large Brazilian oil company real methodology. In order to evaluate the possibility of univariate models and dynamic regression models being used as a forecasting tool for tankers freight rate and to propose a new approach to forecasting the company's freight.

The article is organized as follows. Section 39.2 presents the literature review, which considers the academic efforts on modeling the freight market for shipping, the forecasting methods that were used and, finally, the parameters used in the performance measurement of the predictions of this study. In Sect. 39.3, the implementation is discussed and the respective results of the freight forecast models for the route studied are presented. Finally, Sect. 39.4 brings conclusions and recommendations for future research.

39.2 Literature Review

Although there are well-established market practices for the negotiation and contracting of the shipping service, there is no consensus on the methods for forecasting freight of tankers that will support this chartering process.

To reflect the non-stationary and nonlinear nature of the tanker freight market price series, as well as to promote understanding of volatility characteristics, Zhang and Zeng [16] proposed a method based on empirical decomposition (EMD—Empirical Mode Decomposition) and BEKK multivariate GARCH (MVGARCH). The time series used in the study was the BALTIC BDTI index, which consists of eighteen representative routes involving the ship classes Aframax, Suezmax, and VLCC.

In an even broader approach than that proposed by Zhang and Zeng [5], Geomelos and Xideas 16] applied multivariate models (VAR and VECM) and univariate models (ARIMA, GARCH, and E-GARCH) to predict freight of five classes of tankers and three classes of dry cargo ships.

Li and Parsons [9] investigated the predictive ability of artificial neural networks for maritime business forecasting and compared it with the ARMA model. The variables considered in the study were (i) freight rate for tankers of dirty products on a Mediterranean route, (ii) demand for tankers, and (iii) supply of tankers for the period from January 1980 to October of 1995.

Santos et al. [10] verified the performance of artificial neural networks (ANNs) to predict period charter rate for VLCC tankers for 1 year and 3 years' Time Charter Party. Six lagged explanatory variables were considered to construct the predictive ANN model: VLCC period charter rate for 1 year and 3 years' TCP, freight rate spot market for the Persian Gulf to Japan route, sale value of the ship for demolition, world crude oil production, delivery of new ships by shipyards and ships withdrawn from the fleet for demolition or loss. ANN consistently provided better predictions than the ARIMA elementary model.

Eslami et al. [4] developed a hybrid model of tanker freight forecasting based on ANN and adaptive genetic algorithm (AGA). The model employs three variables, fleet productivity, oil price, and bunker price, and compares the performance of the hybrid model with two traditional approaches, regression and moving average, as well as the findings of the artificial neural network studies. Also using ANN, but this time combined with a conditional self-regressive heteroscedasticity model, Ji et al. [8] studied the crude oil price in determining the freight rate in shipping.

In this article, we use dynamic regression model that, according to [13], combines the dynamics of time series and the effects of explanatory variables. The model incorporates lags of the dependent variable and also lags of the exogenous variables and the autoregressive error term. Details are available in [7].

For purposes of comparison with traditional approaches of the time series literature, we use the exponential smoothing method and the Box & Jenkins family models.

For further details, see Hyndman and Athanasopoulos [6] and Souza and Camargo [12].

The obtained models will be evaluated with mean absolute percentage error (MAPE) and Bayesian information criteria (BIC) developed by Schwarz [11].

39.3 Implementation and Results

In the study scope, the following time series was used to implement the forecast models:

– Monthly series from January 2010 to June 2018 (102 observations) of the freight rate (WS) of VLCC's oil tankers for the route from West of Africa to China, reported by the Baltic Exchange as BDTI TD15.

This series was extracted from the Shipping Intelligence Network database of London-based Clarksons and considered a benchmark company in shipping market.

The London-based Baltic Exchange [1] is the world's leading source of independent maritime data.

The chart representation of the TD15 series based on the 2018 flat rate is shown in Fig. 39.1.

It is important to note that all applications were performed considering the logarithmic transformation, on both sides of the equation, usually known as log-log. For more details, see Zanini [15]. Forecast Pro for Windows version 3.50 [13] was used to apply forecasting methods.

The variables tested in the model are presented in Table 39.1.

To construct the dynamic regression model, the bottom-up strategy was used; that is, it started from a simple model with only a few variables and refined it, including new variables, evaluating the lags of both the dependent variable and explanatory variables, until finding an appropriate model.

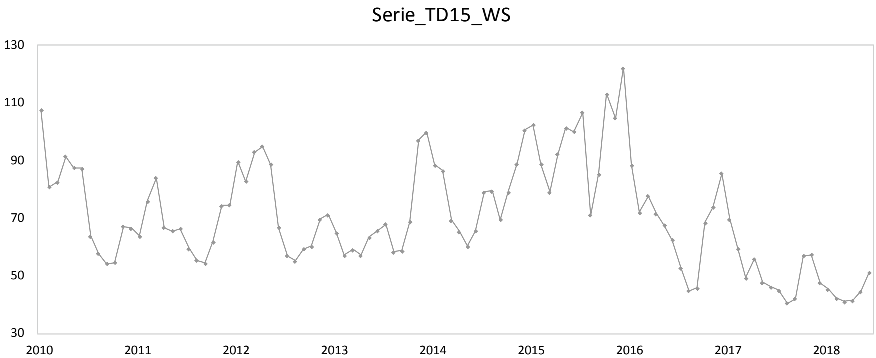

Fig. 39.1 TD15 series in WS from January 2010 to June 2018

Table 39.1 Variables tested in the dynamic regression model

Variable	Unit
Freight Rate TD15 (dependent variable)	WS
World crude oil production	Mbarrels/day
China crude oil imports	Mbarrels/day
Japan crude oil imports	Mbarrels/day
US crude oil imports	Mbarrels/day
VLCC Fleet	Mdwt
Vessel demolition market value	MUS$
Bunker price	US$/mt
Brent crude oil price	US$/barrel

bunker = fuel of ships; dwt = deadweight, a measure of how much weight a ship can carry; mt = metric tons; WS = Worldscale

It was found a model that presented adequate adjustment of the estimated parameters, coherence of the signals of the coefficients found and residues with characteristic of white noise, that is, independent and identically distributed.

The dynamic regression model has the following equation:

$$\begin{aligned}\ln(Z)_t =& 3.35\ln(\text{world crude oil production})_t - 2.42\ln(\text{VLCC fleet})_t \\ & - 0.40\ln(\text{US crude oil imports})_t + 0.83\ln(Z)_{t-1} - 0.26\ln(Z)_{t-2}\end{aligned}$$

where $\ln(z)_t$ is the logarithm of freight rate TD15 at time t, $\ln(\text{world crude oil production})_t$ is the logarithm of world crude oil production at time t, $\ln(\text{VLCC fleet})_t$ is the logarithm of the VLCC's ships fleet at time t, $\ln(\text{US crude oil imports})_t$ is the logarithm of US crude oil imports at time t, $\ln(Z)_{t-1}$ is the logarithm of freight rate TD15 at time t − 1, and $\ln(Z)_{t-2}$ is the logarithm of freight rate TD15 at time t − 2.

In choosing the appropriate model, one must take into account not only the significance of the parameters, but also their consistency with economic theory. In this sense, the model chosen, besides presenting residues with characteristics of a white noise, the variables that entered the model are significant and the estimated coefficients are coherent:

- The relation of TD15 to the world crude oil production is positive; that is, the higher the production, the higher the freight value.
- Regarding the variable VLCC fleet, the relation is negative, since the larger the fleet (capacity supply), the lower the freight and vice versa.
- The US import also establishes a negative relation with the value of the freight, because the larger this variable, the greater the availability of ships in the Atlantic, in other words, greater the number of ships wishing to return to the Middle East (export crude oil region). Therefore, it is opportune for shipowners to offer a discounted freight on the route being analyzed.
- Finally, the lags of the dependent variable can be explained by the cycle time of the trip, which on average is approximately 64 days. The negative coefficient of TD15 in t − 2 is due to the fact that the period for the ship to reposition itself in the loading area is approximately 2 months, that is, the time needed for the ship to be offered to the market. Similarly, the positive coefficient of the dependent variable lagged at 1 month is explained by the unavailability of ships in the loading area until the travel cycle time is completed.

To compare the performance of the dynamic regression model with the univariate models, based on the methodology proposed by Hyndman and Athanasopoulos [6], the exponential smoothing method with no trend and additive seasonality was identified, which best fit the time series under study. Based on the Box et al. [2] methodology, after all the diagnoses and findings, the SARIMA $(1,0,0)\text{x}(1,0,0)_{12}$ model was identified as the most appropriate for this study.

The in-sample performance of the models used was evaluated from the MAPE, BIC and also the explanatory coefficient (adjusted R^2), according to Table 39.2.

Table 39.2 In-sample performance of univariate models and dynamic regression models

	Exponential smoothing	ARIMA	Dynamic regression
MAPE (%)	9.9	10.8	**9.4**
BIC	9.0	9.3	**8.9**
R^2 Ajustado (%)	76.4	74.7	**78.8**

Table 39.3 Oil company's current methodology performance and the performance of the models evaluated in this study

MAPE (%)					
H	N	Exponential smoothing (%)	ARIMA (%)	Dynamic regression (%)	Methodology (Brazilian oil company) [%]
1	12	7.6	9.4	7.0	**8.5**
2	11	11.4	15.6	11.3	**14.0**
3	10	11.6	18.1	9.9	**17.6**

Note H = Horizon; N = Number of forecasts

After evaluated the predictive performance of the univariate models and the dynamic regression model, it was also tried to compare the performance of these models with the performance of the freight rate (WS) forecast of the route studied here of a large Brazilian oil company, for a horizon of 3 months, as is the forecast currently in the company.

The results presented in Table 39.3 demonstrate the predictive capacity of the models studied and, due to their best results presented in comparison to the performance of the current methodology of oil company, the possibility of using this forecast system prototype developed in this study as a business tool for forecasting oil tankers' freight rates.

39.4 Conclusions

The few studies on freight forecasting in the maritime transport market found in the literature explored several statistical methods, but in the research carried out, studies involving the dynamic regression model were not found. This is a differential of this study in relation to those found in the literature.

The univariate models, exponential smoothing and ARIMA, proved to be adequate for modeling forecasting of oil tanker freight. However, the incorporation of exogenous variables into the forecast models demonstrated a representative improvement in the accuracy of freight forecasts. This conclusion met the main objective of this study, which was to verify the performance of time series models, through dynamic regression, in maritime freight forecasts of the spot market.

One point that deserves greater attention in this study is the comparison of the performance of each of the three models evaluated with the results of a methodology used by a large Brazilian oil company. The product developed in this article showed the viability of univariate and causal models to be used as a business tool to predict the oil tankers' freight rate.

This study, however, is restricted to the application to freight rate (WS) of VLCC class oil tankers to the route from West of Africa to China. This fact appears as an opportunity to apply of the same prediction models in other routes and for other classes of ships. It would be interesting to apply the model to the remaining routes of the Baltic Exchange.

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Chapter 40
Developing a Holistic Implementation Design Model for Supplier Portals in the Automotive Industry

Peter Verhoeven and Benjamin Nitsche

Abstract The purpose of the paper is to develop a holistic design model for supplier portals in the automotive industry, which will examine a set of success factors in different management areas and will therefore be a guiding hand for practitioners when implementing a supplier portal.

Keywords Supplier management · Supplier portal · Success factors

40.1 Introduction and Theoretical Background

The automotive industry is worldwide acknowledged as a driving force in terms of economic development, new technologies, innovation, and employment and is thus widely regarded as a key industry, which has recorded strong growth in importance and influence in recent decades.

Increasing complexity of material flows between suppliers and manufacturers is responsible for the growing importance of information networks. This means that an implemented information platform that enables data exchange across system boundaries becomes a success factor in the supply chain. The decisive factor here is real-time data exchange in order to minimize response times within the supply chain. This data exchange within and between companies can be achieved through collaborative supplier portals [17]. A supplier portal offers the possibility to provide and share different processes and information online. These include reporting options, communication with suppliers, or confirmations of orders or appointments by the suppliers. The standardized interaction via a supplier portal helps to overcome system breaks and peer-to-peer connections and thus offers the possibility of coordinating all transactions between a company and its supply network in real time via a uniform data basis [5].

While the influence of these systems on different constructs, such as logistics or partnership, is partly investigated in the literature [4], there is a lack of presentation

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of implementation procedures of the same systems. Basic implementation options, especially in the context of supplier evaluation, were presented sporadically [7], architectures of a supplier portal were considered from an IT perspective [17], or a generally valid procedure model for the introduction of supplier portals was developed [13]. However, there is a lack of a holistic design model that describes and correlates success factors and areas on a technical level and thus provides the user with specific tools for implementation. The aim of this paper is therefore to develop a design model for the successful conception of a supplier portal in the automotive industry.

40.2 Research Design

In order to develop the holistic implementation design model for supplier portals, a multi-method approach was utilized and data triangulation was performed. Therefore, we conducted a systematic literature review and 20 expert interviews to identify success factors for the implementation of supplier portals. The multi-method approach ensured to increase our theoretical understanding, widen our insights with practitioners and minimize the methodological shortcomings of literature reviews.

The methods chosen for the literature review are the database search. There we developed a search string to analyze the database from Business Source Complete (EBSCO). The search string (Fig. 40.1), which was developed in our research group, involving two researchers and one practitioner, is structured in four blocks. It includes different parameters in relation to the object of investigation: (1) enterprise portals or equivalents, (2) implementation or equivalents, (3) success factors, and (4) purchasing or equivalents.

The search string led to 369 articles in the EBSCO database, which were then assessed regarding the inclusion criteria: (1) abstract or summary indicates company

((AB ERP **OR** TI ERP **OR** SU ERP **OR** KW ERP) **OR** (AB Enterprise Resource Planning **OR** TI Enterprise Resource Planning **OR** SU Enterprise Resource Planning **OR** KW Enterprise Resource Planning) **OR** (AB portal **OR** TI portal **OR** SU portal **OR** KW portal) **OR** (AB information technology **OR** TI information technology **OR** SU information technology **OR** KW information technology))
AND ((AB Success Factors **OR** TI success factors **OR** SU Success Factors **OR** KW Success Factors) **OR** (AB Antecedents **OR** TI Antecedents **OR** SU Antecedents **OR** KW Antecedents) **OR** (AB successful implementation **OR** TI successful implementation **OR** SU successful implementation **OR** KW successful implementation))
AND ((AB Enterprise Resource Planning **OR** TI Enterprise Resource Planning **OR** SU Enterprise Resource Planning **OR** KW Enterprise Resource Planning) **OR** (AB supply **OR** TI supply **OR** SU supply **OR** KW supply) **OR** (AB portal **OR** TI portal **OR** SU portal **OR** KW portal) **OR** (AB supplier **OR** TI supplier **OR** SU supplier **OR** KW supplier) **OR** (AB purchase **OR** TI purchase **OR** SU purchase **OR** KW purchase))
AND ((AB Implementing **OR** TI Implementing **OR** SU Implementing **OR** KW Implementing) **OR** (AB Implementation **OR** TI Implementation **OR** SU implementation **OR** KW Implementation))

Fig. 40.1 Search string

portals, supplier portals, or ERP systems, (2) abstract or summary indicates success factors, antecedents, or successful implementation, (3) abstract or summary indicates procurement or suppliers, (4) abstract or summary indicates an implementation, (5) English language. Through this, we identified 147 relevant articles. By qualitatively analyzing those 147 articles, we were able to identify 926 success factors in the context of supplier-related information systems. These 926 factors showed overlap.

In a second step, we conducted expert interviews with 20 practitioners of the automotive industry (12 practitioners from an OEM + 8 practitioners from suppliers). This helped us identify 80 success factors, leading to a total number of 1006 success factors (literature review and expert interviews combined).

To synthesize those success factors, the Q methodology was performed as applied by Nitsche and Durach [19]. Therefore, both authors individually read every single success factor written on a single card and assigned them to groups if they showed a thematic overlap until all cards have assigned. Subsequently, both results were presented to each other, and similarities and differences between assignments were discussed leading to a condensed set of 31 success factors. After that, in an open discussion within the research group, those 31 success factors were grouped in management areas and assigned their corresponding project phases.

40.3 Review Results

The head of the holistic implementation design model is formed by the project phases. These phases are supplemented by the success factors that have been extracted, assigned and modeled from literature and expert interviews. The success of a project to design a supplier portal is thus determined by four management areas. The success factors are assigned to each of these management areas and to the project phases and thus indicate their significance or relevance within the individual phases (Fig. 40.2).

The management area **top management** contains the four success factors *strategy, vision, support*, and *resources*, which must be considered during the implementation of a supplier portal.

As part of the *strategy*, it is the task of top management to develop an implementation strategy based on the management requirements. Among other things, it must be decided whether more processes are to be adapted to the new supplier portal and thus a standardized solution is to be sought or whether the supplier portal is to be adapted to existing processes, which corresponds to an customer-specific solution. The implementation of a supplier portal is a technical, economic, and organizational project, which is why the balance between strategy and technology plays an important role [3, 15, 18, 21].

Based on the strategy, top management must combine a *vision* and goals with the implementation of the supplier portal. In addition to the potential benefits of implementation, it is necessary to identify expected costs, risks, and resources required to justify investments and to provide a clear definition of vision and objectives in relation to economic requirements [8, 11, 18, 20, 28].

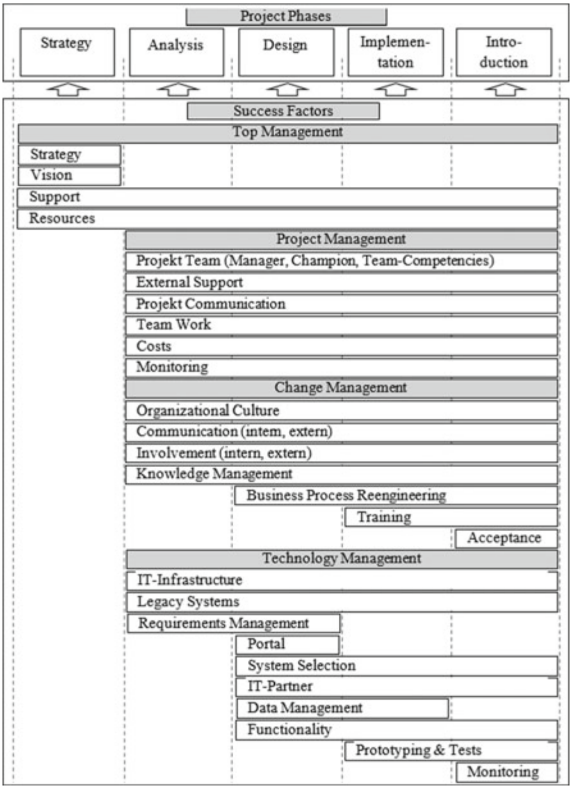

Fig. 40.2 Implementation design model

The success factor *top management support* (also referred to as Top Management Commitment) is the most frequently mentioned in the literature. It therefore represents a role in the implementation of a supplier portal and is indispensable for successful implementation. Top management must therefore be prepared to be involved in the implementation process. The main task is to mediate between the various departments affected by the supplier portal and other stakeholders and to avoid or resolve conflicts [11, 14, 18, 21, 22, 24].

Another success factor from the top management sector is the topic of *resources*. In detail, it is a matter of making them available. In addition to an adequate financial budget and employees assigned to the project, this also includes access to IT systems and other work equipment for which top management is responsible [1, 11, 18, 21, 25, 29].

The management area **project management** contains four success factors, which must be considered during the implementation of a supplier portal.

The success factor *project team* can be divided into the *team competencies, team manager*, and *team champion*. The implementation of a supplier portal requires a balanced team composition with regard to *competencies* and stakeholder representatives. For example, technical and economic experts as well as end users of the portal (employees and suppliers) must be integrated. If capable employees or team members are not available, external support must be called upon. The *project manager* is responsible for the project and leads the project team. He should have authority and be legitimized by top management to make quick and efficient decisions. This also requires working with stakeholders outside the team, so empowering management is essential to support its decisions. The project manager can thus be regarded as a central contact and link between management, project team and stakeholders. The *project champion* is a so-called high-level executive sponsor, which means that he is sent from senior management to establish the project throughout the organization. He thus has an important role in the change management process and is responsible, among other things, for motivating the team and building consensus across the entire project. In addition to the project manager, he is thus an interface to top management. This enables them to ensure that resources and support are provided by top management [6, 8, 11, 12, 18, 20, 27].

Due to the complexity of implementing a supplier portal, it is necessary to fall back on experienced consultants (*external support*) and their expertise. The scope and type of external consulting services depend on the internal expertise that can be provided by the company itself. The use of external support is possible in different phases, from conception to implementation and introduction [9, 14, 27, 30].

Project monitoring is the continuous monitoring of project progress. This is necessary in order to achieve the completion of the project and the associated sub-goals, as provided for in the project plan [3, 21, 24].

Project communication within the framework of project management includes agreements within the team as well as the communication of results and intermediate statuses to external parties and other departments involved. Clear and effective communication is necessary for successful project work at all levels [1, 9–11, 18].

The cross-departmental functions of a supplier portal affect various areas within the company, which is why it is necessary to coordinate the work (*collaboration*) and to work together in the design and implementation of the supplier portal [1, 11, 16].

The success factor *costs* describes the adherence to the budget provided by management for processing the project. Overruns endanger the success of the project [9, 25, 27].

The third management area in the implementation of a supplier portal is **change management**. This is made up of the following success factors.

The success factor *communication* in the area of change management comprises all communication that does not take place within the framework of project management to outsiders and can be divided into the success factors *internal communication* and *external communication* [3, 11, 21, 27].

During and after the implementation, it is necessary to *train* all users (employees and suppliers) in new processes, explain the systems to them, and provide training materials. Furthermore, a central help desk or contact person should be set up and workshops organized. For this, it is necessary to select suitable methods and training partners [10, 11, 21, 31].

Knowledge management is a key success factor during implementation. Generated knowledge must be made available in the organization from the beginning of the project in order to be used in further implementation steps or similar projects. In addition, it is helpful to draw on existing knowledge from previous projects and to transfer as much knowledge as possible from the IT service provider and external consultants to the company in order to ensure autonomous work with the supplier portal [8, 26].

Acceptance is critical when using a supplier portal. The goal must be that the supplier portal is accepted and used on this basis both by users in the company and by suppliers. To this end, it is important to organize an appropriate environment and to motivate those involved or create incentives for use [3, 21].

In the implementation process of a supplier portal, the *involvement* of users and suppliers is of great importance. The success factor inclusion can therefore be divided into the two factors *internal involvement* and *external involvement* [8, 31].

Business Process Reengineering (BPR) describes the adaptation of business processes to the new system. In this context, the extent to which adjustments to the processes are necessary or whether the system can be adapted to existing processes must be considered. It is important to introduce standards and to plan new activities and workplaces [1, 11, 21].

The success factor *organizational culture* describes how the company is organized and managed and thus determines the success of an implementation project. The open-mindedness toward new things or the avoidance of uncertainties contributes significantly to the acceptance and application of the portal. The procedure for implementing a supplier portal must therefore be adapted to the culture [3, 21, 31].

The fourth management area of the design model is the area of **technology management** and consists of technology-oriented success factors that must be taken into account when developing, introducing, and operating a supplier portal.

Legacy systems are historically grown systems in the company and must be taken into account when implementing a supplier portal, as they represent a considerable obstacle and can lead to problems. The successful evaluation and integration of legacy systems therefore have a positive influence on the success of the project. For example, if the existing legacy systems are very complex and extend across several platforms and business processes, a very high technological and organizational effort is required to make adjustments. However, if the architecture of the legacy systems is kept simple and oriented toward standardized business processes, the necessary effort is reduced accordingly [1].

Concerning the *system selection* on which the supplier portal is based, there are various points to consider. First, select a platform. Based on this, possible packages can be decided, which the IT service provider contributes additionally, whereby these decisions are to be made depending on budget, schedule, and project goals [3, 27].

The success factor *IT infrastructure* includes on the one hand the necessary infrastructure in relation to information systems to implement the supplier portal. To this end, an analysis of the IT architecture and IT capabilities of the organization must first be carried out and, if necessary, the infrastructure must be improved before implementation. Furthermore, already existing systems in the company environment must be considered on which to build or which are included in the implementation [9, 20].

The success factor *functionality* describes to what extent the type and scope of functions of the supplier portal ultimately correspond to the requirements at the beginning of the project and to what extent they improve business processes in the operative environment [15].

The *requirements*' *management* for the supplier portal must be considered from different perspectives: IT, economic efficiency, business processes, applications, and user profiles and roles. This requires integrated cooperation between all parties involved [1, 3, 21].

The *IT partner* supports the company during the project in the implementation of the IT landscape. The degree of support depends on the internal expertise of the company. The success of the project is directly linked to the choice of the IT partner and the quality of service offered. However, the choice between increasing external IT competence and low project costs must always be made. The choice of system and the choice and competence of the IT partner are often interdependent [25, 27, 31].

In addition to project *monitoring*, which is carried out during the project to monitor progress, it is also necessary to carry out monitoring after implementation. This is necessary in order to measure the performance of the supplier portal during operation and, building on this, to be able to take improvement measures.

The *design* of the supplier portal is based on the processes included and is described by use cases. In addition to implementing the specific requirements of the company, the portal should be developed intuitively and be oriented toward general design and navigation guidelines. For this purpose, a storyboard should be created describing how processes in the supplier portal should run and how the interactions should take place in detail [3, 15].

The success factor *data management* includes the topics data security, data integration, data accuracy, data quality, and data evaluation. On the one hand, it is important to store the existing data securely (protected against unauthorized external access). On the other hand, data and the underlying application and information architecture from existing systems and new sources must be integrated into the portal system in the required quality and accuracy so that they can ultimately be used for evaluation processes [21, 23, 28].

Prototyping describes a cyclic process consisting of four phases: design, implementation, testing, and adaptation. This cycle is repeated until the result corresponds to the specifications and ideas for the finished product. The development risk associated with the implementation of a supplier portal is minimized by the gradual approach to the final result. Furthermore, the clear, step-by-step prototyping simplifies and improves the cooperation between IT service provider and company and increases the motivation of the project team. The success factor includes carrying out tests during development in order to identify problems in good time and to be able to work out proposals for solutions [2, 9, 18].

40.4 Implications and Final Remarks

For practitioners, the design model helps to work on a supplier portal project in the five defined project phases: strategy, analysis, design, implementation, and introduction. Furthermore, phase-specific success factors can be included and considered before and during the project to ensure a successful implementation. The clear arrangement into four management areas of top management, project management, change management, and technology management assists in assigning responsibilities and increasing the clarity of the process.

For researchers, this study provides a conceptualized design model for the implementation of supplier portals by aggregating a variety of sources and categorizing the results. This could be used as a basis for further research. Conceivable research might include interdependencies between the success factors or how they contribute to the companies overall success.

At this point, the limitations of the design model for the automotive industry should be taken into account. This restriction is to be made based on the data collection, which, with the exception of the literature analysis, was carried out exclusively in the automotive industry. This restriction also creates the need for further research. Similar models are also conceivable in similar sectors such as the mechanical and electrical engineering industries, but also in completely different areas of industries. Furthermore, other functionalities could also be investigated, and thus, design models for other company portals (such as employee or customer portals) could be developed. In addition to other models for corporate portals, studies of technology-oriented systems can also be considered. These could be ERP systems or other collaborative business systems.

In addition to the thematic consideration of the scientific limitations, the findings of this work are limited to the applied research methods. The required information of the design model was generated by a comprehensive literature analysis and expert interviews. Further research on the model using other scientific methods would therefore be conceivable. For example, it would be possible to set up a structural equation model to quantitatively validate the relationships of the design model.

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Chapter 41
Performance Criteria for Liquid Bulk Storage Terminals (LBST), Using AHP

Valdilene do Nascimento Vieira and José Eugênio Leal

Abstract Currently, given the growing need to remain focused on key competencies, the petroleum supply chain industry opens opportunities for the development of outsourcing providers of LBST. In this context, it is worth define and evaluate a set of performance indicators to understand how the components generate value in this service.

Keywords Outsourcing · Liquid bulk storage · AHP

41.1 Introduction

Since the end of the petroleum monopoly in Brazil, in 1997, the logistical structure for movement and storage of crude oil and refined products has been open to multiple companies, attracting growing private investments. Furthermore, according to the National Petroleum, Natural Gas and Biofuels Agency [1], the importation of refined products has been rising in recent years. The importers often do not have logistical infrastructure in the country, so the market for storage services has been expanding. Today, some of the main global players are present in Brazil, competing with essentially national companies.

In 2015, petroleum accounted for more than 30% of the global energy mix [9]. The LBSTs are the elements that provide the link between producing regions and the consumer markets.

Traditionally, oil storage facilities were owned by the large oil and gas companies and refineries. In recent decades, driven by the need to clean up their balance sheets and release capital in a setting of declining oil prices and refining margins, the large oil and gas companies have been selling their logistics assets [28].

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Energy transport infrastructure is one of the most attractive areas for investors looking for good returns without the risks of price fluctuations of energy products. The revenues of storage terminals are generated from rental of space in storage tanks and fees for transport of products from tanks to delivery points and for additional services, such as heating and blending of products, providing additional sources of revenue and alternatives to aggregate value for clients [5, 13, 28].

In this scenario, there is a need to evaluate the components that generate value in these services. The development of instruments to enable comparison of storage terminals according to criteria besides price, mainly in long-term contracts, is of strong interest to companies that contract storage service. And for storage companies, it is important to know the elements that affect performance and those that are seen as differentials by clients.

This study developed and validated a hierarchy of performance indicators with simple application to assess bulk liquid storage terminals, to allow comparison with other terminals and of a single terminal over time.

41.2 Methodology

This study was conducted using the analytic hierarchical process (AHP) to analyze data obtained from a survey. The indicators were developed based on research of the literature in the Scopus and Science Direct databases, with the key expressions "supply chain," "performance indicator," "performance evaluation," "tank," "tank farms," and "storage."

The AHP was developed by Saaty with the objective of simplifying the decision-making process while also enabling consideration of intangible aspects, in structured form [23]. It is based on studies of the functioning of the human brain and its capacity to make decisions intuitively, considering the available information.

The AHP involves organizing the components of a problem into a hierarchical structure that ranges from a general objective to alternatives, passing through criteria and subcriteria, in structured form. The strategy is to decompose a large and complex question into simpler questions that can be compared pairwise and then synthesized into a unified response to the main question [27].

Saaty proposed the pairwise comparison using a fundamental scale of absolute numbers. This scale attributes numerical values to opinions and judgments, ranging from 1 to 9 [24]. The evaluation should take into consideration the criterion to which both questions are related, with one dominating the other.

The objective of the method is to attribute values to the implicit knowledge of experts. Therefore, the process consists of asking such specialists which alternative between two is most important in relation to the criterion at the higher level, and with what intensity [30].

The evaluations of the specialists are used to construct a matrix, which should be sufficiently consistent. The goal is to establish a priority, a single weight, for each alternative, where this weight can be represented by a vector of priorities, called an eigenvector.

However, as the number of alternatives considered grows, the number of comparisons increases drastically, which can result not only in an inconsistent or incomplete matrix, but also a lengthier study and lower response rate by experts, especially those in senior management positions whose time is limited [10].

Leal [16] presents a simplification that aims to make application of the AHP more practical. It consists of presuming the consistency of the judgments, and as a consequence, of the matrix. Therefore, it starts from the most important element of the set, which is evaluated in relation to all the others, to obtain a row of the matrix. The priorities are calculated only based on this row, using the general formula to calculate the priority of all the elements, as described in Eq. 41.1 [16]:

$$pr_j = \frac{1}{a_{ij} * \sum_k {}^{1}\!/_{a_{ik}}} \tag{41.1}$$

where $\boldsymbol{pr_j}$ is the priority of alternative $\boldsymbol{j}$ and $\boldsymbol{i}$ is the alternative for comparison.

To apply the method in this study, we first described the problem, identified the criteria that influence the decision, structured the hierarchy, and validated the proposed concepts with a focus group of professionals.

The model's final questionnaire was tested with four experts, adjusted, and then applied to professionals in the storage market. The potential respondents were identified via the social network LinkedIn and were contacted by e-mail.

The survey had an explanatory purpose, since the objective was to quantify the importance of elements in comparison with others, and was transversal in nature, since the results reflected the situation at a determined period in time. The sample was non-probabilistic, selected by convenience, since the questionnaire was sent to the available respondents [2]. In this type of study, the target public is small and the experience of each respondent is highly relevant.

To make the study more accessible and attract a larger number of respondents, some simplifications of the AHP were adopted, as proposed by Leal [16], represented through a graphic interface adapted from a commercial survey system, allowing the respondents to rank the importance between two alternatives by moving a cursor over a toolbar.

According to the AHP, the evaluations of groups should be obtained by consensus. But since it was not possible to obtain this consensus among physically distant respondents, we used the geometric mean of the responses, which is mathematically equivalent to consensus [26]. From the geometric mean of the evaluations, the priority vectors were calculated based on the simplification proposed by Leal [16]. The AHP is a specific type of research method, since it has its own treatment of results.

41.3 Petroleum Supply Chain (PSC) and Storage Terminals

The PSC starts with extraction, from onshore or offshore wells. The crude oil extracted is transported to bulk liquid terminals, which are connected to refineries through a network of pipes. The crude oil is converted into derivatives at refineries, and these refined products are sent to primary bases, which are bulk liquid terminals for storage of large volumes, designed to supply the wholesale market. From the primary bases, the products can be sent to secondary bases, for supply of the retail market. The crude oil and refined products up to this point are often carried through pipelines [21].

Varma et al. [31] highlight the characteristics of the PSC that differ from the traditional supply chains of manufactured goods. Among them is the bulk processing, where the product is not easily unitized. Therefore, all the commerce, transport, and distribution are in large lots. Besides this, the products are flammable and toxic, posing high risks of handling and contamination, causing the need for additional investments in safety measures. The flexibility of volume, in production or distribution, is low, and the transport cost represents a significant portion of the final product cost. The PSC infrastructure thus needs to be robust and composed of numerous logistics assets [31].

The LBSTs are, in general, a set of installations that are authorized to receive and store the product, be it crude oil from wells or derivatives from refineries, under contract by other companies. The terminals are considered shared resources by these companies, with each one owning a portion of the stored product [11].

Changing business needs have resulted in new configurations of the petroleum supply chain, involving various companies and networks of logistics operators, bringing new competitive paradigms [11]. Among the most important aspects of storage terminals are their capacity, efficiency in mooring vessels, and movement of bulk liquid [18].

41.4 Theoretical Framework

During the latter part of the twentieth century, the interest by companies throughout the world in logistics as a source of competitive advantages grew. The outsourcing of this activity allows firms to concentrate on their core competencies. These productive arrangements that fragment the supply chain have come more recently to the petroleum industry, which traditionally was dominated by totally integrated companies [19, 14].

The main benefits of outsourcing in the petroleum industry are: lower labor costs; access to better technologies; standardization and flexibility of processes; more control over activities; sharing of knowledge; injection of capital; better productivity, communication and transparency; greater resilience in face of crises; and more focus on the core business activity [19].

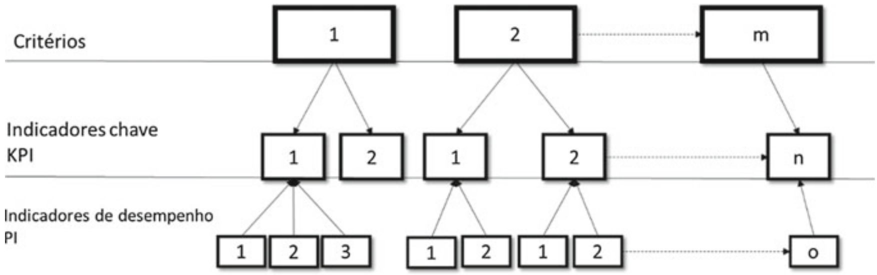

Fig. 41.1 Hierarchy of metrics. *Source* Lohman et al. [17]

Performance indicators should be able to translate strategy into something simple and routine, connected to the operations and measurable, besides allowing the business operations to be reoriented according to changing objectives and situations [6, 20].

Balfaqih et al. [4] conducted a review of the literature on the performance of supply chains between 1998 and 2015, indicating that two main approaches are used the most: approaches based on processes, which start from the comprehension of the main processes and activities of the SC to develop an efficient measurement system; and the hierarchical approach, which evaluates the performance of an SC by decomposing it into various levels. A third relevant approach is based on the perspective of the researcher.

Lohman et al. [17] proposed a model of performance measures based on the balanced scorecard (BSC) of Kaplan and Norton. This system can be viewed as a balanced scorecard adapted to the needs of the company. The study was carried out in Nike and involved organizing a database that included 100 metrics in a hierarchy composed of an upper level, composed of clusters, an intermediate level formed by key performance indicators (KPIs), and a lower level composed of regular performance indicators (PIs). The stratification was established based on the degree of information aggregation [14], as illustrated in Fig. 41.1. To apply the model, it is necessary to set targets and normalize the results [14].

41.5 Performance Indicators for Logistics Systems

The proposed indicators were based on the concepts brought by the studies of Balfaqih et al. [4], Domingues et al. [8], Bagchi [3], SCOR Supply Chain Council [29], Krauth et al. [15], Garcia et al. [12], Bowersox et al. [7], Kravokics et al. [24], and Rodrigue [22]. These concepts are summarized in Table 41.1.

The literature has put forward a large range of suggested concepts for indicators that have been adapted to bulk liquid terminals. After examining these concepts, we grouped the criteria, key indicators, and regular indicators as presented in Table 41.2.

Table 41.1 Concepts identified for indicators

Authors	Relevant concepts
Balfaqih et al. [4]	Criteria studied the most between 1998 and 2015: cost/finance, customer, internal processes, innovation and learning, flexibility, reliability, time, response capacity, quality, management of assets, efficiency, resources, production, and information
Domingues et al. [8]	Identified a set of performance indicators used in supply chains and organized them into the operational, tactical, and strategic dimensions
Bagchi[3]	Damage to goods and cost per ton
SCOR [29]	Availability of equipment
Krauth et al. [15]	Productivity and capacity utilized
Garcia et al. [12]	Logistics costs, complaints due to subpar quality, complaints related to billing, warehouse shipping indicator, loading/unloading time, percentage of damaged goods in the warehouse, utilization of storage capacity, warehouse cycle time
De Bowersox et al. [7]	Cost of service failure, response time, consistency of the delivery cycle, frequency of damages, frequency of lost goods (shrinkage), warehouse productivity
Kravokics et al. (2008)	Cost of movement and storage
Rodrigue [22]	Location, maximization of conformity to industrial activities, local, regional, and global scales, infrastructure

Table 41.2 Proposed indicators

Criteria	Key performance indicators	Regular performance indicators
Response to clients	Flexibility	Types of modes for receiving/shipping
		Scheduling—offshore
		Scheduling—onshore
		Products that can be moved
	Aggregated services	Blending of products with additives
		Formulation
		Blending for classification
		Laboratory analyses
Financial aspects and resources	Financial factors	Total logistics costs
		Price of the service
		Cost of failures
	Resources	Technology for scheduling/optimization
		Degree of automation in the process/control

(continued)

Table 41.2 (continued)

Criteria	Key performance indicators	Regular performance indicators
	Use of assets	Turnover of fixed assets
		Total volumetric capacity
		Location and accesses
Environment and safety	Atmospheric emissions	
	Leaks/spills	
	TFA [= ?]	
Internal processes	Service quality	Control of specification
		Compliance with logistical planning
		Product losses
	Productivity	Layover time—offshore mode
		Availability of storage facilities
		Availability of receiving/shipping facilities
		Layover time—onshore mode

41.6 Results and Conclusion

The survey was conducted from July 1–13, 2018, and obtained 29 valid responses. The respondents were presented with the 26 indicators identified in Table 41.1. The complete results of the ranking can be found at the link https://goo.gl/93iKUn.

The profile of the respondents was defined regarding the type of company in the supply chain (58% were from cargo owners and 42% from storage companies), the person's function with the company (55% stated they make tactical or strategic decisions, 26% operational decisions and 19% exercise support functions), and experience (74% had more than 10 years of experience, 7% between 5 and 10 years, and 19% under 5 years).

The proposed set of indicators assesses the factors that generate value from the service and allow comparing the provision of services between LBSTs, in light of the challenges and changes faced by the petroleum supply chain in Brazil.

The simplified AHP captures the tacit knowledge of the experts in the area. This process is facilitated by the survey method, supported by presentation of the questionnaire in an intuitive interface.

Concern for the environment was indicated as the most relevant point by both the cargo owners and storage companies. For the former firms, after the environment the most important point was financial aspects, where total logistical cost of the operation was the most relevant, followed by cost of failures and price of services. Other important indicators were flexibility of handling various products and control of specifications. In the KPI category, the standout was layover time in water mode. These items represented more than 60% of the relevant aspects for an LBST in the vision of cargo owners. For cargo owners, these are good items to consider in contracting a supplier of storage services, while for service providers they indicate areas in which to invest for clients to perceive good value of the service.

For the respondents drawn from storage firms, after the environment the most relevant aspects were: losses (in the internal quality criterion group, in the service quality KPI), followed by compliance with logistical planning and control of specification, both in the internal process criterion and service quality in the KPI. The next component in order was flexibility of modes and products that can be handled, both in the client response criterion. The element to complete the 60% of relevant aspects for an LBST, in the vision of the respondents from storage companies, was the availability of receiving and shipping facilities. These were considered good indicators to guide improvement in processes or management.

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Chapter 42
Integrated Optimization Model for the Fuel Supply Chain of a State Company (SC) in Brazil

Daniel Barroso Bottino and José Eugênio Leal

Abstract Following the adoption of a new price policy by Brazil's oil SC, questions have arisen regarding the price levels to be adopted in the domestic market. This research describes an optimization network model for the fuel distribution chain in Brazil that integrates with refining planning modeling to estimate the best price scenario to maximize the SOE's profitability.

Keywords Network modeling · Optimization · Downstream supply chain · Fuel distribution · Oil refining

42.1 Introduction

For much of the past, Brazil's supply of petroleum products consisted largely of a legal monopoly enjoyed the country's main state-owned enterprise (SOE). Until the enactment of the Oil Law (Law 9,478/1997), it was the only company authorized to import petroleum products into the country. Despite the lifting of the legal market reserve, the monopoly situation has been perpetuated *de facto* through the setting of artificial fuel prices by the SOE in order to curb inflation in the country. Only in 2016, with the adoption of a new price policy by the SOE, did the fuel market begin truly living under a new reality in which domestic product prices largely aligned with the international market. This improved profit margins in the supply chain, making it feasible for new competitors to enter the market and help serve the country's demand. As a result, imports of gasoline and diesel attained historic highs, with lower utilization of the national refining complex and loss of market share by the SOE. Decisions regarding exports of oil and petroleum products are made in a scenario in which exports are pitted against the profitability of selling in the domestic market. Refineries are also optimized for their most profitable use. A plant can operate at maximum volumetric capacity at the cost of lower efficiency in refining and processing, or it can operate below maximum volumetric capacity in order to increase efficiency and

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create more added value. A refinery's profits, therefore, are directly dependent on its ability to determine the optimum level of operation according to the markets and alternatives at its disposal. In sum, the strategy and plan adopted must seek to bring the best possible profits while making the domestic market sustainable in the long run and ensuring a healthier oil industry with the introduction of other operators and competitors.

Optimization models—which allow decision-makers to forecast what changes price variations may cause in different market scenarios—can be an efficient tool to support downstream chain planning and define the best way to optimize production resources and logistics assets, thus increasing their capacity to realize more profits. Models and systems that can predict the probable purchasing decisions of customers according to available supply play a vital role in supporting the company's planning activities, since the demand it expects to meet will invariably shape what it decides to produce. Taking those aspects into account, this publication sought to present a model for the current downstream chain that integrates two existing optimization models: one that attempts to estimate how customer decisions will shift as the prices practiced vary, and another that determines the optimum refining and delivery levels required to reach a certain price (and consequently drive a certain level of demand) that maximizes profits for national refining companies.

42.2 Background

The oil industry has one of the most complex and advanced supply chains in the world, covering a wide array of activities ranging from extraction to distribution of the finished product to consumers. Authors such as Furman et al. [10], Fanchi and Christiansen [8], and [11] have traditionally divided this industry into two or three sectors: upstream, midstream, and downstream. According to [22], in general any compound derived from petroleum can be marketed.

Products like diesel and gasoline are commodities, traded in the international market at prices based on the opportunity cost of obtaining the products at a given locality, the logistical challenges involved, the limitations of other competitors, and its acquisition value in the international market. According to [19], the price reference for each and every sale locality is known as Import Parity Price, or simply *IPP*, which represents the most economical alternative for supply from the import market. In addition to the price of the commodity, the IPP also includes costs like ship freight, demurrage, port taxes and costs of storage, and terrestrial transport. The new (i.e., post-2006) pricing policy for gasoline and diesel sold in the SOE's refineries follows three principles: adherence to the IPP, i.e., the price calculated for the international fuel to be sold to the Brazilian distribution companies at the sale hubs; periodic reviews of margins to account for profits and offset taxes and risks inherent to the business, such as exchange rate fluctuations, volatility in commodity prices, and overstocking in ports, and market share. In other words., it may be more attractive to increase or reduce supply depending on the marginal value and opportunity cost of other products in the oil industry [19]. Relying on these premises, the SOE calculates its average realized price (ARP), which it applies to “A”-type products (i.e., before the addition of biofuels) in order to align national product prices with the IPP.

The mathematical models for the oil industry were approached by several authors. [17], for instance, note that the oil industry, due to its highly capital-intensive nature, is particularly favorable to investments and efforts to develop mathematical programming tools that can support decision making in the planning process. [21] discussed the use of formulation-based MILP optimization as a tool to model multi-tank pipeline flows and the corresponding effects on consumer markets. Oliveira et al. [18] added uncertainty to supply calculations using a combination of two-stage stochastic MILP modeling and scenario building. [14] developed a multistage stochastic programming framework to solve the petroleum product distribution problem. [23] and Katzer et al. [12] mention the importance of MINLP models for refinery operation scheduling. For [15], geographic information systems (GIS) can be instrumental in solving transport and location problems due to their great capacity to store, display and manipulate spatially distributed data. [16] presented the combined use of externally developed PLIM and GIS in solving facility placement and transportation problems. Cormen et al. [6], [5], [7], and Ahuja et al. [1] addressed network problems through the definition of flow conservation and the minimum cost flow problems in networks, with highlight to the out-of-kilter algorithm developed by Ford and Fulkerson [5]. Minimal path algorithms solve the most fundamental problem and have great applicability in the most complex subroutines.

Most downstream oil supply chain studies have attempted to design the network and determine flows [3]. Mathematical programs are chiefly dedicated to optimizing distribution and the transportation of products from the refinery to the market [9]. Kazemi and Szmerekovsky [13] considered an integrated distribution network structure featuring distribution centers, multiproduct allocation, and multimodal configurations, addressing the problem in the context of transportation planning. Aires et al. [2] discuss a vertically integrated supply chain model for the Brazilian SOE. Pompermayer et al. [20] wrote on how market equilibrium models consider fully competitive markets. Tominac and Mahalec [24] concluded that there are few studies in which refining production and distribution planning were modeled considering a context in which refiners compete with each other.

42.3 Methodology

While the Brazilian state oil company operates in an integrated manner in several segments of the oil industry, we will focus our analysis on the downstream chain. As shown in Fig. 42.1, refining activity produces several petroleum products, some with higher market value than petroleum (like diesel and gasoline) and others whose market value is lower than it, such as fuel oil and green coke oil. The average yield obtained from one oil barrel is shown in Fig. 42.1.

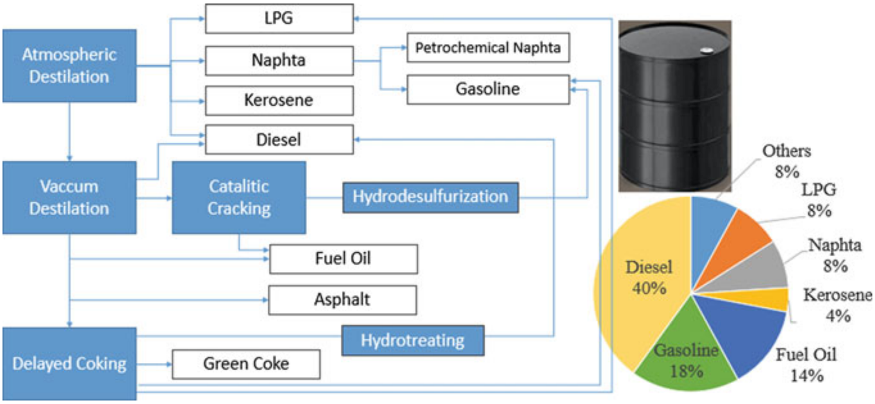

Fig. 42.1 Refining regime and average fuel output

The prices practiced by the company must reflect a balance between the need to optimize the refining plant (always taking into account alternatives with oil exports) and the attractiveness of importing petroleum products from other agents in order to guarantee the necessary market share. When conversion plants reach their limit, petroleum processing must be done by distillation alone, which results in large quantities of low-value product. It is at this point that it becomes worth exporting crude oil and importing refined oil in order to meet the demand of markets not served by refining. As such, the goal of operational planning is to seek the most optimized use of resources in order to maximize profits for the company, integrating analyses and consequent direction planning of supply chains into the process.

Downstream chains can be modeled into two "subchains," with the first comprising refining production and logistics and the second covering the distribution of products to customers (distributors). The two subchains intersect at the "point of sale" to the distributors, as shown in Fig. 42.2. The changes in demand at these points of sale (which are driven by the distributors' acquisition costs of the product) will be decisive for the definition of the SOE's operational planning for refining. In short, the model begins by seeking to understand the network of distributors (i.e., the SOE's direct

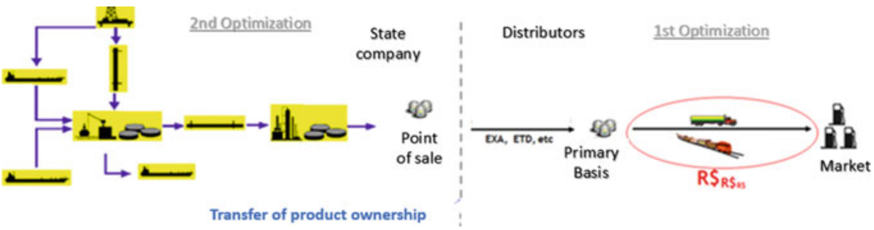

Fig. 42.2 Downstream chain planning systems

customers), and then attempts to optimize the resources available in a way that maximizes profits.

The first optimization model evaluates distribution costs from the point of sale until the final resale to the end customer, relying on a GIS-based optimization model. The SIAM (Logistic Market Analysis System) tool was used at this stage to represent the flows of fuel distribution companies. This system allows users to compare scenarios according to the supply available in order to present solutions for geographically distributed markets. The GIS layer makes it possible to break down product distribution according to the demand in each municipality that will be served by a given producer's/importer's point of sale. The aim of the system is to predict the behavior of a distributor according to the rationality of the costs of serving their markets, representing acquisition, operation, and transportation costs incurred at distribution with the related network capacity restrictions. This made it possible for us to identify the maximum price the market is willing to pay for a given fuel before migrating toward nearby alternative sources (in this case, import hubs whose prices were kept fixed in all scenarios). It produces as output a configuration of influences in each point of sale in the market that indicates the optimal flows from refineries to points of demand, logistics cost variations, and revenue impacts for each point of sale in each scenario. In addition to numerical reports, the system also generates maps with configurable layers that make it easier to visualize the resulting scenario and the effects of each change made to the input variables.

In the second stage of the optimization process, the supply planning parameters of the producer are fed into PLANINV ("Investment Planning," a tool developed in-house at the SOE using AIMMS) in order to determine the production plan that maximizes operational results while taking into account the existing restrictions and the markets defined by the previous model, as shown in Fig. 42.2. Flows are defined in such a way as to optimize the use of the refining complex and balance the availability of products in the national market against exports and imports. An equilibrium point will be formed for each scenario, with alternatives to oil weighed in. Inputs fed to the model include data on the logistics refining infrastructure (with capacity limits), internal and external markets, domestic production and third-party supply (of oil or petroleum products), and international and domestic market prices of products for which demand service is not guaranteed (i.e., those for which is possible to choose whether or not to meet the demand depending on the opportunity cost).

In essence, the model seeks to answer the question of what the most appropriate prices and delivery conditions should be if one wants to optimize distribution to meet the needs of a market with competition. Figure 42.3 illustrates an example of market response expectations as projected by the model. The company's profits grow at first due to higher sale prices in the market and the possibility of exchanging oil (crude vs refined) through exports with an optimized refining complex, but this profit tends to fall when sale prices extrapolate this optimum point, as the substantial loss of market share reduces the company's revenue in the domestic market and the consequent drop in refining levels leads to high-opportunity-value products no longer being produced in their ideal quantity. This, in turn, would lead to an impossibility of achieving maximum efficiency at the refining park, leading to the need to import products to serve other markets. The lack of a national market brings limitations to

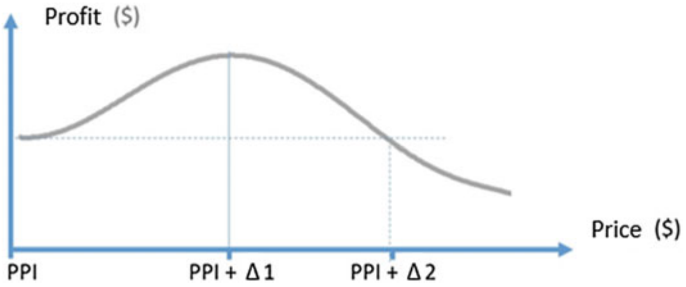

Fig. 42.3 Expected gains from changes in fuel prices

how the model represents distribution flows, with lower marginal value alternatives.

42.4 Chain Modeling

Our experimental modeling was carried out having as scope the distribution logistics for "A"-type gasoline and diesel (i.e., not mixed with biodiesel) in the downstream chain, from the refinery to arrival at the municipalities (customers). The logistics for biofuels were not addressed. For this study, we considered demand to be inelastic to price, varying only in terms of the choice between a national producer or an importer.

Supply levels of gasoline, diesel 10 (low sulfur content), and diesel 500 (high sulfur content) were represented in 31 units of the SOE, 5 domestic producer units, and 15 localities where imports enter the country, totaling 51 points of sale. Table 42.1 illustrates supply volumes and demand in the municipalities, as available at [4], as well as their IPP (calculated based on import prices per port with disclosed numbers plus freight costs incurred at arrival at the company's point of sales). In addition to the above, other data points used as inputs for the model include road transportation costs for the georeferenced layer of the network, variable distance traveled, cost and capacity of rail and waterway transportation, and operating costs of the bases.

Table 42.1 Product offers and demands

Volumes (1000 m^3)	Gasoline	Diesel 500	Diesel 10
SOE	3202	4292	1630
Domestic producers	165	38	–
Importers	759	922	1004
Total offer	**4126**	**5252**	**2634**
Total demand	**2686**	**2548**	**1474**
Average IPP (R$/liter)	1.67	1.81	1.84

For the profit-optimization model of the SOE, it is necessary to input information from the production and import of oil all the way to the sale of petroleum products in the existing markets, with the gasoline and diesel markets represented as defined by the previous model. Refining is one of the most complex parts of the model, as it covers all refineries in the complex and their respective plants and takes into account product degradation, yield, operating factor, and inputs in the plants. After the petroleum products are produced, they may be sold locally or transported to terminals that sell at different prices. This transportation usually occurs through pipelines or waterways, with a small share carried by rail or road.

We decided to develop different scenarios modifying the ARP for each fuel at R$ 20/m^3 intervals. After running the model, we saw the need for developing eight scenarios for a good representation of the case. Four additional scenarios were also tested to validate the model: two in which the company practiced the IPP (one considering a maximum supply limit at the nodes and another with unlimited supply), and two in which no importers were considered (one using the IPP and another using the ARP). After this step, these results were inputted in PLANINV to finally answer the question of which scenario would represent the maximization of profits for the company. With twelve scenarios for each of the three products, the final pool of possibilities would reach a total of 12 × 12 × 12 scenarios. However, since the validation scenarios serve to verify competition conditions at IPP but are not feasible (importers exist and supply is finite), it was decided for this study that only the original eight ARP variation scenarios would be used. Since diesel 10 and diesel 500 are substitutes for each other in the market, working with different margins (in addition to the market valuations already represented in the prices) can represent market migration to the side with lower prices. Therefore, these models had their results grouped together to form an 8 × 8 matrix, with a total of 64 scenarios.

42.5 Results

Our analysis of the SIAM scenarios revealed that, when a margin of R$ 120 was applied in relation to the IPP, importer utilization reached an average 95% of supply, with 30 of the 39 import hubs reaching 100% utilization. This indicates capacity constraints on the nodes, which may encourage new investments in infrastructure in order to increase the supply and expand presence in these markets. Table 42.2 shows

Table 42.2 SOE market share

Scenarios	IPP – 20 (%)	IPP (%)	IPP + 20 (%)	IPP + 40 (%)	IPP + 60 (%)	IPP + 80 (%)	IPP + 100 (%)	IPP + 120 (%)
Gasoline	84	82	82	78	75	70	68	67
Diesel 500	98	94	85	83	72	67	66	64
Diesel 10	93	86	72	68	53	48	43	39

the SOE's market share in each of the scenarios, with stronger losses in the diesel market in the transition to IPP + 60.

The optimization for the SOE indicated that, as diesel market share decreased, kerosene and diesel exports reached a plateau, with a subsequent increase in oil exports and a consequent decrease in the attractiveness of refining in-country. Gasoline, which showed unmet demand when added to the naphtha market, saw smaller imports by the SOE as demand tapered. A comparison of the highest- and lowest-demand scenarios for both products (ARP = IPP − 20 and ARP = IPP + 120, respectively) reveals refining utilization decreases from 83 to 66% from the former to the latter, while oil exports jumped from 20 to 39% of total oil produced.

Figure 42.4 illustrates profits for the SOE as determined by the model runs. The first picture shows variations profits obtained between the different scenarios at R$ 20 intervals in price margins (with diesel kept at a fixed price and demand level in all scenarios), while the second shows the results of the same modeling with the roles of gasoline and diesel reversed. It was not possible to observe synergies between gasoline and diesel production in the model; the decision of prices to be practiced can be made in isolation.

Although the model indicates greater gains with prices at IPP + 120 for gasoline in comparison with the other scenarios, this result must be assessed judiciously. The curve already shows a downward trend at this point, which suggests that these values may have been influenced by the maximum supply limits for imports, forcing the distributor to choose the national company. This result, despite better short-term profits, can encourage increased reliance on imported supply and constitute a misguided strategy in the long run. After the IPP + 120 scenario, IPP + 20 was the one that presented the best result, followed by IPP + 40, which indicates this range is the most adequate for the company to optimize its profits. For diesel, the scenario that showed the highest profits was IPP + 40, with IPP and IPP + 20 also showing favorable results in a scenario with a larger market and lower prices. Scenarios above IPP + 40 were not shown to be beneficial, with significant market losses. The best scenario resulted in a 77% utilization rate at refineries (1.83 million barrels of oil produced per day), figures similar to those published by the company. Figure 42.5 illustrates the SIAM results of the best scenario for the area of influence of each

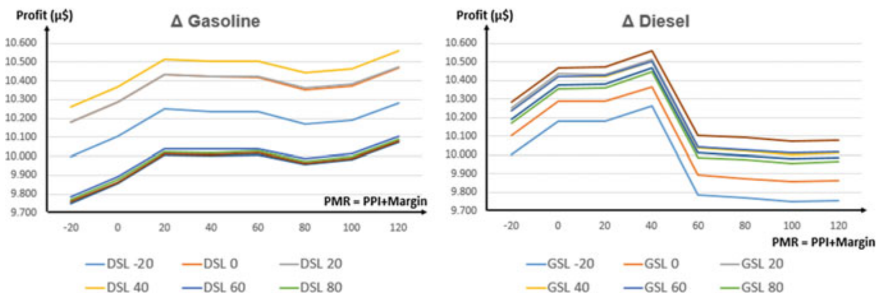

Fig. 42.4 SOE profits for different prices of gasoline and diesel

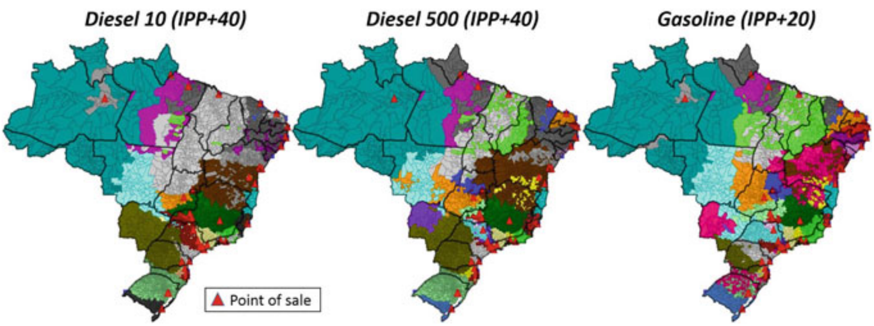

Fig. 42.5 SIAM results for the best prices indicated

point of sale (shades of gray represent importers). It should be noted that, despite its massive territorial size, the northern region has low consumption density, which leads to low volumes of demand. The most consumption-dense areas are concentrated in the southeast and near the coast.

42.6 Conclusions

The first step in our study was to understand and characterize the problem question that would define the modeling itself and the choice of models, following by an analysis of the business itself which developed into the modeling proposed hereunder when understood. It integrates two additional models, one built in AIMMS and another that associates optimization with the use of GIS.

The results indicate higher gains with a reduced market share for the SOE, i.e., through allowing a portion of the market to be served by third-party imports, as is already the case today. The optimum refining levels projected by the model were also in line with the numbers published. Thus, the original question has been answered and can now be used by the industry in its planning. In addition, we postulate that the integrated optimization model proposed herein can be used to obtain similar answers from other industries, especially the commodities market, since the country predominantly uses the road modality for transportation of cargo.

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Chapter 43
Development of a Benchmarking Instrument to Assess Supply Chain Volatility

Benjamin Nitsche

Abstract This manuscript aims at developing a benchmarking instrument that enables managers to critically assess the volatility management performance for a product's supply chain to identify needs for action. Additionally, based on a survey among 87 manufacturing firms, the current state of volatility management in modern supply chains will be discussed.

Keywords Supply chain volatility · Benchmarking · Performance assessment

43.1 Introduction

Managing supply chain volatility (SCV) is one of the core challenges of modern supply chains (SC) [4, 11]. Since volatility has been a challenge over decades, researchers on the one hand focused on describing the multidimensional sources of SCV and on the other hand developed management strategies dealing with it. However, to efficiently manage volatility, SC managers need to assess the impact of those SCV sources on their particular SC first, before initiating management strategies [7].

In general, to continually manage unintended changes in material flows in a SC, managers need to regularly identify and understand the cause, assess the impact, implement mitigation strategies, monitor changes, and learn from experiences [12]. This SC business continuity planning process is commonly accepted in SC risk management literature, motivating researchers to not only identify strategies dealing with risks, but also develop different instruments to assess the peculiarity of risks on a SC [1]. Nevertheless, research on the assessment of SCV is sparse. Christopher and Holweg [4] were the first to develop a SCV index that assesses the state of SCV from a macroeconomic point of view. However, a case-based evaluation of the current state of volatility of a product's SC taking a microeconomic, focal firm point of view is still missing but could assist managers in a more target-oriented SCV management.

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Hence, this study aims at developing an assessment instrument that enables SC managers to critically evaluate the current state of volatility of their product's SC and identify concrete needs for action. The assessment incorporates means of benchmarking to not only provide managers with an assessment of their SCV management performance, but also to show them how they perform against their competitors. Therefore, the research objectives (RO) of this study are:

RO1: Identify appropriate measures to assess the state of SCV of a product's SC
RO2: Propose a benchmarking instrument that assesses the state of SCV of a product's SC and benchmarks it against competitors
RO3: Analyze the current state of SCV management.

43.2 Development of a Benchmarking Instrument to Assess Supply Chain Volatility

43.2.1 Introduction to the Benchmarking Instrument

In order to set the conceptual constraints of this study and the developed instrument, the taxonomy developed [5] is applied in order to guide SC managers that intend to apply this instrument for assessing the state of SCV of their product's SCs. The decision level affected is strategical as well as tactical since the benchmarking instrument seeks to assist managers in critically assessing their SC structures and adjusting them on a medium and long term. The type of flows investigated is mainly physical because SCV results in a mismatch of supply- and demand-side material flows at the focal firm [8], but informational flows are also affected and investigated. Although the developed instrument assesses SCV of a product's SC at the focal firm, the level of SC maturity has to be understood as inter-organizational since it includes data directly connected to suppliers and customers. The type of benchmarking is external because the user of the benchmarking instrument will benchmark the volatility of a product's SC against the performance of other manufacturers. Concerning the contextualization of the developed instrument, it has to be stated that it was developed for manufacturing companies. Quality management aspects, human resource management as well as sustainability initiatives are out of scope of the benchmarking instrument [5].

43.2.2 Measures to Assess Supply Chain Volatility

In order to assess the level of volatility of a product's SC, appropriate qualitative and/or quantitative performance measures have to be defined that characterize the focus of the benchmark [2, 3]. Therefore, the study builds upon the SCV conceptualization of Nitsche and Durach [8]. According to them, SCV is caused by 20 different sources that contribute to five distinct dimensions of SCV (*organizational, vertical, behavioral, market-related*, and *institutional and environmental volatility*). Based on this conceptualization, the benchmarking instrument will assess the level of SCV according to the first four dimensions of SCV. The fifth dimension of SCV was excluded from the benchmarking instrument due to its high context dependency as argued by Nitsche [7]. Moreover, to make the practical application of the instrument more feasible, it was intended to limit the number of variables for each dimension. Therefore, the measurement of the dimensions focusses on the most important sources of volatility in their respective dimension that have been proposed by Nitsche [7].

Organizational volatility: This dimension of SCV is mainly caused by *intra-organizational misalignment* and *inaccurate forecasting* [7]. Building on a conceptualization of Wagner et al. [9], *intra-organizational misalignment* (OA) will be measured qualitatively (7-point Likert scale) via a self-assessment of six distinct characteristics of organizational alignment (formality of the planning process, promotions planning integration, information availability and exchange, planning efficiency, assignment of roles and responsibilities, and integration of planning systems). The average of those variables will be used for the benchmarking instrument.

In general, there are multiple measures to assess the accuracy of a forecast in SCM [6]. The mean absolute percentage error (MAPE) is often used by practitioners and was also considered as appropriate by other benchmarking studies [10]. To assess the level of inaccuracy in forecasting, the benchmarking instrument includes the MAPE one, three, and six months ahead on a product family (MAPE1f, MAPE3f, and MAPE6f) and product variant level (MAPE1v, MAPE3v, and MAPE6v).

Vertical Volatility: Although *long lead times* have been stated as the most impactful source of *vertical volatility* [7], it was decided to include the source of *variable lead times* into the benchmarking instrument since the length of lead time has to be assessed in combination with their variability in the context of SCV [7, 8].

To benchmark the SCV source of *long lead times* from a manufacturers' point of view, the user will be asked to state the supplier lead time (LTS_i) in days for each supplier of A-level components belonging to the product as well as their transportation lead time (LTT_i). Additionally, the average production lead time of the final product (LTP) as well as the delivery lead time to the manufacturers' A-level customers (LTC_j) has to be defined.

To assess the SCV source of *variable lead times*, the on-time delivery rate [3] of suppliers of A-level components of the product ($OTDS_i$) as well as the on-time delivery rate to the A-level customers ($OTDC_j$) has to be stated. Additionally, the spread of lead times at the supply side is benchmarked, asking the user to indicate the longest time span minus the shortest time span between ordering and receiving the A-level components (SP_i, in days, for each supplier).

Behavioral volatility: This dimension of SCV is induced by *erratic behavior of customers* as well as *erratic behavior of decision-makers in the SC* [8]. Both sources have been ranked among the most pressing sources of SCV by SC managers [7]. To

Table 43.1 Variables to assess behavioral volatility

	Variable	Description (indicate agreement to the statement, 1(totally disagree) to 7 (totally agree)
Erratic behavior of customers	EBC_1	In general, our customer demand is very hard to predict
	EBC_2	Market trends are difficult to monitor because customer preferences change constantly
	EBC_3	Our customers often adjust already placed orders
	EBC_4	Customer loyalty to our brand is relatively low, and the customer changes their preferences constantly
	EBC_5	Our customers often adjust orders (quantities or other specifications) in a short-time window before planned delivery
Erratic behavior of decision-makers in the SC	EBD_1	At the end of the year, we order more than we actually need to get a cash-back from our supplier
	EBD_2	Sometimes we order more than actually needed in order "to be safe"
	EBD_3	Sometimes we order less than actually needed in order to reduce our safety stock level
	EBD_4	Due to lack of confidence in our IT system, we adjust order quantities that are generated by the system based on personal experience
	EBD_5	Due to lack of confidence in our IT system, we adjust forecasts that are generated by the system based on personal feelings
	EBD_6	When we expect a shortage of a component (not clear yet), we order more than actually needed
	EBD_7	Sales people place customer orders early in advance before an actual customer order exists
	EBD_8	If the actual demand in one month is higher or lower than planned demand, we immediately adjust our future plans
	EBD_9	If we expect a price increase in the near future, we order more than we actually need to benefit from the current price

Table 43.2 Variables to assess market-related volatility

	Variable	Description (indicate agreement to the statement, 1 (totally disagree) to 7 (totally agree)
High level of competition	HC_1	We often lose customers to our direct competitors
	HC_2	We are forced to an intense price competition with our competitors
	HC_3	We often have to rely on the same suppliers as our direct competitors
	HC_4	In our market, it is difficult for us to differentiate ourselves from our competitors
	HC_5	We offer a high number of product variants of our representative product
	HC_6	There are a high number of substitutes for our representative product at the market

assess both sources, qualitative measures have been defined (see Table 43.1) that the user of the benchmarking instrument has to rate via a self-assessment.

Market-related volatility: Prior research evaluated *high level of competition* as the most important source of *market-related volatility* [7]. Fierce competition is, among others, characterized by a high number of product variants offered by the focal firm itself and/or a high number of substitutes offered at the market leading to more demand volatility at a single-part level. Additionally, if competitors are fighting for the same source of supply, volatile material flows originating at the supply side can be a consequence [7]. Table 43.2 outlines the qualitative variables chosen for assessing the dimension of *market-related volatility*.

43.2.3 Benchmarking Instrument

The basic idea of the benchmarking instrument is that a user that would like to assess SCV affecting a product's SC will benchmark his volatility management performance against others. Therefore, he inserts the data that has been described before. This data subsequently gets benchmarked against data of other manufacturers seeking to identify areas to focus on. SCV is a matter of fact in all SCs and cannot be completely eradicated. But, in order to stay competitive, managers need to know where their volatility management performance is worse than the performance of others to initiate purposeful management measures. The benchmark that builds the basis for this instrument was conducted through an online survey with 87 participating manufacturing firms from different industries. Based on their feedback, the user of the benchmarking instrument assesses SCV of its product's SC.

The assessment is done through a weighted scoring model that calculates volatility scores from "1" (low volatility) to "10" (high volatility) for four dimensions of SCV as well as an overall SCV score. Figure 43.1 provides a schematic representation

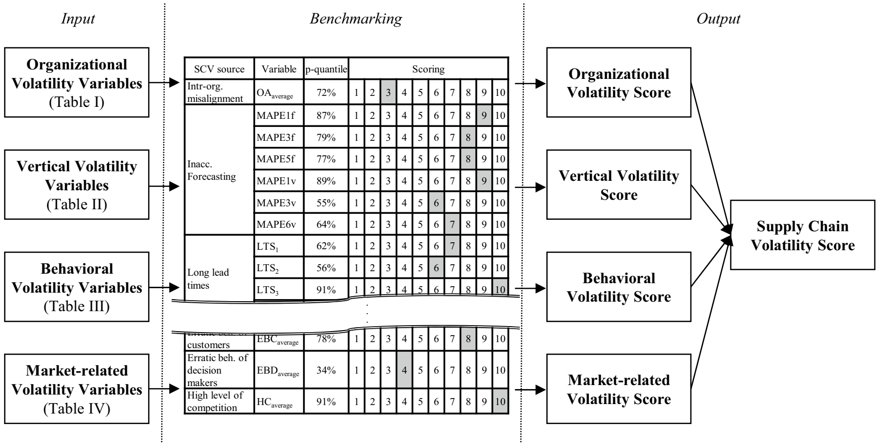

Fig. 43.1 Exemplary schematic representation of the structure of the benchmarking instrument

of the general structure of the benchmarking instrument. Every input variable has to be benchmarked using the benchmarking table (see Table 43.3). Therefore, the user has to check in which group the input variable has to be assigned and chose the corresponding score.

Organizational Volatility Score: The *Organizational Volatility Score* (SC_{OV}) is calculated as the mean of the sub-scores for *intra-organizational misalignment* (SC_{OA}) and *inaccurate forecasting* (SC_{MAPE}). The SC_{OA} is derived from the benchmarking of the mean of the corresponding input variables described before. The SC_{MAPE} results from the benchmarking of MAPE variables. In general, a lower MAPE one month ahead is of higher importance in the context of SCV that a low six month ahead MAPE, since more expensive measures have to be undertaken to match supply and demand on a short term (e.g., special freight, higher stock expenses). Hence, to calculate the SC_{MAPE}, a weighting is applied to incorporate the higher importance of a short-term MAPE over a mid-term MAPE into the SC_{MAPE} calculation.

$$SC_{MAPE} = 0.3 \cdot SC_{MAPE1f} + 0.3 \cdot SC_{MAPE1v} + 0.15 \cdot SC_{MAPE3f} + 0.15 \cdot SC_{MAPE3v} + 0.05 \cdot SC_{MAPE6f} + 0.05 \cdot SC_{MAPE6v} \tag{43.1}$$

Vertical Volatility Score: The user of the benchmarking instrument will not only be enabled to assess the level of volatility that is induced by its company itself, as in the case of the SC_{OV}, the instrument will also enable the assessment of the effect of certain members in the SC (e.g., suppliers, customers) on SCV. The *Vertical Volatility Score* (SC_{VV}) is calculated as the mean of the two sub-scores of the assessment of *long lead times* (SC_{LLT}) and *variable lead times* (SC_{VLT}). To assess SCV induced by *long lead times* (SC_{LLT}), different input variables have been defined. SC_{LLT} itself incorporates four sub-scores for the impact of supplier lead time (SC_{LTS}), transportation lead time (SC_{LTT}), production lead time (SC_{LTP}), and delivery lead time (SC_{LTC}). In general,

Table 43.3 Overview of benchmarking values

					Volatility score									
					Best in class		Advanced		Typical		Catch up		Latecomer	
SCV dimension	SCV source	Input variable	Average	Median	1	2	3	4	5	6	7	8	9	10
Organizational volatility	Intra-org. mis alignment	OA avrg	4.64	4.67	>=6.17	>5.5	>5.2	>5	>4.67	>4.5	>4	>3.83	>3.27	<=3.27
	Inaccurate forecasting	MAPE1f	9.27	6.00	<=2	<4.8	<5		<6	<10		<11.8	<20	>=20
		MAPE3f	15.67	15.00	<=5	<6.6	<10		<15	<18	<20	<22	<30	>=30
		MAPE6f	22.58	20.00	<=5	<10	<11.2	<15	<20	<25	<30	<33	<40	>=40
		MAPE1v	10.86	10.00	<=2.3	<3.6	<5	<6.4	<10		<10.1	<15	<20	>=20
		MAPE3v	17.98	15.00	<=5	<8	<10		<15	<20	<21.2	<30	<34.2	>=34.2
		MAPE6v	24.92	23.00	<=8	<10	<12.9	<15.4	<23	<28	<34.1	<40	<50	>=50
Vertical volatility	Long lead times	LTS	50.48	30.00	<=5	<12.8	<20	<28.8	<30	<46.8	<60	<78.4	<110.8	>=110.8
		LTT	11.04	5.00	<=1	<2	<3	<4	<5		<7.2	<13.4	<32.4	>=32.4
		LTP	25.06	7.00	<=0.6	<1	<3	<5	<7	<10	<17	<30	<73.6	>=73.6
		LTC	8.72	4.00	<=1	<2		<3	<4	<5	<7.3	<10	<20.7	>=20.7
	Variable lead times	OTDS	81.18	90.00	>=97	>95	>90.8	>90		>84.86	>80	>75	>52	<=52
		OTDC	87.28	92.00	>98.9	>98	>95	>94.6	>92	>90		>81	>70.5	<=70.5
		SP	39.04	25.00	<=4	<6.8	<11	<16.2	<25	<30	<40	<48.4	<94	<=94
Behavioral volatility	Erratic behavior of customers	EBCavrg	3.62	3.60	<=2	<2.6	<3	<3.28	<3.6	<3.8	<4.2	<4.6	<5.2	>=5.2
	Erratic behavior of DM	EBDavrg	3.73	3.89	<=2.44	<2.78	<3.31	<3.6	<3.89	<4.07	<4.33	<4.44	<4.93	>=4.93
Market-related volatility	High level of competition	HCavrg	4.22	4.17	<=2.87	<3.33	<3.83	<4	<4.17	<4.5	<4.67	<5	<5.5	>=5.5

those four lead times sum up to the SC lead time (t_{total}). The longer the lead time gets, the more devastating the effects on SCV become. This being said it is proposed to weight the sub-scores by the share of their respective lead time on the total SC lead time. Therefore, it is proposed to use the median values of all supplier lead times (t_{LTS}), transportation lead times (t_{LTT}), production lead times (t_{LTP}), and delivery lead times (t_{LTC}) and relate them to the median total SC lead time of the product's SC ($\mathrm{t}_{\text{total}}$).

$$\mathrm{SC}_{\text{LLT}} = \frac{t_{\text{LTS}}}{t_{\text{total}}} \cdot \mathrm{SC}_{\text{LTS}} + \frac{t_{\text{LTT}}}{t_{\text{total}}} \cdot \mathrm{SC}_{\text{LTT}} + \frac{t_{\text{LTP}}}{t_{\text{total}}} \cdot \mathrm{SC}_{\text{LTP}} + \frac{t_{\text{LTC}}}{t_{\text{total}}} \cdot \mathrm{SC}_{\text{LTC}} \tag{43.2}$$

To calculate the sub-scores of SC_{LTS} and SC_{LTT}, it is proposed to weight the scores for each supplier by the share of purchasing volume of the supplier i (ps_i) in the total purchasing volume for the assessed product ($\mathrm{ps}_{\text{total}}$). Same will be applied for SC_{LTC} where the score of each customer will be weighted by the share of the sales volume of the customer (pc_j) in the total sales volume of the product ($\mathrm{pc}_{\text{total}}$). The sub-score for production lead time (SC_{LTP}) results from the benchmarking of the product's production lead time (LTP) independently from suppliers or customers.

$$\mathrm{SC}_{\text{LTS}} = \sum_i \left(\frac{\mathrm{ps}_i}{\mathrm{ps}_{\text{total}}} \cdot \mathrm{SC}_{\text{LTS}_i} \right) \tag{43.3}$$

$$\mathrm{SC}_{\text{LTT}} = \sum_i \left(\frac{\mathrm{ps}_i}{\mathrm{ps}_{\text{total}}} \cdot \mathrm{SC}_{\text{LTT}_i} \right) \tag{43.4}$$

$$\mathrm{SC}_{\text{LTC}} = \sum_j \left(\frac{\mathrm{pc}_j}{pc_{\text{total}}} \cdot \mathrm{SC}_{\text{LTC}_j} \right) \tag{43.5}$$

The assessment of volatility induced by *variable lead times* (SC_{VLT}) includes three sub-scores, in particular for the on-time delivery rate of suppliers ($\mathrm{SC}_{\text{OTDS}}$), for the on-time delivery rate to customers ($\mathrm{SC}_{\text{OTDC}}$), and for the time window of incoming deliveries (SC_{SP}). SC_{VLT} will be calculated as the mean of those three sub-scores.

$$\mathrm{SC}_{\text{VLT}} = \frac{1}{3} \cdot \mathrm{SC}_{\text{OTDS}} + \frac{1}{3} \cdot \mathrm{SC}_{\text{OTDC}} + \frac{1}{3} \cdot \mathrm{SC}_{\text{SP}} \tag{43.6}$$

As previously explained, the scores of each supplier for $\mathrm{SC}_{\text{OTDS}}$ and SC_{SP} will be weighted by the share of the purchasing volume of the supplier in the total purchasing volume. Consequently, the $\mathrm{SC}_{\text{OTDC}}$ for each customer will be weighted by the share of sales volume of the customer in the total sales volume of the investigated product.

$$\mathrm{SC}_{\text{OTDS}} = \sum_i \left(\frac{\mathrm{ps}_i}{\mathrm{ps}_{\text{total}}} \cdot \mathrm{SC}_{\text{OTDS}_i} \right) \tag{43.7}$$

$$\mathrm{SC}_{\mathrm{OTDC}} = \sum_{j}\left(\frac{\mathrm{pc}_j}{\mathrm{pc}_{\mathrm{total}}} \cdot \mathrm{SC}_{\mathrm{OTDC}_j}\right) \tag{43.8}$$

$$\mathrm{SC}_{\mathrm{SP}} = \sum_{i}\left(\frac{\mathrm{ps}_i}{\mathrm{ps}_{\mathrm{total}}} \cdot \mathrm{SC}_{\mathrm{SP}_i}\right) \tag{43.9}$$

Providing all the described input, the user of the tool will be enabled to not only assess vertical volatility in its product's SC but also to assess which supplier or customer contributes most to the volatility that affects its product's SC.

Behavioral Volatility Score: The *Behavioral Volatility Score* ($\mathrm{SC}_{\mathrm{BV}}$) is calculated as the mean of the two sub-scores for *erratic behavior of customers* ($\mathrm{SC}_{\mathrm{EBC}}$) and *erratic behavior of decision-makers* ($\mathrm{SC}_{\mathrm{EBD}}$). Those sub-scores themselves result from the benchmarking of the mean of the input variables EBC and EBD as described in Table 43.1.

Market-related Volatility Score: To assess market-related volatility, the source of *high level of competition* is measured via a qualitative self-assessment of six variables as described in Table 43.2. Thus, the *Market-related Volatility Score* ($\mathrm{SC}_{\mathrm{MV}}$) results from the benchmarking of the mean of those input variables.

Supply Chain Volatility Score: To calculate the total SCV score ($\mathrm{SC}_{\mathrm{SCV}}$) of a product's SC, $\mathrm{SC}_{\mathrm{OV}}$, $\mathrm{SC}_{\mathrm{VV}}$, $\mathrm{SC}_{\mathrm{BV}}$, and $\mathrm{SC}_{\mathrm{MV}}$ are necessary. As proposed by Nitsche [7], the corresponding four volatility dimensions do not impact SCV equally. To calculate $\mathrm{SC}_{\mathrm{SCV}}$, the weights proposed by Nitsche [7] will be applied.

$$\mathrm{SC}_{\mathrm{SCV}} = 0.341 \cdot \mathrm{SC}_{\mathrm{OV}} + 0.276 \cdot \mathrm{SC}_{\mathrm{VV}} + 0.203 \cdot \mathrm{SC}_{\mathrm{BV}} + 0.179 \cdot \mathrm{SC}_{\mathrm{MV}} \tag{43.10}$$

43.3 Current State of Supply Chain Volatility Management Performance

To gather required benchmarking data, a survey among manufacturing firms operating in different industries was conducted from June to July 2018. It was intended to cover a heterogeneous group of different types of manufacturing firms. For filling in the survey, participants had to fill in general company-related data first and afterward had to think of a representative product that is manufactured by their company and that they know very well. Afterward, all questions have been asked with regard to the representative product. In total, 87 responses have been collected coming from different manufacturing industries (mainly machinery/equipment, automotive, consumer goods, and chemicals/pharmaceuticals).

Table 43.3 outlines the benchmarking results of all questionnaire participants. The average, median, and distribution of variables are detailed. The categories for the corresponding volatility scores result from ten quantiles (deciles), meaning that the best values belonging best decile get the lowest volatility score of "1" going up to a volatility score of "10" for the worst values belonging to the worst decile. Values that are often represented sometimes form two or even three deciles. This means that the user must use the average of the respective scores for benchmarking.

It can be observed that best-in-class companies in the area of organizational alignment assess themselves with average scores of above 5.5 (7-point Likert scale), while the worst companies scored mean values below 3.27 for the six categories of organizational alignment. For the SCV source of *long lead times*, the biggest share in the total lead time belongs to the supplier lead time (LTS), meaning that this area should be prioritized when trying to mitigate SCV originating from long lead times in the SC. Companies with an average of above 110 days of LTS for their main components form the worst decile of investigated companies. Best-in-class companies achieve very low LTS for their main components of below five days. Although the median of on-time delivery rates on the supply and demand sides (OTDS and OTDC) is 90%, respectively, 92%, best companies score delivery reliabilities of above 99%.

For sources of *behavioral volatility*, the majority of participants rank themselves with scores below 4 (7-point Likert scale), meaning that a high level of erratic behavior of decision-makers as well as erratic behavior of customers is not a matter of fact in all SCs. However, companies with erratic behavior scores of above 5 rank among the worst in class resulting in a high level of SCV origination from the behavioral dimension.

43.4 Implications and Final Remarks

By incorporating volatility management performance data of 87 manufacturing firms, a benchmarking instrument was proposed that enables a case-based assessment of SCV management performance of a manufacturer. Building on prior research in the field of SCV management, the benchmarking instrument assesses SCV according to four distinct dimensions of SCV.

For managers, the benchmarking instrument enables them to investigate the volatility of a product's SC and monitor it on a long run, seeking to identify areas to focus on when trying to manage SCV efficiently. With the help of the instrument, they are able to assess whether the volatility of their product's SC is induced by themselves, by certain actors within their SC, and by a high level of competition at the market or other reasons. Therefore, the study is the first of its kind that facilitates a holistic assessment of SCV, one of the core phenomena in SCM. Additionally, for practitioners this study provides valuable information about the current state of volatility management performance in the manufacturing industry. Based on the feedback of 87 manufacturing firms, a benchmark has been condensed and incorporated into the SCV assessment that enables managers to compare their SCV management performance against others. This is of high importance since performance data generated by the focal firm itself is more valuable if it can be put into relation with performance data of competitors.

For researchers, the study provides a holistic approach to measure the volatility of a product's SC, which can be the basis for further research. Prior research in the assessment of SCV evaluated SCV from a macroeconomic perspective via measuring the volatility of exchange rate, raw material prices, and others [4]. Although it is of importance to measure and monitor the volatility of SCM-related market prices, from a practitioner's point of view, a case-based evaluation of its specific state of SCV is necessary to derive SC-specific information and initiate more purposeful actions from it.

However, like every study, also this one has its limitations that have to be pointed out. Since it is the first study of its kind, it was intended to cover a heterogeneous group of manufacturing companies, but for future analyses, the sample size needs to be increased and focused on certain industries. Especially a more in-depth analysis of benchmarking data according to different manufacturing industries would be necessary and of particular relevance for practitioners.

Nevertheless, the study extends prior research on the assessment of SCV that has so far taken a macroeconomic perspective, by a microeconomic view that is of importance especially for SC managers that are managing SCV on a daily basis. To the best of the author's knowledge, the study is the first of its kind that seeks to assess SCV management performance in a holistic way.

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Chapter 44
Short Food Supply Chain of Brazilian Organic Food: A Systematic Analysis of Literature

Brenda Guimarães Negrão, Patrícia Guarnieri and Ana Maria Resende Junqueira

Abstract The study aims to identify an overview on Brazilian literature approaching short food supply chains of organic food in Brazil, through a systematic literature review.

Keywords Short agrifood chains · Organic food · Short food supply chains

44.1 Introduction

In Brazil, the organic production chain is little different from other agrifood chains, being characterized as a short agroalimentary chain. So, the debate on the commercialization through short food supply chains is closely linked to the trade of organic and agroecological food. This is an emerging issue, and although there are not many studies on short food supply chains of organic food, the concepts used indicate the proximity between the farmers and the consumer [17, 22].

There are already signs of increasing commercialization in short agrifood chains in Brazil, but as it is an emerging theory, there is still no academic homogenization regarding short marketing chains [10].

The productive chain of organic food establishes the relation between the various agents involved in the chain links. Thus, from its analysis it is possible to identify bottlenecks and to base intervention or adjustment and development strategies [22]. The production chain of organic foods as proposed by Ormond et al. [17] was the first one described for the organic segment, where the functions that make up the productive chain, the agents that execute them and the forms of relationship between them are identified. It is important to emphasize that the organic food has a facility of insertion in the market; it is enough to be in agreement with the legislation and with consumer requirements.

The markets for short agrifood chains are significant, since the product reaches the consumer with a considerable degree of information and is loaded with value on its

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production process. Therefore, quality in relation to productive practices that involve environmental, health and food safety issues becomes a key factor in this process and the need to rebuild the relationship of trust between farmers and consumers is growing, so the short productive chains lead consumers to closer to the origins of their food and, in some cases, involve a direct contact between the farmers and the final consumer, increasing the value of food from the organic, agroecological and artisanal production of the short food supply chains [9, 14, 19].

Hence, given the growth and strategic dimension of the short food supply chains of organic food, it is necessary to question what is the Brazilian situation in relation to the knowledge of the short food supply chains of organic foods? Thus, the objective of this article is to identify how investigations are being approached on the supply chain of organic food in Brazilian publications. To do so, a search was carried out in a comprehensive database, with no specific period of publication, as it was an emerging topic, and 16 studies were analyzed as described in the next section.

44.2 Methodology

As for the technical research procedure, Cronin et al. [6] present two types of the literature review: the narrative or traditional revision of the literature that summarizes the literature, but does not leave explicit to the reader what were the criteria followed for the selection of sources, and a systematic review of the literature, which uses a well-defined approach to review the literature, following a pre-established protocol for selecting and analyzing sources.

Thus, for the review to be reliably evaluated, Cronin et al. [6] assert that the reviewer needs to meet five criteria: (I) The research needs a question; (II) it is necessary to define what are the inclusion and exclusion criteria; (III) selection and access to the literature; (IV) evaluation of the quality of the literature that will be included in the review; and (V) finally perform the analysis, synthesis and dissemination of results. So, for this review, the search criteria are described below:

- **Formulation of the research question**: How are the studies on the short food supply chains of organic foods being addressed in Brazil?
- **Define inclusion or exclusion criteria**: The criteria selected were about keywords, publications and national scientific articles published in journals. The research was carried out in the Google Scholar database, since this tool allows a wide survey, searching results on several scientific bases, generating a considerable number of publications to be refined according to the selection criteria. Due to the fact that it is a developing subject in Brazil, no publication period was selected. In addition, the search terms "supply chain of organic food," "supply chain and organic products," "supply chain organic food," "short food supply chain of organic food" were used to filter the studies that are interested to the chosen theme and direct them to the purpose of the study. Finally, articles published in journals were selected.

- **Selection and access to the literature**: The results of the search in the database resulted in a total of 1050 items, but strictly following the inclusion and exclusion criteria, there were only 16 publications referring to the years 2002–2017, since the excluded were articles referring to other countries, theses and dissertations and also deviated from the theme.
- **Evaluate the quality of the literature included in the review**: The 16 articles selected for the review were evaluated based on the reading of the abstract, introduction, methodological procedures and final considerations of each publication.
- **Analyze, synthesize and disseminate the results**: For the analysis, 16 articles were selected that speak directly about short food supply chains of organic food. For the synthesis, Table 44.1 is elaborated where the classification of each publication is presented synthetically. And, finally, in order to disseminate the results, a discussion about the data obtained from these articles was elaborated.

44.3 Presentation, Analysis and Discussion of the Results

First, the total of 16 articles resulted in 95 citations from 2002 to July 2018, with 6.3 being the average of citations per year (all articles). However, some articles have not been quoted, but this fact can be explained because the articles are very recent. The articles were organized as Times Cited—highest to lowest, that is, from the most cited to the least cited in order to organize them by relevance.

Table 44.1 shows all articles in descending order, with article title, authors, year of publication, total citations since its publication and type of approach.

Analyzing the table, it is possible to observe that, in the selected articles, ten fit into a direct approach to the topic and 6 in an indirect approach. In short, the articles of indirect approach make a more general analysis of short food supply chains of organic food; that is, they do not go deep into the subject, being the short food supply chains of organic food mentioned only marginally in these articles.

In addition, it should be noted that no author focuses directly on this topic of study, since it is usually linked to another subject. Among the authors who published the most, we highlight Schneider with 4 (four) publications and Abreu with 2 (two).

Regarding the main key-words analized in the 16 publications under consideration, the term "familiy farming" is the most recurrent, with 6 citations, followed by "agroecology" with also [6]; "organic food", with [5] and "short food supply chains" with [3]. Thus, it can be assumed that short chains of organic food are directly related to family farming and quality.

The methodologies chosen by the authors for the 16 studies analyzed were classified as shown in the chart of Fig. 44.1. In it, we can perceive that the nature of research focused on qualitative–quantitative studies:

Based on the chart of Fig. 44.1, it is possible to observe that 38% of the articles used the qualitative and quantitative methodologies jointly, through interviews,

Table 44.1 Most relevant articles for research

Title	Authors	Number of citations	Approach
Participatory certification practices in organic farming: network, seals and innovation processes	Radomsky [18]	23	Indirect
Transferal of devices for recognition of organic agriculture and local appropriation: an analysis of the Ecovida network	Byé et al. [3]	16	Direct
Production and consumption of food: new networks and actors	Cassol and Schneider [4]	15	Indirect
Delimiting the boundaries between conventional and alternative markets for the family farm	Niederle [15]	12	Indirect
Short food supply chains, cooperation and quality products in the family farming—the process of agrifood production relocalization in Santa Catarina, Brazil	Schneider and Ferrari [23]	12	Indirect
Alternative food networks and new production–consumption relations in France and Brazil	Darolt et al. [7]	6	Direct
Evaluation of quality management among organic food farmers: alignment of process and consumer	Anacleto et al. [1]	3	Indirect
Organic farmers and sustainability	Sá et al. [20]	3	Direct
Performance of family farmers in the marketing of organic and agroecological products in the state of Pará	Santos et al. [21]	2	Direct
New views for sustainable production in family agriculture: Assessment of American lettuce cultivated with different types of organic fertilizers	Celestrino et al. [5]	2	Indirect

(continued)

Table 44.1 (continued)

Title	Authors	Number of citations	Approach
Family production diversity and organic product commercialization of Vitória (ES)	Sposito and Abreu [24]	1	Indirect
Talk came to kitchen: A look at the use of natural agrifood cuisine in contemporary	Zaneti and Schneider [25]	0	Indirect
The importance of certification in short circuits of organic food	Dias et al. [8]	0	Direct
Costs systems institutional formalization agro-industrial base of family ecological—SAFES	Gazolla et al. [12]	0	Indirect
Social organizations and marketing channels accessed by agroecological farmers: A case study in the open-air market central Chapecó, SC	Klock Filho et al. [13]	0	Direct
Contributions of marketing strategies and consumer behavior toward the construction of the ecologically based food system	Araújo and Marjotta-Maistro [2]	0	Indirect

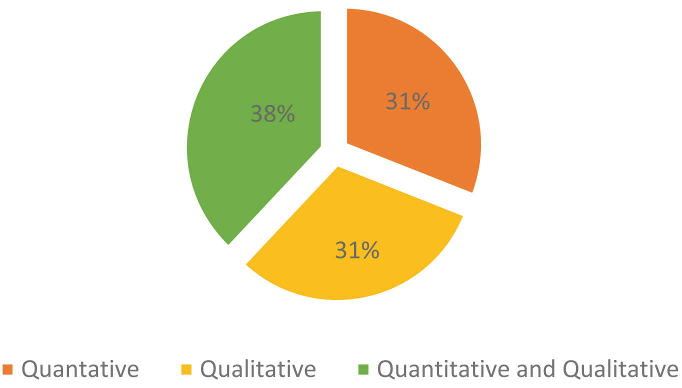

Fig. 44.1 Chart of the nature of the surveys

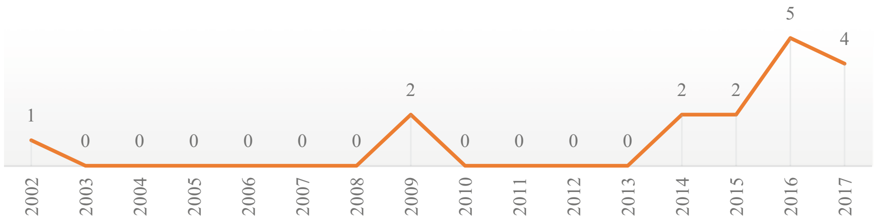

Fig. 44.2 Graphical evolution of publications

quantitative survey (through semi-structured questionnaires), observations, visits, field research and bibliographical research [3, 5, 13, 20, 23, 24].

It is also worth mentioning that the predominant methodological procedure was the "case study." It was used in the majority of them [13], in which they tell a little about organic food companies and farmers [1, 3, 7, 8, 12, 13, 15, 18, 20, 23]. In these surveys, the authors discuss the history of these ecologically based companies and food producers, as well as their origins and challenges. Thus, these works reiterate the importance of the links between the agents of the short food supply chains. Another important point about these works is that they do not only cover foods of plant origin. There are also studies focused on organic products of animal origin.

Regarding the period of publication, it can be seen in the chart of Fig. 44.2 that the researches related to short food supply chains of organic foods presented a larger proportion at the beginning of this twenty-first century. And, in the following years, there was a decline of publications in the period from 2010 to 2013, growing again the following year (2014). Perhaps this proves that, although it is an emerging issue, it is not yet consolidated and is not being discussed as it should be.

Another important factor that can be observed is that, prior to the year 2002, no specific studies were found on short food supply chains of organic foods in Brazil. However, the theme is not so current. Thus, by the brief historical rescue carried out by the 16 analyzed articles, it is noted that this theme has been studied since the beginning of the twentieth century. However, no specific publications were found prior to the year 2002 in the database consulted.

Based on the analyzed articles, we can see that, although Brazil has an agricultural vocation in all regions, it is verified that the concentration of studies on short food supply chains of organic food is in southern and southeastern Brazil [1, 3, 8, 12, 13, 16, 18, 20, 23, 24]. In addition, the south and the southeast of Brazil are essentially agricultural regions, with national prominence in these activities. It is worth noting that, despite presenting few works, the northern and northeastern regions presented publication on the theme.

It is important to emphasize that other studies always refer to the south and southeast regions as examples of some cases and analyses. This concentration is due to the fact that the southern region is one of the pioneers in studies on family agriculture and short food supply chains in Brazil. In addition, this is an essentially agricultural region, with national prominence in these activities [3, 22].

From the case studies referring to the states of the Brazilian South [11], four studies have as coauthor the professor and researcher in sociology and rural development Sérgio Schneider [4, 8, 23, 25]. Therefore, it is understood that he is considered one of the main researchers on the subject in question, although the studies on short agrifood chains can be considered “marked by sociological tendency of the perspective of a central author” [10].

Because it is a multidisciplinary area, the analyzed articles are inserted in several fields of action. The highlights for ten very different works, but in the same theme, are as follows: First is the environmental management, because it refers to organic foods in which, for their production, it is necessary to implant practices and techniques for the environment and that are inserted in the short food supply chains of commercialization when production costs and profitability are analyzed to be related to production performance indicators [12, 13, 20, 21].

The second is sociology, because it is about the improvement in the social environment, that is, of the influences between interpersonal relations within production and the links of the chains, being able to analyze more deeply the dynamics between these links [3, 9, 18, 23, 24].

And the third outstanding field of action is marketing, as it is a mean to overcome the limitations of family farming in marketing so that it is possible to carry out the most diverse actions of dissemination of organic foods. Therefore, the strategies are encompassed in the marketing [2, 21, 24].

Hence, in order to be able to research on the proposed theme, it is necessary to enter the field of different areas of study, in order to understand this phenomenon of the short chains of organic foods which is increasingly popular not only in the conventional production system but mainly in the organic. And although there is a significant amount of publications on the subject, it is worth noting that the analyzed articles have been published in journals of different approaches, reinforcing the idea that it is a multidisciplinary area.

Thus, it was observed that the studies found on short food supply chains of organic food are more general and less specific. And these few studies mostly target a particular region of the country, so the results, concepts and development cannot be generalized to the other states.

44.4 Conclusions and Future Research

Organic agriculture is a production system that aims at the quality of life for those who produce and for those who consume organic foods. Although there are many publications on organic foods, specific studies on the short food supply chain of organic food in Brazil are recent and, therefore, the studies in the area are few and widely dispersed in terms of year of publication and focus of approaches.

In spite of this, in Brazil, although the short food supply chains of organic foods are very concentrated in the south of the country and have strategic potential, the short food supply chain of organic food is still poorly studied because it is very recent, resulting in an inconclusive study deserving more focus, since given results obtained, the country has potential to promote social and economic development.

As a contribution to future studies, the present work allows to visualize the Brazilian overview on the short food supply chains of organic food, being able to verify the main fields of action in which it is inserted.

Organic agriculture is one of the most widespread alternative forms of agriculture in the pursuit of sustainability. Therefore, there is a need for new, more comprehensive research on the phenomenon of short agrofood supply chains of organic food, especially in regions of the country that are poorly studied. And because it is a multidisciplinary field that covers several areas of study, a better understanding of different theoretical points of view only enriches this field of study, both from a national and from an international point of view. This will bring more benefits to the sector, representing more solidity in the construction of organic short food supply chain of organic food.

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Chapter 45
Sales and Operations Planning Application: A Case Study in Brazil

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Abstract This paper addresses a research–practice gap in the sales and operations planning (S&OP) literature by offering the main lessons learnt from a case study. Findings indicate that S&OP has been key to manage the enterprise's complexity and to align internal efforts toward its goals with a positive impact on performance.

Keywords Supply chain management · Supply planning · Packaged consumer goods

45.1 Introduction

S&OP is a cyclic process that balances demand with supply, consolidates the business functional areas' plans (operations, sales, marketing, and finance), and aligns them with the highest enterprise's strategic plan [2, 14, 15, 17, 20, 22] to maximize profit [6]. S&OP, if properly executed, may contribute to increase company's performance improving revenue, profit, and supply chain results regarding costs, service levels, forecast accuracy, inventory level, and asset utilization [3, 13, 14, 17]. S&OP has been considered by scholars and practitioners as an important supply chain management process [14, 17] that has been adopted by a growing number of organizations from all geographies [1, 10, 14]. Even though the literature about S&OP has grown significantly [14, 17, 20], there still is interest about new case studies to investigate

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open opportunities [6, 7, 14, 17], such as more empirical studies in different industries and contexts [9, 14].

This paper addresses a research–practice gap in sales and operations planning providing scholars and practitioners with relevant information that must be considered in a real-life context in order to develop and implement S&OP successfully. The objective of this research work is to present the learning from a case study in the Brazilian subsidiary of a multinational corporation that manufactures and commercializes consumer products. The paper contributes with empirical evidences to evaluate how S&OP practices are implemented and provides indications about benefits achieved. The remainder of the paper is as follows. Section 45.2 offers a theoretical background on S&OP, and Sect. 45.3 offers the research method adopted. The case study and its findings are presented in Sect. 45.4. The main results are discussed in Sect. 45.5. Conclusions and suggestions for future research close the paper in Sect. 45.6.

45.2 Theoretical Background

S&OP is a business process [6, 14] performed cyclically [2, 11, 17] that aligns the enterprise's business functional areas' plans (e.g., operations, sales, marketing, and finance) based on a consensus [1, 4, 6, 22] to optimize profit [6]. S&OP balances demand and supply [1, 11, 22], considering the organization's operations and financial capacities [5]. Usually, the demand forecast is handled at an aggregate level and covers a planning horizon compatible with the organization's strategic planning periodicity [6, 17]. This planning horizon frequently encompasses 18 months ahead, but one year is also a period often elected by many companies because of their budgeting frequency [22]. S&OP links the reconciled tactical business functional areas' plans with the strategic plan [1, 15, 17, 21, 22].

S&OP success factors include, among others, empowered representatives from the business functional areas (e.g., operations, sales, marketing, and finance) actively collaborating in the S&OP team, a champion to coordinate the activities, information technology (IT) support, adequate set of metrics, engagement of key partners (suppliers and customers), and sponsorship from senior executives [6, 8, 16, 17, 22].

S&OP is generally executed in five steps [11, 17, 22]. The steps are described according to Wallace and Stahl [22]. Data gathering is step one. The enterprise resource planning system is fed with data and typically updates regarding production, supply, sales, inventories, new products, costs, and prices, on the first day of the month. Historical demand information is provided to sales and marketing. Demand planning is step two. On the first days of the month, sales and marketing teams review the information received, add planned new product launches, and build the demand plan. Supply planning is step three, when the demand plan received is simulated to generate the supply plan. The supply plan incorporates capacity constraints. Pre-meeting is step four, when representatives from the functional areas (e.g., operations, sales, marketing, and finance) discuss the discrepancies found between demand and supply plans and work together to mitigate the gaps. The agreed S&OP plan proposal with financial figures and the unresolved issues that need senior executives' decision are brought to the executive meeting (step five). In the executive meeting, the senior executives resolve the pending issues from previous steps, approve the final S&OP plan, and review key performance indicators, projects' progresses, and new product launches.

45.3 Research Method

The research is a case study as it analyzes the S&OP process in a real-life context situation [23] in the Brazilian subsidiary of a multinational corporation that manufactures and commercializes consumer goods. Some criteria were considered to choose the Brazilian subsidiary. The S&OP process in this subsidiary is representative of the global S&OP implementation of the multinational corporation, thus conferring representativeness to the sample [23]. The Brazilian subsidiary has an established S&OP process with the traditional five-step cycle running. The sample is representative of the company as this is the biggest operation in Latin America, contributing with approximately 40% of the regional revenues. Additionally, Brazil is the biggest country regarding territory, population, gross domestic product (GDP), and market size in the region.

Extensive field observations were performed to collect information. Interviews were conducted with executives using a semi-structured questionnaire [23], inspired from Manuj and Sahin [12]. Interviews were face to face and followed a protocol consistent with Yin's [23] guidelines. Additional questions were made to clarify the information when needed. The interviews covered the functions of supply and S&OP manager (1 position), supply planner, demand planning manager, two sales directors, supply chain director, production planning manager, financial planning manager, and general manager. Direct observation was also an important instrument to collect data. One of the researchers took part in all the meetings of the S&OP cycle. Observations covered more than one year, coinciding with the period of global implementation when procedures were standardized, personnel was trained, and S&OP procedures were audited. An internal team guided the S&OP global implementation, following Wallace and Stahl's [22] model. Internal documents were verified and analyzed as evidence of the practices in the subsidiary. Validity checks and triangulations were performed by comparing field observations, answers from interviews, internal documents, and public data about the company.

45.4 Brazilian Subsidiary Case Study

The organization studied is the Brazilian subsidiary of a multinational corporation headquartered in the USA and present in more than 50 countries that manufacture and commercialize a wide portfolio of consumer products. The corporation's revenues are around $6 billion annually, and it employs around 18,000 people worldwide. It has customers from different market channels, e.g., wholesalers, distributors, and retailers. The multinational corporation decided to create a global project to deploy the S&OP to all subsidiaries expecting that the process is going to increase the internal collaboration and the focus on results and improve the overall performance. There are several subsidiaries around the world, as for instance the Brazilian subsidiary, that have worked with S&OP for years but there are others in earlier implementation stages or using other planning processes. The global S&OP team is training the employees to implement the standard process and has started to audit the most advanced subsidiaries. The S&OP manual is the reference guide created to present how the cycle must be executed and it is used to train people and to assess the subsidiaries around the world.

The Brazilian subsidiary employs around 1400 people and commercializes around 6500 stock keeping units (SKUs), delivering to approximately 8000 clients, being responsible for close to 40% of the Latin American annual revenues. The biggest business in the country is responsible for approximately 85% of the sales. Approximately, 65% of the portfolio is locally manufactured and the rest is imported from a dozen countries (e.g., USA, China, Taiwan, Indonesia, India, and Mexico). The local industrial plants use information technology tools to plan the shop floor production scheduling. The company has two DCs, each one specialized in some product lines. The supply manager and his team plan the product needs (master production plan for local plants and sourcing plan for imported goods), supported by a material requirement planning (MRP) system. The subsidiary's supply strategies are make-to-stock and buy-to-stock, based on sales forecast. The sales department is divided into four different teams by business (product line) or by market channel; each one is led by a director and is focused on specific customers. The marketing department is divided by business (product line), and there are three directors conducting the brand and product strategies. Sales and marketing departments provide an aggregate and are opened by item demand forecasts, based on historical sales and on the planned market initiatives. In the biggest business, the sales administration team has skilled trained people and uses the software Demand Solution to generate the demand plan. The four sales directors, the three marketing directors, the finance director, the human resources director, the supply chain director, the two industrial directors, and the managing director compose the local senior management team. The supply chain director has the overall responsibility for managing the S&OP cycle with the participation of all directors. The managing director sponsors the process.

The demand plans for all product lines, the supply plan, the inventory data, the new product launches, the trade promotions, costs, prices, and the budget are the main S&OP process inputs.

The organization follows Wallace and Stahl's [22] five-step model, and there is an agreed published calendar for the S&OP cycle meetings. S&OP is a corporate priority, and the managing director sponsors and supports the process locally. There is a good level of collaboration and participation observed in the Brazilian subsidiary. Finance representatives do not attend the meetings very often, with the exception of the executive meeting, but they are informed about the meeting results. In general, the people involved in the S&OP process are committed and the S&OP activities are considered part of their normal responsibilities. Not everybody has the same level of commitment and knowledge though, but there is no resistance against the S&OP process.

The business functional areas' representatives that compose the S&OP team are defined and have adequate autonomy to perform their tasks. The supply manager is responsible for managing the S&OP cycle in Brazil. In case of difficulties or disputes, the supply chain director or the managing director supports him. The S&OP process has a meeting calendar, a defined list of topics that should be covered in the meetings, a participants' list with clear roles and responsibilities, defined information that needs to be generated (demand plan, capacity plan, metrics, etc.), meeting minutes, and presentations showing the S&OP plan, threats, opportunities, gap mitigation action plans, and metrics. There are official metrics and reports that are used as part of the S&OP process. The standard set of metrics that all the subsidiaries worldwide have to keep track and report includes: service levels, inventory figures, forecast accuracy, total number of SKUs, excess and obsolete items, among others. These key performance indicators (KPIs) are calculated the same way everywhere and are presented in a scorecard together with their targets during the cycle meetings. They are also sent to the multinational corporation headquarter, where information gathered from all subsidiaries is consolidated. Manufacturing KPIs are reviewed in operations that have local plants. Not all KPIs can be obtained automatically from the ERP, and a few still need to be calculated manually in spreadsheets. Besides these KPIs, other reports became widely used and are commonly presented: top 20 clients' service levels, top 20 offenders (product lacking shown in terms of quantity and financial impact), excess and obsolete item list, and concentration of sales per week.

The S&OP process implemented in the Brazilian subsidiary generates a demand plan, including new product launches, a supply plan with identified capacity constraints, and an approved S&OP plan with financial analysis. The management team supports the process and actively participates in the cycle meetings, and all business functional areas are represented. The process aligns internally the organization.

45.5 Discussion

The S&OP process implemented in Brazil follows the multinational corporation's manual which is consistent with Wallce and Stahl's [22] model.

The Brazilian subsidiary is a complex organization considering context parameters as the number of facilities, number of employees, number of suppliers, number of customers, portfolio of products, etc. Lately, the subsidiary has launched consistently more than 600 new SKUs per year. It also brings in 40% of Latin American revenues. Thomé et al. [19] demonstrated a strong correlation indicating the positive effect that the S&OP has on manufacturing companies' performance. The study showed that this benefit is even potentialized by the increase in the complexity. Thomé et al. [18] also analyzed the S&OP positive impact on the firm's performance.

The demand planning process performed in Brazil has generated good results: The aggregate forecast accuracy has been consistently between 73 and 76%, despite all the new product launches. Although the skilled forecasters in the sales team and the IT tool used seem to be the main reasons for the good results, another factor may also help to improve the accuracy at an aggregate level: The customer basis in Brazil (8000 customers) generates a more stable and predictable demand, less dependable on individual customers, even with a large portfolio of products. Other positive trends observed are an increase in the service levels and inventory kept on target. The results are promising, but it is still too early to come to final conclusions based on historical data about the S&OP process impact on the Brazilian subsidiary's performance. The new standard process has been recently implemented. But the benefit of the S&OP process to manage the complexity and internally align the Brazilian organization is empirically clearly perceivable in this case.

The four sales teams actively participate in the S&OP process, but the demand plan ownership varies depending on the team. Some are more committed with the forecast than others. The sales teams' main focus is primarily delivering the financial budget targets. Sometimes, this mindset impacts forecast accuracy, inventory balance, and service level.

One strategy to improve the S&OP process and incentivize collaboration among the participants is the adoption of cross-functional process indicators. The multinational corporation in the case study, for example, books the sales only when the orders are effectively received by the customers. The final sales result is determined when all returns are discounted. Everybody's bonuses depend on this final number. As a consequence, the sales teams are concerned to bring the orders as soon as possible and sell as close as possible to what was previously forecasted by them. The sales teams know the lead times to deliver to the different regions in the country from the DCs, and they bring the customers' orders accordingly. They usually look at the available inventory and talk to logistics and supply planning before they close deals that were not forecasted. Additionally, forecast accuracy and service-level targets are two criteria taken into account in the annual performance assessments of the executives in the Brazilian subsidiary. In general, there is good collaboration between sales and operations and the sales teams are committed with S&OP but exceptions happen occasionally when it becomes difficult for them to deliver their sales targets from a financial perspective.

When the manufacturing plants are embedded in the local business sharing the same budget and common objectives like in the Brazilian subsidiary, they are committed to deliver the subsidiary's targets, their response is faster, and there is more flexibility from manufacturing. In other countries, there are plants owned by the multinational corporation that are completely independent from the local subsidiary, they are considered global suppliers, and they treat the local subsidiary as a normal customer with limited flexibility. The Brazilian local plants manufacture 65% of the portfolio, giving more flexibility and quick response, allowing lower inventory levels. Industrial directors' participation sponsoring S&OP helps improve results. Again, it is an example on how common process indicators and targets help the S&OP process succeed.

Finally, it was noticed that finance does not participate as actively as the other business functional areas in the process. Even though the S&OP has a strong focus on sales, marketing, and operations, considering the objective of balancing demand and supply, finance participation is very important because the final objective of the process is optimizing profit. The Brazilian subsidiary could take more advantage from finance team's participation in S&OP, adding value to the discussions with its business expertise.

45.6 Conclusions

The paper investigated in detail the S&OP process implemented and running in the Brazilian subsidiary of a multinational corporation that manufactures and commercializes consumer products. The organization has a solid implementation following their S&OP corporate manual and Wallace and Stahl's [22] model. Key elements of the S&OP process are present, and a complete cycle is executed every month sponsored by the subsidiary's management team. The multinational corporation is standardizing the process worldwide, and as a consequence S&OP is a top priority and its consolidated results are examined even by the CEO, his direct reports, and some board members periodically. Clearly, the Brazilian subsidiary has obtained benefits by adopting the S&OP process because of the type of industry, size of the business, and their complexity (portfolio, suppliers, customers, market channels, structure). Without a process to ensure alignment among all the business functional areas, it would be extremely difficult to deliver the business targets with this level of complexity. Some positive trends have been identified, but more time is needed to base conclusions on historical data as the new standard process has been recently implemented.

The study raised questions and subjects for future academic researches. How is S&OP consolidated globally in a multinational corporation? What actions and plans result from this review? How effective is it? What should be the role of finance in S&OP? These are some of the subjects of interest to be investigated in the next steps.

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Chapter 46
Programming Optimization of Roasted Coffee Production in a Coffee Roasting Company

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Abstract This work focuses on the development of a methodology to support the planning of aggregated production within a roasted coffee industrializing company. The methodology involves optimization techniques and computational tools for the assigning of lots to roasting lines while minimizing total costs and fulfilling the specifications of the process.

Keywords Production programming · Coffee roasting process · Optimization model

46.1 Introduction

The roasting process consists in the transformation of green coffee grains by means of thermal transference using a roaster, giving place to several physical changes such as size, color, weight loss, and chemical reactions that grant the attributes of flavor and aroma which are characteristic of the beverage. When the process begins, the coffee grain absorbs heat and loses moisture, weight, size, and some gases. Then the "first crack" happens, here the grain grows in size and gradually becomes a darker color due to the caramelizing sugars. Depending on how roasted the coffee is wanted, a "second crack" may be produced, generating liberation of the grain's internal heat. From that moment forward, the temperature of the grain is reduced using water or cold air to obtain the desired color and flavor. Chemical reactions continue to happen internally in the grain during hours or even days. Once the process is finalized, the grain emits CO_2 in smaller or larger quantities according to its final roasting. Consequently, it is necessary to go through repose and a degassing process before entering the following stages of the process. In the process, coffee loses mass caused by the loss of organic material and volatile gases. The loss may vary according to the quality of the raw material and the roaster used. In addition, some energetic resources are necessary to roast the coffee such as fuel (to operate the burners, the primary source of heat),

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water (used in the coffee roasting process), and electric energy (to move the engines of the roasters). In the same way that mass loss depends on the raw material that is used, the energy consumption also depends on the raw material used, the final color of the roasted coffee and the roaster used to process the coffee [2].

46.2 Description of the Problem

After the coffee is roasted, it has three different possible paths to take: (i) it is directly packaged, (ii) it is ground and packed, or (iii) it is ground and submitted to an industrial extraction process to produce coffee. There are production necessities generated depending on the client of the process which are required through orders for coffee to roast. Each one of these roasters has different production capacities and velocity, depending on the processed product. Also, depending on the raw material and the used resource, the coffee mass loss and energy consumption are different [2].

After roasting the coffee, it is provided toward storage silos of the client machines. In these silos, the roasted coffee needs to remain a certain amount of time in degassing before it can be consumed. Degassing time is variable to each product. Lastly, after the repose time in storage, the product is consumed at a specific speed. The consumption speed for roasted coffee varies accordingly to the client machine and finished product.

Consequently, a solution to the subsequent questioning is necessary: In aims of operation costs minimization and assuming all restrictions of the process how can the production orders be assigned?

46.3 Mathematical Model

To optimize the use of the resources available to process coffee, an optimization model is proposed in aims of minimizing costs of energy consumption and of the mass loss of the processed coffee, subject to the processing capacity of the roasters, the demand, and the capacity of response to delivering times, degassing, and consumption of the roasted coffee. Thus, sets are defined in the following way, **P** as the set of orders for coffee to be roasted and **T** as the set of roasters: **P**: Orders (i) and **T**: Roasters (j).

Below is each one of the parameters used in the optimization model:

- CE_{ij}: Cost of the energy consumptions of one kilogram of coffee from order i in roaster j. The cost of energy consumption corresponds to the cost of water, electric energy, and natural gas consumption for a kilogram of coffee processed in the roasters.
- CM_{ij}: Cost of the loss of mass when one kilogram of coffee from order i is processed in roaster j. The cost for the mass loss corresponds to the percentile reduction of mass between the green coffee that goes into the roaster and the processed roasted coffee, and it is calculated with the cost per kilogram of the used raw material.

- DDA_i: Kilograms of required roasted coffee in order i for the client of the process.
- VPT_j: Velocity of the roaster (kg/h) j to process green coffee.
- TD_i: Required time of degassing (h) for the roasted coffee in order i.
- VC_i: Velocity of consumption (kg/h) of the roasted coffee required in order i.
- CMT_j: Maximum processing capacity of the roaster j.

The decision is to determine what quantity of coffee from order i is to be processed in roaster j. Then, the variable of the decision of the optimization model is named below:

- X_{ij}: Kilograms of roasted coffee from order i assigned to roaster j.

Based on the previously mentioned, the problem is presented by the following optimization model:

$$\mathrm{Min} \sum_{i \in P} \sum_{j \in T} \left[\left(\mathrm{CE}_{ij} + \mathrm{CM}_{ij} \right) * \mathrm{X}_{ij} \right] \tag{46.1}$$

Subject to:

$$\sum_{j \in T} \mathrm{X}_{ij} \geq \mathrm{DDA}_i \quad \forall i \in P \tag{46.2}$$

$$\frac{X_{ij}}{\mathrm{VPT}_j} + \mathrm{TD}_i \leq \frac{\mathrm{DDA}_i}{\mathrm{VC}_i} \quad \forall i \in P, \; j \in T \tag{46.3}$$

$$\sum_{i \in P} \mathrm{X}_{ij} \leq \mathrm{CMT}_j \quad \forall j \in \mathrm{T} \tag{46.4}$$

$$\mathrm{X}_{ij} \geq 0 \quad \forall i \in P, \forall j \in T \tag{46.5}$$

The objective function (46.1) minimizes total costs through energy consumptions and mass loss of all the processed products in all the roasters. In formula (46.2), the demand restriction is presented, in which the total quantity, of roasted coffee from order i in kilograms, is assigned to all the roasters, and it must be higher or equal to the demand requirement made in order i. This restriction is for every i that belongs to set P. In (46.3), the restriction indicating that the times of delivery and degassing of roasted coffee should not exceed the time of consumption of the roasted coffee by the client of the process. The restriction formulated in (46.4) shows that the sum of the quantity of roasted coffee assigned to each roaster should not exceed the processing capacity of each roaster. In formula (46.5) a restriction of no negativity for the assigned quantity of roasted coffee from order i to each roaster j.

46.4 DOE for Cost and Fulfillment Simulation

To understand the behavior of the optimization model, over costs, and the fulfillment of the demand, two experiment designs were developed [4] in the statistics software r-project [1]. In these experiments, the effects of the demand were evaluated (DDA_i), the degassing time (TD_i) and the processing capacity of the roasters (CMT_j) over the total costs and the fulfillment of the required demand by the clients of the process ($\%\mathrm{DDA}_i$). For both designs, the following levels were taken into account for every one of the factors:

- DDA_i: Two levels for the demand factor, one with 10 orders and the other with 19 orders of coffee to roast.
- TD_i: 11 levels, valued in the number of hours, were used with the degassing time. The levels correspond to 0, 4, 8, 12, 16, 20, 24, 28, 32, 36, and 40 h of degassing for the roasted coffee.
- CMT_j: For this factor, the maximum capacity of every roaster was varied, starting from a base scenario, correspondent to 100%. 11 levels with values of 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, and 150%.
- Two replicas were made for every one of the treatments.

With the previous experimentation, it is known that the sample for each design is equal to 484 treatments. With the designed plan, the simulation ran the data in a computational tool built with Microsoft Excel, in which the Solver optimizer was used [3] and the Simplex solution method [7], to find the optimum values for each run. A real company from the industrial sector of roasted coffee in Medellin, Colombia, provided the database used for the simulations which provided information on costs, specific characteristics of the products and the roasters, to ensure the most realistically possible results. Figure 46.1 shows the main panel of the computational tool built for the data simulation; in it, a particular solution is evidenced found according to a required demand of roasted coffee (DDA_i) by five clients of the process, with a total of ten assigned orders (first two columns). This solution allows selecting the product from a pull-down list for every one of the clients of the process, information with which costs of a said product are charged automatically for each roaster, indicating

Fig. 46.1 Tool template for the implementation of optimization to the weekly aggregate plan. Own preparation using data from a Coffee Roasting Company

as well a visual panel addressing the path for the solution of the problem. In the yellow-colored matrix, the decision variables (X_{ij}) corresponding to the assigning of roasted coffee from orders *i* and roasters *j*. Also, the total quantities assigned to each order can be seen with their respective total cost of operation. Additionally, the times of supplying roasted coffee and the consumption times after the degassing stage are shown.

The tool also includes a summary chart, where the demand made by each client of the process and the relation to the weekly processing capacity can be observed, to quickly identify if, from the start, there is enough capacity to fulfill the requirements. Going further, it allows for the reduction of the weekly processing capacity for each roaster, according to the requirements of scheduled maintenance, with the possibility of diminishing availability hours for the machines or completely block any of the roasters to take it out of service, if necessary.

Thus, for the first design of experiments, the effect of factors DDA_i, TD_i, and CMT_j over the fulfillment of the demand (%DDA_i) was validated, corresponding to a percentage of the delivered versus the required. An analysis of variance was made [6] where the effects of the factors over the response variable were verified, through the validation of p value [5], assuming a significance level of 0.05. According to the ANOVA, it is evident that all the factors and their interactions affect the response variable with *p* values lower than the significance level of 0.05, except for the CMT_j:TD_i interaction, and the triple interaction CMT_j:DDA_i:TDi.

Now, if we observe the boxplot graphs in Fig. 46.2, it is evident that each of the factors affects compliance with the demand. According to the graph of roasters (CMT_j) maximum capacity, fulfillment of the demand (%DDA_i) decreases as the processing capacity of the roasters decreases, this effect is related to restrictions (46.2) and (46.4) of the optimization model; by reducing the capacity of the roaster, the amount of coffee assigned to it also diminishes, and if the DDA_i is higher than

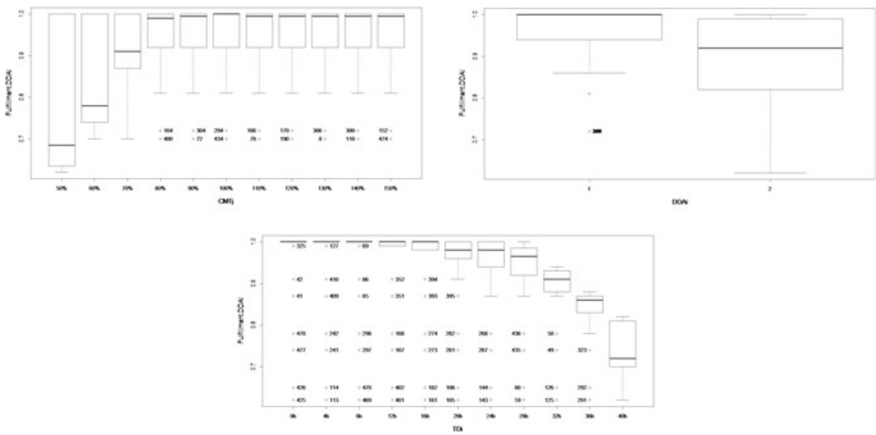

Fig. 46.2 Boxplot graphs of each of the factors against compliance with the demand. Own preparation using data from a Coffee Roasting Company

what can be assigned to the roasters, restriction (46.2) is not satisfied. In the graph of the requested demand for roasted coffee (DDA_i), the fulfillment of the demand is lower as much as the demand is higher, which can be explained again from the relation of restrictions (46.2) and (46.4), where the assigned coffee cannot exceed the maximum processing capacity of the roasters (CMT_j), but neither can be lower than the requested demand (DDA_i), so if the demand is greater than the maximum processing capacity of the roasters, it tops up the capacity of the roasters and restriction (46.2) is breached, affecting the percentage of compliance with that demand. For the graph of degassing times (TD_i), it is evident that as the hours of degassing required for the products increase, compliance with the demand decreases, given by restriction (46.3) of the model. For example, suppose that the degassing time of a product i (TD_i) is 40 h, the processing velocity of the roaster j (VPT_j) is 3000 kg of coffee per hour, the demand for roasted coffee of the product i (DDA_i) is 200,000 kg of coffee and the velocity of consumption of roasted coffee of product i (VC_i) is 2000 kg of roasted coffee per hour, then restriction (46.3) is rewritten as follows:

$$\frac{X_{ij}}{3000\ \text{kg/h}} + 40\ \text{h} \leq \frac{200,000\ \text{kg}}{2000\ \text{kg/h}} \tag{46.6}$$

Clearing X_{ij}, it remains that $X_{ij} \leq (100–40\ \text{h}) * 3000\ \text{kg/h}$, then $X_{ij} \leq 180{,}000$ kg, which means that restriction (46.3) is fulfilled, but restriction (46.2) is breached since the assigned one is lower than what is on demand. If the degassing time changed from 40 to 0 h, the equation changes to $X_{ij} \leq (100–0\ \text{h}) * 3000\ \text{kg/h}$, then $X_{ij} \leq 300{,}000$ kg, which indicates that restriction (46.3) is met and ensures that restriction (46.2) is also fulfilled, since the assigned can be greater than or equal to the requested.

From the previous behavior, several assertions can be made in the quest to potentiate the industrial process of coffee roasting regarding meeting the demand: Increment of the velocity of roasted coffee processing of the roasters (CMT_j), reduction of degassing times of roasted coffee (TD_i), decreasing the consumption velocity (VC_i), and regulating the demand for roasted coffee (DDA_i) taking into account for the maximum processing capacity of the roasters.

To increase the processing velocity, of roasted coffee, in the roasters from the industry, two things can be done: First is to invest in a roaster, which implies an extremely high cost; the second is to work on increasing the green coffee load of each batch, looking for the same roasting times, or sustain the same load of green coffee and reduce the roasting cycle times, always guaranteeing the same taste parameters of the finished product. For the second option, the cost of implementation corresponds to the cost of performing the experiments in the process that is usually much lower than the investment than in option 1 [8].

Modifications can be made to the storage and degassing silos of roasted coffee to reduce degassing times (TD_i), for example, making partitions or compartments to the silos to reduce the size of the lots of roasted coffee to be stored, in this way increase the flow of delivered roasted coffee. Another intervention that can be carried out in the industrial process to reduce degassing times is to provide systems for the extraction of CO_2 in the storage silos, to accelerate the degassing process.

If you do not have a budget to invest in technology or infrastructure, the most usual way to improve compliance with demand is to make a line balance, that is, regulate the demand for roasted coffee to the maximum processing capacity of roasters and reduce the consumption velocities of roasted coffee in the client processes to sustain a continuous flow and satisfy the demand, based on the processing capabilities of the restriction machine of the productive system.

Understanding the effect of the factors DDA_i, TD_i, and CMT_j on the fulfillment of demand (%DDA_i), we proceed to review the effect of these same factors on the total costs of operation. For this, an analysis of variance was performed where the effects of the factors on the response variable were also verified, through the validation of *p* value, which must be lower than a level of significance of 0.05, to approve the hypothesis in question. According to the ANOVA, it is evident that all factors and their interactions affect the response variable, except for the CMT_j:TD*i* interaction, and the triple interaction between CMT_j:DDA_i:TD_i. If the boxplot graphs in Fig. 46.3 can be made evident, an observation is that each of the factors affects the total cost of operation.

Figure 46.3 shows three boxplot graphs, where the variation of each of the factors on total operating costs is evident.

The first graph shows the evolution of the maximum capacity of the roasters (CMT_j) against the operating costs, and it is observed that from 50 to 80% the cost increases until reaching a maximum value. This behavior occurs because compliance with demand at these levels is below 100%, already shown since the first DOE. Once the optimum maximum cost has been reached, as the capacity of the roasters continues to increase, the optimum cost decreases until it stabilizes at a value. According to formula (46.4), to the extent that the CMT_j is lower, the kilograms of coffee to be assigned to each roaster must be reduced, then, following the objective function of costs (46.1), the full capacity of the most efficient roaster is utilized in terms of costs

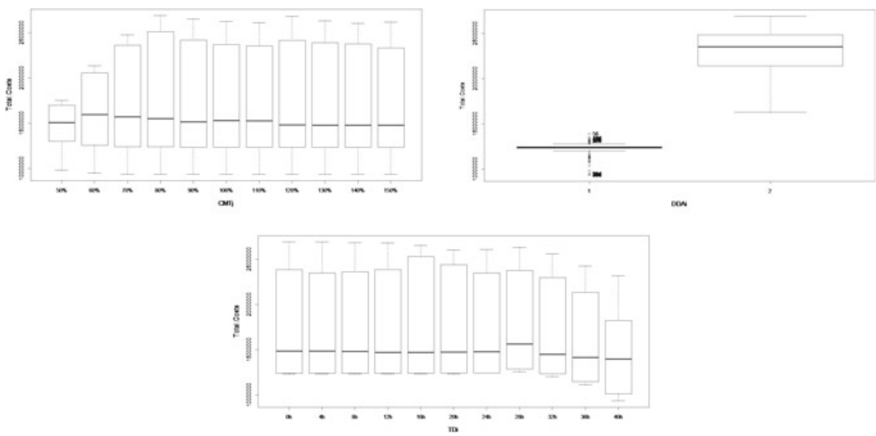

Fig. 46.3 Boxplot graphs of each of the factors against compliance with the demand. Own preparation using data from a Coffee Roasting Company

and in the same sense the assigning continues until completing the demand (DDA_i) or the maximum capacity of all the roasters. In the boxplot graph, where the levels of the factor versus the cost of operation are shown, it can be evidenced that as the DDA_i increases, the kilograms of coffee to be assigned to the roasters and consequently the total operating costs must increase.

The objective function formula is shown in (46.1). In the third graph in Fig. 46.3, it is shown that while the hours of degassing required for roasted coffee (TD_i) increase, total operating costs remain stable until they reach 28 h of degassing, where they begin to diminish, where if reviewed from the fulfillment of the demand ($\%DDA_i$); at this level, a breach is evidenced, so the costs decrease due to less amount of coffee assigned (X_{ij}).

Concluding, operational costs are mainly affected by the processing capacity of roasters (CMT_j) and the demand for roasted coffee to be processed (DDA_i). Since the free allocation of roasted coffee is restricted to the most efficient roasters, and in the sense that more coffee is required to be processed, it is harder for the model to meet the demand, which assigns coffee to less efficient roasters until it is satisfied.

At the industrial level, to reduce these operating costs, the first thing done is to standardize the operation among the roasters, starting from the most efficient one. Then, by replicating operating parameters such as: (i) rotation frequencies of the roaster's fan, which has a direct impact on the energy efficiency of the roaster and the coffee mass loss; (ii) the frequency of rotation of the roaster's drum, which is related to the way in which the thermal energy transfer is carried out; (iii) the parameterization of energy demand from the burner in the roaster, which, depending on how it is carried out during the roasting cycle, has a result of energy consumption and a direct impact on the product resulting from the process [9].

46.5 Concluding Remarks

One of the essential results of the research work is the delivery of an optimization model that allows the weekly aggregate planning of the production in a roasted coffee production plant, seeking the minimum operating costs. The costs consolidate in the objective function, the costs of electricity, thermal energy, water consumption, and costs for mass loss. The result of the model is the allocation of some quantities of coffee requested in available roasters, at minimum cost and subject to restrictions of demand, processing capacity, and delivery times.

A technological tool was built to implement the optimization model, parting from a weekly necessity of coffee to be processed, an aggregate coffee planning can be carried out in the available resources, according to all the real characteristics of the process and the preventive maintenance requirements of the equipment. For those who carry out the planning activity, this tool is critical, since it allows to have a complete overview of the operation and to establish simulated scenarios according to production and maintenance requirements, which in the real environment are impossible to perform. In addition to this, allow the owner of the process to build technological improvement projects based on process simulations, with the objective of minimizing operating costs with the highest levels of services concerning satisfaction of demand.

With the structured mathematical models, the implementation was made in an Excel file, employing the Solver optimizer using the Simplex method to solve the problem. With the help of the r-project software, two experimental designs were constructed to validate model behaviors and establish improvement paths for industrial processes. These experimental designs were simulated in the structured application in Excel, where the results associated to the model showed that the processing capacity of the roasters has a direct impact on the final operating costs, since they do not have a capacity restriction, the assignment of the orders is made freely to the less efficient roasters, thus having the minimum operational costs. Another interesting result shows that both the degassing times and the processing capacity of the roasters have a direct effect on the fulfillment of the required demand, improving the satisfaction of the demand results when the degassing times are minimum and the capacity of processing is maximum.

The contribution of the research work is to apply an optimization model to the problem of production programming for batch processing machines, framed in a production line with unlinked parallel machines. The solution is contextualized in a real operating environment for the process of industrialization of roasted coffee, giving a solution to the problem of making a weekly aggregate planning according to the minimum operating costs.

This allocation of the orders to the roasters with the minimum operating costs is the primary input to perform the optimization of the detailed daily planning for each roaster as soon as possible, discussed in the following section of this research work, which is out of the scope of this publication. For the next phase of planning, an allocation made to some processing potholes, according to a sequence that allows minimizing the maximum time of completion of the roasted coffee supply time, the degassing time and the consumption time of the degassed roasted coffee—Makespan. The main restrictions for this model are the storage capacity of roasted coffee, the daily processing capacity, and the order assigned to the roaster from the weekly aggregate planning.

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Chapter 47
Analysis of Shelters' Supply Chain in Peru and Colombia

Eduardo Sanchez, Stephanie Villanueva Benites, Nathalie Lobon Munoz and Fiorella Ruiz Rondon

Abstract Natural disasters affected the population in negative ways; the most important challenge is to give them the dignity to live. The aim of this paper, based on case studies, is to analyze the supply chain of shelters (comparison in terms of time, cost and quality) in Perú and Colombia.

Keywords Humanitarian shelters · Peru and Colombia · Humanitarian supply chain

47.1 Introduction

Peru and Colombia as many countries in Latin America face major challenges that seriously threaten their development [12].

Piura (Perú) suffered from El Niño effect in the austral summer of 2017; 6769 houses collapsed. In the other hand, over the past 8 years, more than 12.3 million Colombians have been affected by natural disasters. This represents 26% of the Colombian population.

The affected population by natural disasters do not always have the capacity in terms of experience, skills, materials, and equipment to deal with all aspects of handling the procurement and logistics of transitional settlement and shelters [3]. According to Van Wassenhove, it has been estimated that logistics accounts for about 80% of the total costs in disaster relief.

This research-oriented project aims to provide a comparative analysis and identify the best practices between Peru and Colombia of the processes of supply, storage, and distribution of humanitarian shelters based on the review of the solutions given by

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the both governments following disasters, specifically in Piura (Peru) and in Mocoa, Pacific, and Caribbean coast (Colombia) as case study.

47.2 Literature Review

Shelter is a critical determinant for the survival of the affected population in the initial stages of a disaster. It is essential to provide security, personal safety, protection from the climate, and to prevent disease outbreaks. It is also important for individual human dignity and to enable the affected population to recover from the impact of disaster [6].

In the first place, we will focus on the definition of three types of humanitarian shelters that appear in this investigation: emergency, transitional, and permanent.

47.2.1 Emergency Humanitarian Shelters

According to Quarantelli's definition: Emergency sheltering refers to actual or potential disaster victims seeking quarters outside their own permanent homes for short periods: hours in many cases, overnight at most [9]. Based on the scale of the disaster, the short-term shelter demand can turn into a temporary housing need for the displaced population, which is a local government responsibility [11].

47.2.2 Transitional Humanitarian Shelters

Temporary or transitional shelters are places victims can stay for a longer period before it is safe to return to permanent residences. The daily necessities such as food, water, sleeping arrangement, and other needed services must be provided in temporary shelters, and thus, requires more significant preparedness by governmental agencies [8]. However, temporary sheltering is never intended to replace primary housing.

47.2.3 Permanent Humanitarian Shelters

Temporary housing can transition to permanent housing when displaced households cannot return to or refuse to return to their pre-disaster home [2].

	Case 1 Peru, Piura 2017	Case 2 Peru, Piura 2017	Case 3 Peru, Piura 2017	Case 1 Colombia, Mocoa 2017	Case 2 Colombia, Doña Ana 2013	Case 3: Colombia, Choco 2010-2011	Case 4: Colombia, Manatí 2011
Type of organization	Non-governmental	Governmental	Governmental	Both	Both	Both	Governmental
Shelter Type	Transitional shelter	Emergency shelter	Emergency shelter	Emergency shelter	Core housing	Housing repair / retrofitting	Transitional shelter
Associated entities	Piura en Acción	Schools and community associations	DRE, COER and Programa de Apoyo Social	Colombian Red Cross and UNGRD	Colombian Red Cross, Spanish Red Cross, Connection Colombia UNGRD	Colombian Red Cross and Local Government	Colombia Humanitarian Local Government

Fig. 47.1 Table 1 Structure of case studies

The research approach for this paper is a case study (see Fig. 47.1). There are seven research cases: three cases are from Peru and belong to Piura region where there was a flood in March 2017, and the other four cases are from Colombia in the regions of Mocoa, Caribbean, and Pacific coast. In Colombia, the last one was in Mocoa, where a landslide devastated 36 neighborhoods—on April 1, 2017.

This research will show an exhaustive analysis of how process was done regarding the supply chain of shelters. In evaluative situations like this one, the case studies commonly have been used to document and analyze implementation processes [10].

- In Piura, government and non-government entities like Universidad de Piura, Piura en Acción, and others, delivered shelters to the people who were affected by the flood.
- Colombia is in the humid tropics under the influence of the intertropical confluence zone makes a unimodal pattern in the Amazon, Pacific, Orinoquia, and most of the Caribbean regions, and a bimodal distribution in the Andean region with high and frequent rains. This condition is strongly altered by the presence of the El Niño and La Niña phenomena occurred between 2010 and 2011, which affects the precipitation regimes causing events of hydro-meteorological origin such as droughts, floods, torrential floods, and mass movements, among others.
- In Mocoa, under UNGRD's (Unidad Nacional para la Gestión del Riesgo de Desastres) overall leadership, local authorities installed 13 formal shelters and gradually relocated people seeking shelter for their homes and communities.

47.3 Methods and Procedures

The participation of these entities was extremely important in the post-disaster activities. Therefore, the case of study method has been chosen. The case of study method also has been used to document and analyze the outcomes of interventions and may cover programs sponsored by federal agencies or initiatives supported by private foundations [14]. The research method in this paper included the main following activities.

47.3.1 Research Information About the Solutions for the Supply Chain of Shelters

A preliminary research about shelters provided by governmental entities and by non-governmental entities was done. The documents researched include policies, site observations, and published government official papers.

This research helped to define which shelters' supply chain study. The type of categories found were three: permanent, transitional, and emergency shelters. The supply chain of each kind of shelter was development, this meant developing seven experiences: three in Perú and for in Colombia. This preliminary study also allows to prepare and execute better the next step: interview with experts.

47.3.2 Interviews with Experts

According to the previous experience in the field, interviews are done for obtaining information about the establishment of the situation and content validity of the processes of sourcing, storage, and distribution of humanitarian shelter [5]. This step included the following parts:

To structure the questionnaire. It contained semi-structured and yes/no questions, open-ended and Likert-type questions.
To select the experts to which apply the questionnaire. An expert is defined as someone involved in supplying post-disaster shelter assistance [7]. According to this, the list of experts for this research was built using published reports and referrals from colleagues. In the case of Peru, the interviews were done to one professor of Universidad de Piura, one head of volunteers of Piura en Accion, and one public worker from INDECI (Instituto Nacional de Defensa Civil), entity in charge of transporting the materials of shelters to the zone of disasters. In the case of Colombia, the interviews were done with representatives of the following local authorities that have been set up humanitarian shelters: one of the UNGRD (Unidad Nacional para la Gestión del Riesgo de Desastres) one of Colombian Army, one of Civil Defense, and one of the Colombian Red Cross.
To apply the questionnaire. Each expert was provided with the preliminary questionnaire and during the interview. They were asked to reflect on their experiences as well. The interviews lasted between 100 and 140 min. It also included visiting the affected zone by the disaster.

47.3.3 Description of the Solution

Based on the preliminary research done and the results of interviews, we describe how the supply chain was done for seven types of shelters.

47.3.4 Analysis of the Solutions

As the last step of the methodology, a deep analysis of each solution was developed. A comparison between each solution, in terms of indicators (time, cost, and quality) versus category of shelter (emergency, permanent, and transitional), was done.

47.4 Experimental/Numerical Setting

As own criteria, experts recommended not to consider pilot designs. According to IFRC (2014), saving costs and time accelerates the community to create economy opportunities and take care of their own needs (*World Disasters Report Focus on culture and risk*, [13]). For this reason, time, cost, and quality were the main variables to consider in the selection:

- **Time**: It includes the analysis of the practical aspects of transport, storage, and procurement of materials and the analysis of which materials can be procured in local markets and which need to be imported. The more complex a design is, more training and resources will be required to build it. This can lead to delays, and the time is a critical variable in a disaster.
- **Cost**: According to IFRC, the money available for housing varies in each disaster and is often a critical determinant of shelter cost and ensuing design. As a result, there are significant variations in costs of shelters between responses. In this research, will be considered the following costs: materials, transport and warehousing which will be extracted from the information of the interviews and from the prices offered in the market.
- **Quality**: It was determined as a percentage of the qualification results obtained in the interviews of the facilities that each type of humanitarian shelter has: access to water, access to a toilet, waste disposal, indoors climatic conditions, security, public spaces, privacy, electricity access, and access to facilities.

47.5 Result and Discussion

The analysis was focused on reviewing the results in terms of three variables: cost, time, and quality, which are displayed on the next three charts: Fig. 47.2 (indicators

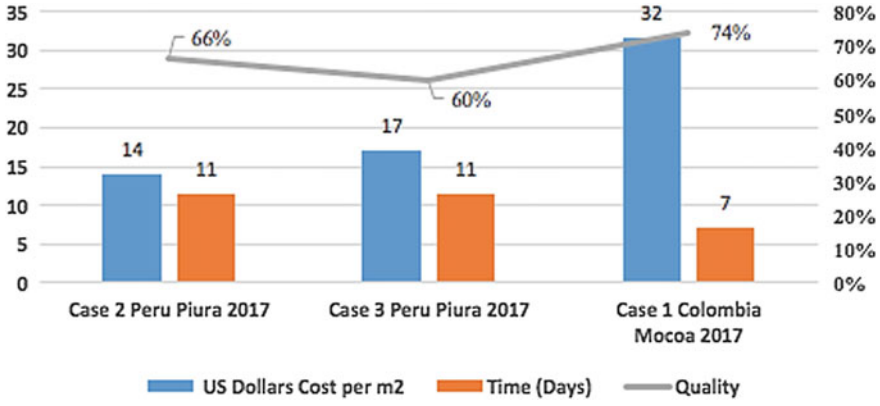

Fig. 47.2 Indicators for emergency shelters

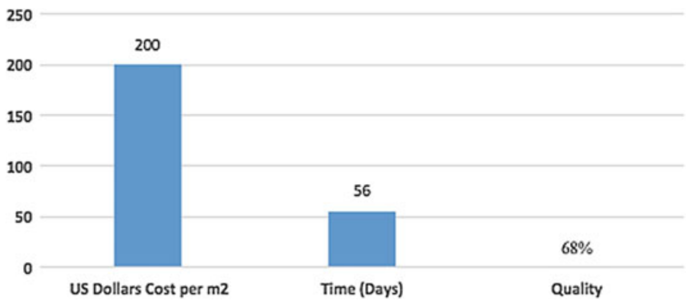

Fig. 47.3 Indicators for transitional shelters (Case 4: Manatí, Colombia)

for emergency shelters), Fig. 47.3 (indicators for permanent shelters) and Fig. 47.4 (indicators for transitional shelters).

47.5.1 Emergency Humanitarian Shelters

This category was delivered in Piura (case 2 and case 3) by the government and case 1 in Colombia (Mocoa) by two (a governmental and non-governmental) entities.

- **Costs per m^2**: In this variable, it is identified that case 2 of Perú is 56% more favorable, and this is mainly due to the cost of the materials. In this case, the government policy is to carry out the purchase of the emergency items from the headquarters of the country immediately after the emergency is happening. On the other hand, in the case 1 of Colombia, there is a physical inventory policy. For instance, in the case of Mocoa, there were pre-positioned inventories in the four humanitarian logistics centers that there are in the country. In these logistic

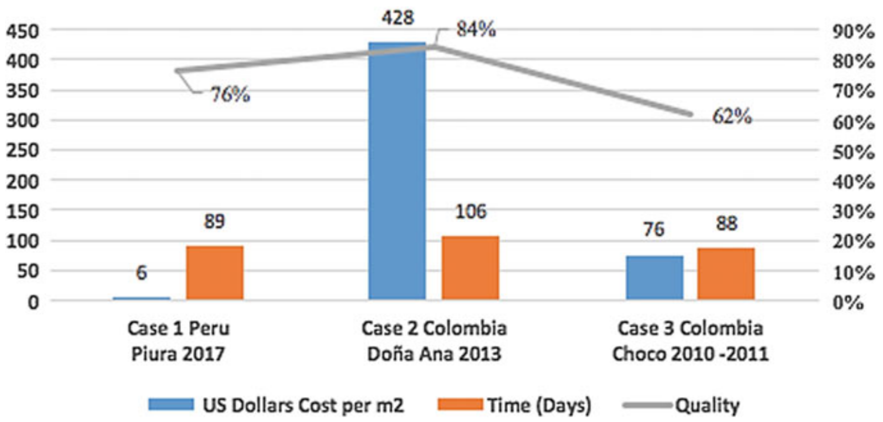

Fig. 47.4 Indicators for permanent shelters

centers, there are safe inventories which are previously acquired through public bidding where suppliers participate which must guarantee that before an event they must respond in less than 24 h at the event site.

- **Time**: The most effective scenario is case 1 of Colombia, Mocoa (7 days). It was determined that they are below 37% of those in Peru. In Peru, the time of supply is greater due to the fact that inventory is not available, the policy is to make purchases at the time of the emergency.
  In Colombia, the times are shorter because when the emergency occurs, there are already inventories, and this must be sent from the closest logistic centers of the tragedy location.
- **Quality**: In terms of quality, the case of Mocoa presents a better rating in security and electricity service. As a practice to highlight in Colombia, there is the creation of the UNGRD, which is a government entity that articulates public, military, and social organizations, which generates a robust support for the affected population.

47.5.2 Transitional Humanitarian Shelters

Unfortunately, from the seven studied cases, just one of them belongs to this category (case 4 of Colombia, Manatí in 2011). The Colombian government was in charge of delivering the shelters.

The case of Manati in Colombia is 63% higher than in case 3 in Choco Colombia, which is a permanent housing option, mainly due to the cost of materials that were supplied by local suppliers. In terms of duration and costs, the transitional option is not profitable.

In terms of times, it is favorable since there are prefabricated materials that reduce the activities of construction and construction of the refuge.

47.5.3 Permanent Humanitarian Shelters

This category of shelters was delivered in Piura (case 1) by two non-governmental entities and in Colombia (case 2 and 3) by both (a governmental and non-governmental) entities.

- **Costs per m^2**: The case of Piura in Peru (case 1) has a significant difference of 92%, compared to the costs of the two cases in Colombia. This is mainly due to the fact that in this case, they have the support of volunteers from different fields. Having volunteers from Universidad de Piura (professors, students, technical workers, etc.) eliminates administrative and labor expenses; those expenses are higher in the cases of Colombia. However, this increases the time as we will comment in the next paragraph.
- **Time**: The differences between the times of delivery are not meaningful; however in the case of Colombia, it is emphasized that the lead time of material is longer because the economic resources come from the central government. They need to tender; in other words, the approval times for disbursements are greater.
  In case 3 (Choco—Colombia), the transport of material was done by sea, and this transit time increases because they do not have contracting standards and this generates delays in the services to be hired.
  Another important fact to mention is that the storage service was used only in the case of Doña Ana. In other cases, it was not necessary because the materials for this type of construction mostly do not require special protection.
- **Quality**: In terms of quality, Doña Ana Project in Colombia has a result of 84%, which has the best ranking of the three cases. This is because it was a project built with the technical support of the Colombian Red Cross and the financial support of the Colombian Government. The project has an excellent score on basic water and electricity services.

47.6 Conclusion and Future Research

- For **emergency shelters**, the case of Colombia, it is more effective in time and quality than cases in Perú. In Colombia, there are pre-positioned materials in strategic points of the country. This allows reducing the time of arrival of these physical elements to the tragedy location (7 vs. 11 days). Another positive fact is that Colombia has a government policy defined since 2012. This allows clear guidelines and coordinates the different technical areas to achieve better results that guarantee a dignity shelter immediately a higher percentage of quality (74% vs. ~60%).
- According to the results of **permanent shelters**, the more effective option is case 1 of Perú. It has the lowest cost per m^2 (US$6), with a reasonable time of delivery (89 days) and an acceptable quality level (76%). The main reason to

reach these results is because it is done by 100% volunteers. Each weekend, a group of professionals (engineers, social workers, etc.), went to the affected zone; they offered their professional knowledge and valuable time. This allowed a high-quality shelter and not to have high administrative and technical expenses.
On the other hand, the case of Colombia has the highest quality level (84%). According to the research, this is due to the participation of organizations such as the Red Cross, which have experience and technical support.
- In the case of the **transitional shelters**, we suggest to review the purchase policies with the suppliers of materials. Even when transport times where shorts, costs were 63% more expensive. On the other hand, it is important that government entities evaluate whether it is possible from the beginning to execute permanent shelter projects that give greater value to the community, considering that for the evaluated cases the cost per m^2 was lower.

As future research, it is suggested:

- Further research could develop a model in order to set strategic points where to set the inventory of materials for the shelters. As well as a model that determines the right quantity of materials of this emergency inventory. For instance, how many tents in each strategic location. Future studies could seek how mechanisms can be created to form teams of volunteer professionals who participate in shelter projects.
- Further research could explore Latin America government policies that allow the collaboration between non-governmental and governmental entities in humanitarian activities. Further research could evaluate these indicators in the other Latin American countries.

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Chapter 48
Valuation of a Crude Oil Refinery in Brazil Under a Real Options Approach

Carolina de Castro Lopes, Frances Fischberg Blank and Davi Michel Valladão

Abstract Oil refineries are complex projects subject to uncertainties. Given that Brazil is an oil product importer, this work provides an investment analysis of a refinery considering managerial flexibilities. Crack spread and exchange rate are modeled as stochastic processes and the deferral and shutdown options are evaluated.

Keywords Oil refineries · Crack spread · Real options

48.1 Introduction

The refining industry is responsible for processing crude oil and producing its derivatives. The pure petroleum has no value; it is the process of refining it into diesel and gas used by the vehicles, kerosene used as aviation fuel, diesel and derivatives for bunkering of the ships, LPG and other derivatives that give its use.

Establishing a new refinery is a costly project subject to many uncertainties that can impact its revenues and costs. The main uncertainty in the cash flow is the difference between the supply cost, set by the oil price, and the price of the final products [18, 24]. While other expenses may be easily predicted, the oil and product market prices are constantly changing [16]. The difference between the product price and oil price is called the crack spread.

Refinery projects present flexibilities that allow different managerial decisions depending on an uncertain future. Uncertainties must be included when assessing the feasibility of investments and, although widely used in investment analysis, the discounted cash flow method (DCF) and its main indicator, the net present value (NPV), do not take into account implicit flexibilities. On the other hand, the real options valuation theory considers the uncertainties and incorporates the value of the managerial flexibilities in a project.

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When it comes for the refining industry for considering the refining industry, what becomes relevant are the options to wait, the option to switch, and the switch input–output option. The option to wait is important given the size of the investment on refinery projects and the uncertainty of the future return on investment, which depends on the oil and its derivative prices.

The switch option is taken at times when the oscillations in the prices of the oil and products can lead to the reduction of the crack spread, and therefore, the decision to temporarily shut down the refinery becomes the best choice.

While we can find many papers on modeling the oil and derivative prices, individually or using the spread of the both products [1, 6, 7, 10, 23], we cannot find many directly related to the modeling of the crack spread of an oil refinery [24, 27]. Given that Brazil is one of the countries that import refined products, this paper was meant to contribute to the literature on the subject, offering an analysis of the investment in an oil refinery, staring with the modeling of crack spread adapted to the reality of the refining process in Brazil.

Although every refinery has its own crack spread based on the amount of the processed oil and derivatives produced, there is a measure that represents a gross margin of an average refinery, called crack 3:2:1. The 3:2:1 ratio refers to the proportion of the derivatives produced: out of the 3 barrels of oil 2 barrels of the gasoline and 1 barrel of the diesel are being produced [21], which is the standard proportion on the North American market. In Brazil, the demand for diesel is higher than for gasoline. Based on that, we can adapt the 3:2:1 proportion to the Brazilian reality, producing out of the 3 barrels of petroleum 2 of diesel and 1 of gasoline.

This paper offers a practical use of real options theory and ways to apply it when analyzing feasibility of establishing an oil refinery in Brazil. Based on two uncertainties given by the crack spread and exchange rate, the paper assesses the option to wait and switch option in the refinery project, as well as how they interact. The proposed project is in its final stages (85% already done), and this is why the objective in this paper is threefold: (i) to analyze an incremental investment for finishing the project; (ii) compare with the total cost of a project for opening a new refinery; (iii) and what decisions would have been changed if the project hadn't been started yet.

This article comprises five parts. After this introduction, a literature review presents how the real options theory is applied in the refining industry. Then, a methodology procedure is described, followed by the results of the proposed project evaluated under the real options approach. Finally, the last section concludes the paper.

48.2 The Real Options Theory Applied to Refining Industry

According to Dixit and Pindyck [11], the traditional rule of DCF incorrectly compares the conditions of investing today and not investing at all, neglecting three major factors in investment decision making: irreversibility, optimal timing, and uncertainty of investment. The real options theory allows the correct valuation of possible managerial decisions for every stage of the project. In the refining industry, some of the main examples are the options to invest gradually, option to wait, options to switch or abandon, and the switch input–output option.

Dunne and Mu [12] studied the effects of the uncertainty of the investment in refinery business in USA, analyzing how the decision to expand the capacity reflects on volatility of the crack spread. When the uncertainty associated with refinery margins goes up, regulatory bodies defer investments, supporting the importance of irreversibility and uncertainty of the investment in this industry.

The value of the crack spread is, like many other commodities, regulated by the offer and demand system. When prices go up, the producers of the commodities rise the offer, that way reducing the price. On the other hand, when the prices are down, the producers limit the offer and that way prices go up. This is common in mean reverting processes, and these properties in commodities prices are, in general, exhibited in the long-term run. Price spreads and the oil and products prices are usually described by mean reversion models (MRM) [5, 6, 21, 26, 27].

Since oil and products prices are set on the international market, in order to analyze a project in Brazil, the exchange rates must be included as a relevant factor, normally modeled in literature as a geometric Brownian motion (GBM) process [22, 25].

According to Minardi [20], one of the advantages of the real options approach is that, when having established a great operational policy, it makes the company aware of what is the best moment to act. For example, should the company temporarily shut down and restart later, making the managerial conducting closest to optimum? Kulatilaka and Trigeorgis [19] point out that the majority of the real options can be assessed as special cases of switching flexibility model. They say that the option to switch represents a change between operating and non-operating modes.

In the refining industry or facilities with similar characteristics as the ones in petrochemistry, it is common to assess the switch option [26, 27], and the switch input–output option [5, 16, 21]. We also find cases of deferral of the investment [26] and abandonment [18].

It is important to notice that, keeping in mind that there are different flexibilities in projects in this sector, the value of the options changes when they interact and coexist together. It is not valid to simply sum up all the options whenever they influence each other [8].

48.3 Methodology

The main uncertainties for the refinery project in this paper are the crack spread 3:2:1 adapted to the Brazilian market and the exchange rate. The definition of the stochastic processes used in modeling went through econometric tests based on historical series in order to verify how well they can explain the data. The data on oil, diesel, and gasoline prices can be gathered from contracts negotiated on the North American market. Starting with the spread data, Heydari and Siddiqui [14] propose to deseasonalize the crack spread series by breaking it down to:

$$\text{crack}_t = x_t + f_t \tag{48.1}$$

where x_t stands for stochastic variable and f_t a deterministic seasonal function. The stochastic variable is based on Ornstein–Uhlenbeck arithmetic process represented by:

$$\mathrm{d}x = \eta(\bar{x} - x)\mathrm{d}t + \sigma_x \mathrm{d}z \tag{48.2}$$

where x stands for the crack spread value, η represents the speed of mean reversion, $\bar{x}$ the level of long-term equilibrium, σ_x volatility, and $\mathrm{d}z$ the Wiener increment.

To obtain the values of the options, it is necessary to work with risk-neutral processes for the stochastic variables. Thus, in order to simulate the crack spread over time, the discretization equation of the MRM process given by Eq. (48.2), in the risk-neutral version, is:

$$x_t = x_{t-1}\mathrm{e}^{-\eta\Delta t} + \left(\bar{x} - \left(\frac{\pi}{\eta}\right)\right)\left(1 - \mathrm{e}^{-\eta\Delta t}\right) + \sigma_x\sqrt{\frac{1 - \mathrm{e}^{-2\eta\Delta t}}{2\eta}}N(0, 1) \tag{48.3}$$

where the risk premium is given by $\pi = \mu - r$, and μ is an adjusted risk rate referring to crack spread.

Exchange rate is commonly modeled as a GBM given by the equation:

$$\mathrm{d}c = \alpha c\mathrm{d}t + \sigma_c c\mathrm{d}z \tag{48.4}$$

where c is the exchange rate, α is the drift parameter, and σ_c is the volatility. The equation for discretization in the risk-free version is:

$$c_t = c_{t-1}\mathrm{e}^{\left((r-\delta_c)-\frac{\sigma_c^2}{2}\right)\Delta t+\sigma_c N(0,1)\sqrt{\Delta t}} \tag{48.5}$$

where δ_c represents the convenience yield here given by the foreign exchange rate.

In order to confirm the adequacy of these processes, the unit root test of Dickey–Fuller can be applied, and for additional analysis, the variance ratio test can also be used [8].

Once the uncertainties are defined, the value of the project with options to wait and switch may be calculated.

The option to defer the investment may be perpetual, or it may have an expiration date. The option value can be calculated based on the contingent claims method. Considering the value of the project V as the underlying asset that follows a GBM, we get a partial differential equation (PDE) known as Black and Scholes and Merton equation:

$$\frac{1}{2}\sigma_V^2 V^2 F_{VV} + (r - \delta_V) V F_V - rF = -F_t \tag{48.6}$$

where σ_V^2 is the volatility of the project, δ_V represents the cash flow distribution rate, and the r risk-free rate. These parameters are estimated using the Market Asset Disclaimer (MAD) method, proposed by Copeland and Antikarov [4]. In order to estimate the parameters of the stochastic process of V, a Monte Carlo simulation is performed, adapting the MAD method as proposed by Dias [9].

If there is no expiration date, the option may be treated as perpetual, and the time variable is removed from Eq. (48.6), which becomes an ordinary differential equation (ODE) that has analytical solution. The boundary conditions are:

$$F(0, t) = 0 \tag{48.7}$$

$$F\left(V^*, t\right) = V^* - I \tag{48.8}$$

$$F\left(V^*, t\right) = 1 \tag{48.9}$$

and the solution is given by:

$$F(V) = AV^{\beta} \tag{48.10}$$

$$V^* = \left(\frac{\beta}{\beta - 1}\right) I \tag{48.11}$$

where V^* is the threshold, β is the positive root of the characteristic equation for the ODE and A the constant determined by the boundary conditions.

If the option has an expiration date, it results in an American option, and there is no analytical solution. In this case, Bjerksund and Stensland [2] propose an analytical approximation, which was used in this paper.

The value of the option (F) must be higher than the NPV of the project without flexibilities, so there is worth in the option to wait and the decision to invest must be based on a project's critical value called threshold (V^*). When the present value of the cash flows provided by the project V if higher than V^*, it indicates that the investment should be done immediately. Otherwise, it is best to defer the investment.

The proposed project also comprises an option to switch; the refinery might shutdown for a period of time, when the gross margin is lower than the variable costs. The optimal mode of operation can be determined depending on uncertainties at any moment, having a certain cost load depending on the change between the operating and non-operating mode, seen in the cost provoked by hibernation of the units.

The cash flow that has the switch option value is determined as the maximum between the cash flow with no switch option and the hibernation cash flow which incorporates the cost of the period when the unit is not functioning. This way we have the optimal cash flow at any moment comparing the operating and non-operating modes:

$$\text{Optimal CF}_{i(t)} = \text{Max}\left(\text{CF}_{\text{operating}(t)}; \text{CF}_{\text{hibernation}(t)}\right) \tag{48.12}$$

where $\text{CF}_{i(t)}$ stands for the cash flow at any moment in any case, where i = operating mode or hibernation mode. The value of the switch option is given by the difference between the expected present value for the optimal cash flow and the present value of the cash flow in the operating mode.

When the switch option and option to defer the investment are considered simultaneously, the option to defer might lose value because the option to switch might reduce the event of the negative cash flows.

48.4 Results

For modeling the crack spread, we used a daily database with from October/2005 to February/2018. The following contracts, with an expiration date in a month, were used: Cushing, OK Crude Oil, New York Harbor Regular Gasoline, New York Harbor Reformulated RBOB Regular Gasoline, and New York Harbor No. 2 Heating. The data was collected from negotiated prices at NYMEX [13] and updated for the same date from Consumer Price Index (CPI) [3]. With data being deseasonalized, we get the f_t is equal to approximately US$ 19/bbl. For the stochastic variable x, the Dickey–Fuller test rejected the null hypothesis, and thus the GBM, showing evidence of mean reverting properties, characteristic confirmed by the variance ratio test. The parameters found for the MRM were $\sigma_x = 18.38$ p.a. and $\eta = 2.51$. Given the choice of seasonal adjustment with no intercept, the long-term equilibrium mean $\bar{x}$ was statistically equal to zero.

The exchange rate time series comprised daily data collected from January/2002 to February/2018 from IPEA [17]. The values were adjusted according to inflation in American and Brazilian markets, using as the reference the CPI [3] and the IPCA [15], respectively. Based on the Dickey–Fuller test, the GBM was confirmed to be a suitable stochastic process for the exchange rate. The estimated parameters were $\sigma_c = 15.74\%$ p.a. and $\alpha = -0.73\%$ p.a.

According to the traditional static analysis, the present value V calculated using the DCF method was US$ 2575 million, resulting in a NPV of US$ 867 million as an incremental investment and negative in US$ 2375, if the project hadn't been started yet.

Based on the modified MAD method and using a 4% p.a. risk-free rate, the volatility and the cash flow distribution rate for V were estimated at $\sigma_V = 13.02\%$ p.a. and $\delta_V = 4.24\%$ p.a.

Taking into account the incremental investment, as well as the total investment, Table 48.1 presents the threshold values V*, the option value F, and the net premium for the option, calculated from the difference between the F and the NPV, for the different expiration dates.

Table 48.1 Results for the option to defer the investment

Expiration dates	Incremental investment			Total investment		
	V^*	F	F-NPV	V^*	F	F-NPV
(in years)	(in million dollars)			(in million dollars)		
1	2056	867.0	0.0	5959	0.0[a]	2375
2	2156	867.0	0.0	6248	0.0[a]	2375
3	2219	867.0	0.0	6432	0.3	2,375
4	2266	867.0	0.0	6567	1.4	2376
5	2302	867.0	0.0	6671	3.2	2378
Perpetual	2604	867.3	0.3	7546	114.0	2489

[a]The option value is slightly higher than zero

If the investment hasn't been made yet or had to be done in full, the best choice would be to defer it, regardless of the option expiration date. For the incremental investment, it is recommended to invest immediately if the expiration date is up to 5 years and defer the investment if the option to wait is perpetual.

For the switch option, the present value for the optimal cash flow was US$ 2782 million, so this option adds US$ 207 million to the original NPV. In the presence of the switch option, the option to wait loses its value in the case of incremental investment, and even for the perpetual option, the best decision turns to be the immediate investment. In the case of the investment in the new refinery, the decision to defer the investment remains. In this case, the option to defer is worth 114 million dollars and when the switch option is added the value is reduced to 14 million dollars.

Parameter sensitivity analysis was also performed. When the volatility parameter is reduced to 8% p.a., the best decision is to invest immediately, while when increased to 35% p.a. it is better to defer the investment. When it comes to convenience fee, regardless of the expiration date, if it goes to 5% p.a., the best decision is to invest immediately; but when reduced to 2%, the best decision is to defer the investment. The switch option is influenced by the cost of hibernation of units, so different scenarios were studied including this information. In this case, the value of options changed insignificantly because the results of the optimal cash flow gains were not significant. This happens because, even if during few years the operating cash flow might be negative, in only a few of scenarios the present value of the 25 yearly cash flows become negative.

48.5 Conclusion

This paper identified the main uncertainties for investing in a new oil refinery in Brazil, presenting an adjustment of the crack spread to the reality of the Brazilian refineries.

Keeping in mind the complexity of oil refinery projects and the high investments involved, it is extremely important to evaluate embedded managerial flexibilities from a real options approach. Given that there are refinery projects in Brazil that are on hold, the option to wait stands out as relevant. On the other hand, exercising the switch option in Brazil means raising the volume of oil exported.

The analysis based on the real options theory indicated the deferment of the investment as the best decision in cases where the traditional DCF method recommended immediate investment. When analyzing the remaining investment value in order to finish the project, the NPV is positive, recommending the immediate investment, where the real options approach does not always support that decision. According to the real options approach, for the remaining investment, if it is a perpetual option to invest, the project should be postponed. For the expiration dates up to 5-year expiration, the decision to invest immediately is supported. In cases of the full investment into a new refinery, the best decision is always to defer it.

The option to switch was examined as well, taking into account the possibility to switch between operating and non-operating mode, and in all of the analyzed scenarios, this option raised the value of the refinery. Besides that, the option to switch reduces the value of the deferral option, and the immediate incremental investment for finishing the project is recommended independently of its expiration date.

These results are of the extreme importance because they show how the decision to invest in a refinery may be analyzed in a more robust approach, incorporating the modeling of the uncertainties, as well as the value of the managerial decisions neglected in the traditional analysis of the investments. This approach is of great academic and practical use, especially in Brazil, where we see on-hold projects in this sector.

For the future works, we propose modeling-specific crack spread data for the Brazilian market, in order to better represent the reality of the country. The stochastic crack spread may be better described by using a MRM process with two or three factors. Finally, the input–output switch option, especially in the case of input resources, might as well be incorporated.

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Chapter 49
Application of a Heuristic to Reduce Fuel Consumption for the Traveling Salesman Problem

Emilio Estévez López and Mariana Turati Palazuelos

Abstract Due to the pollution and increment in fuel price, that a department store in Mexico faces, a heuristic that can solve TSP is proposed. It minimizes fuel consumption, considering elevation, traffic and truckload while delivering. The results indicate that the proposed delivery policy reduces fuel consumption up to 15%.

Keywords Heuristic · TSP · Logistics

49.1 Introduction

The transfer of goods, people, or information is something necessary in mostly every company. Globalization and technology have allowed for this particular area to develop fast and change constantly. However, as a necessity, transportation and delivery could become a high and required expense [2]. The cost of transportation represents a significant part of the overall logistics that spent. It is a major target for cost reduction. The effects of a poor transportation policy convert into pollution and excess of costs.

Elevation, traffic, and load are variables known for having a direct impact in fuel consumption. A better fuel efficiency is obtained when the vehicle maintains a constant and moderated speed. A study performed by the Environmental Protection Agency shows that acceleration, vehicle weight, and speed limit are the factors that influence on fuel efficiency. The performance of a vehicle is better when stops are reduced. In traffic, the vehicle is constantly stopping and accelerating to reach a certain speed. Traffic produces a 38.88% increase in fuel consumption and aggressive acceleration could have a 50% increase [4].

Truckload or extra weight is another important factor in the overall fuel efficiency. According to the National Commission for the Efficient Use of Energy, fuel consumption increases 2% for every extra 50 kg weight [16]. This also depends on what type of vehicle is used, but truckload consumes more fuel, especially if there

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is a difference in elevation between the beginning and end of the delivery journey. Overcoming an uphill inclined road means a greater amount of energy and engine power which leads to fuel consumption. This is because the engine needs enough force to overcome the force applied by slightly going against gravity and maintaining a certain speed. On the contrary, it is easier to achieve movement in a downhill inclined road because the movement goes along with gravity force [5].

Although truckload, elevation, and traffic have the most impact, other factors might help with the vehicle performance. A specialized vehicle, aerodynamic factor, vehicle maintenance and routing improvements would cause an improvement in the fuel consumption factor and a reduction of transportation costs and pollution [16].

An investigation article, by students from Tecnológico de Monterrey Campus Santa Fe, was taken as a base for this model (Marín 2017). An opportunity to improve the mathematical formulation was seized to propose a better delivery policy for a department store in Mexico. The factors these students considered to calculate fuel consumption were truckload, elevation, and traffic, the same variables that are proposed in this research. The methodology of the algorithm presented is based on other research papers to have a more solid approach, while considering these variables, rather than just using ratios of start points and end points, thus, obtaining a more reliable output, to be able to adjust the delivery policy and have a positive impact in the environment.

49.2 Methods and Procedures

The goal of this mathematical model is to generate delivery routes that minimize fuel emissions considering truckload, traffic, the distance traveled, and the road elevation. The capacity of the vehicles is a restriction for the routes. A Google Maps API was used to calculate the route from any point *i* to any point *j*, measuring the elevation in every turn, time, and distance. Table 49.1 shows the steps followed to obtain these data.

To estimate the CO_2 emissions an adaptation of the function proposed by Hickman et al. (1999) and Jancovici (2007) for the heavy-duty vehicle (HDV) between 32 and 40 tons for general merchandise was utilized. They considered an average speed of 80 km/h, the road is assumed to be flat, and the CO_2 emissions produced are considered to be a linear function between what the truck produces when it's fully loaded and when it's empty [12].

The function for CO_2 emissions is expressed in terms of the distance "*d*" traveled in kilometers and the load of the truck "*q*" in kilograms as follows:

$$CO_2(q, d) = d * (\mathrm{ef}_1 - \mathrm{ee}_1\, Q * q + \mathrm{ee}_1) \tag{49.1}$$

where ef_1 is the CO_2 emissions when the vehicle is fully loaded referring to weight, and it is a constant equal to 1.096 kg/km for an HDV truck, ee_1 is the CO_2 emissions when the vehicle is empty, and it is equal to 0.772 kg/km for HDV truck [14] and

Table 49.1 Pseudocode of the Google Maps API algorithm

Pseudocode of the Google Maps algorithm:
1. Read file of points with the latitude and longitude of the center of distribution and the clients to visit
2. Create 5 empty matrices
3. Read the Google Maps API Key
4. For each point *i* do
1. For each point to visit *j* do
1. Get directions from point *i* to point *j* with a departure time for when the trucks will leave the center of distribution (actual time)
2. Get the matrix of time
3. Get the elevation of every indication (substep) from Google Maps to get from point *i* to *j*
4. Get the matrix of elevation (RISE), adding positive gradient
5. Get the matrix of elevation (FALL), adding negative gradient
6. Get the matrix of distances from Google Maps
7. Get the matrix of velocity, calculating average speed
8. Until there are no more points *j*
1. End for
c. Until there are no more points *i*
3. End For
4. Write file with the five matrices for elevation, time, velocity and distance

where the constants considered for the model, and Q is the vehicle capacity, so the units are kg*CO_2/km [12].

To calculate the emissions between every node (i,j) traveled we used the formulation proposed by Elbouzekri et al. (2013).

$$CO_2(q, d)_{ij} = d * (\mathrm{ef}_1 - \mathrm{ee}_1\ Q * q_{\mathrm{ij}} + \mathrm{ee}_1) \tag{49.2}$$

Also, the function proposed by Greenwood and Bennet was considered, to calculate fuel consumption in L/1000 km, as a quadratic function of velocity, affected by traffic. Where coefficients from a_0 to a_2 represent coefficients from a given truck and S is equal to the velocity [7].

$$\mathrm{FC} = a_0 + a_1/S + a_2\ S^2 \tag{49.3}$$

Greenwood and Bennet add RISE and FALL to this function to consider road gradient. RISE is the vertical distance traveled upward, and FALL is the distance traveled downward [14]. The values of the constants a_3 through a_5 correspond to the truck, too [9]. Their fuel consumption is as follows, where IRI is the rugosity of the road which is left out of the final equation as it remains constant [8]:

$$\mathrm{FC} = a_0 + a_1/\mathrm{S} + a_2\ \mathrm{S}^2 + a_3\,\mathrm{RISE} + a_4\,\mathrm{FALL} + a_5\,\mathrm{IRI} \tag{49.4}$$

As the last function calculates fuel consumption, instead of CO_2 emissions, the result must be multiplied by a factor; an average consumption of 5 L/100 km then corresponds to 132 g CO_2/km [11].

$$CO_2/\text{km} = (132/50000) * (a_0 + a_1/S + a_2\, S^2 + a_3\, \text{RISE} + a_4\, \text{FALL}) \quad (49.5)$$

Finally, the model proposed considers time traveled and the elevation along the road as well as truckload as factors that will affect the CO_2 emissions produced. As a result, the final CO_2 emissions:

$$\begin{aligned} CO_2(q, d)_{ij} = d * ((\text{ef}_1 - \text{ee}_1\, Q * q_{ij} + \text{ee}_1) + (132/50) \\ * (a_0 + a_1/\text{S} + a_2\, S^2 + a_3\, \text{RISE} + a_4\, \text{FALL})) \end{aligned} \quad (49.6)$$

An ant colony optimization (ACO) algorithm was adapted and presented given the complexity of the problem to estimate good solutions instead of the optimal solution which wouldn't be achievable in a reasonable time as it is shown in the results section. The ACO is a methodology proposed by Dorigo et al. [15];

The components of the ACO algorithm in Table 49.2 are used in Table 49.2 to explain how the solutions were obtained.

The pheromone update is made by two equations, one to reinforce the paths taken and one to diminish the paths that do not optimize. Local update is given when an ant k chooses path (i, j), representing the evaporation rate of the trail, and 0 is constant:

$$ij = (1-)^* ij + 0^* \quad (49.8)$$

Table 49.2 Pseudocode for the ACO algorithm

Pseudocode of the ACO algorithm:
1. Fixed number of ants
2. Fixed number of iterations
3. Fixed parameters (α, β, γ, 0, Q, d_{ij}, t_{ij}, e_{ij}, ee_1, ef_1)
4. Initialize pheromone trail *ij*
5. iter 1
6. while (iter < itermax)
a. For each ant k do
i. Random choice of an unused truck
ii. Build route for this truck using Eqs. (49.4), (49.5), (49.6)
iii. Local updating pheromone trail using Eq. (49.8)
iv. Until Ant k has completed its solution.
b. End for
1. Save the best solution found by the ants
2. Update the pheromone trail using Eqs. (49.9), (49.10)
3. iter iter + 1
4. End while [13]

Table 49.3 Parameters of the ACO

Parameter	Value	Parameter	Value
α	1	a_0	44.1
β	2.3	a_1	3905
γ	0.1	a_2	0.0207
1	$1d_{iji,j}$, if ij	a_3	3.33
r_0	0.9	a_4	−1.78
0	Average of initialized pheromone trail	conv	132/50000
m	n (number of clients to visit and the warehouse from which it is departing)	ef_1	1.096 kg/km
ee_1	0.772 kg/km	Iterations (itermax)	500

Global update is given for every path (i, j) when an iteration has ended for all ants m and the best route so far is considered:

$$ij = (1-)^{*}ij +^{*} (1\text{best solution}), if(i,\ j)\ \text{best solution} \tag{49.9}$$

$$ij = (1-)^{*}ij, \text{if}(i,\ j)\ \text{best solution} \tag{49.10}$$

49.3 Experimental/Numerical Setting

The parameter settings for the ACO algorithm are shown in Table 49.3 and are based on the parameters used by Bouyahyiouy.

Real data from a department store in Mexico was used, containing the latitude, longitude, and demand and location of the clients. Every set has a different number of nodes, as the collection of data was made during 18 different days. The model that has the goal to minimize CO_2 kg emissions, results were compared to an ACO minimizing distance. These instances and both policies are reported in the results.

49.4 Results

The results retrieved from both models previously explained are presented on Table 49.4 and a comparison of their costs, distance, and emissions and are depicted in Figs. 49.1 and 49.2.

As the model proposed minimized CO_2 emissions, it increased distance. The sets tested have a different number of nodes, as these increase the gap between the two

Table 49.4 Comparison of results between the two policies

		Minimizing Distance		Minimizing CO_2	
	Nodes	Distance	CO_2	Distance	CO_2
Set 1	21.00	15.07	42.90	17.34	43.88
Set 2	26.00	15.34	34.79	16.42	34.46
Set 3	23.00	14.97	43.64	17.41	44.09
Set 4	25.00	16.47	46.95	17.56	42.23
Set 5	22.00	16.36	42.97	16.30	41.83
Set 6	22.00	16.71	45.01	16.51	43.18
Set 7	20.00	16.02	44.90	17.00	42.55
Set 8	34.00	48.90	85.80	52.03	73.36
Set 9	35.00	53.93	107.25	65.77	90.10
Set 10	34.00	55.77	85.80	60.23	81.39
Set 11	22.00	34.60	62.92	41.58	53.31
Set 12	27.00	44.16	72.39	44.96	57.64
Set 13	38.00	57.05	101.88	70.38	96.41
Set 14	32.00	50.62	85.80	63.54	79.42
Set 15	31.00	54.97	88.66	64.84	82.07
Set 16	27.00	47.10	77.22	57.70	72.12
Set 17	38.00	63.86	106.44	74.51	94.31
Set 13	31.00	49.87	83.12	56.09	75.80
Average	28.22	37.60	69.91	42.79	63.79

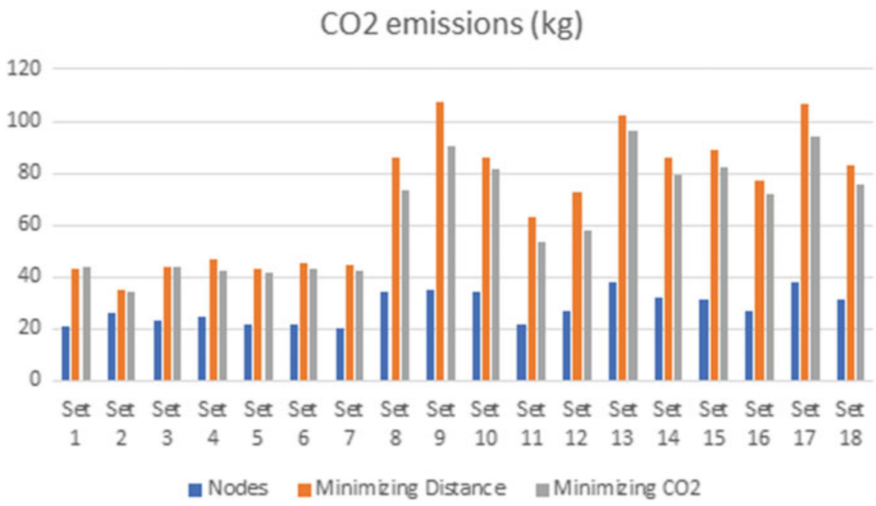

Fig. 49.1 Comparison of CO_2 emissions

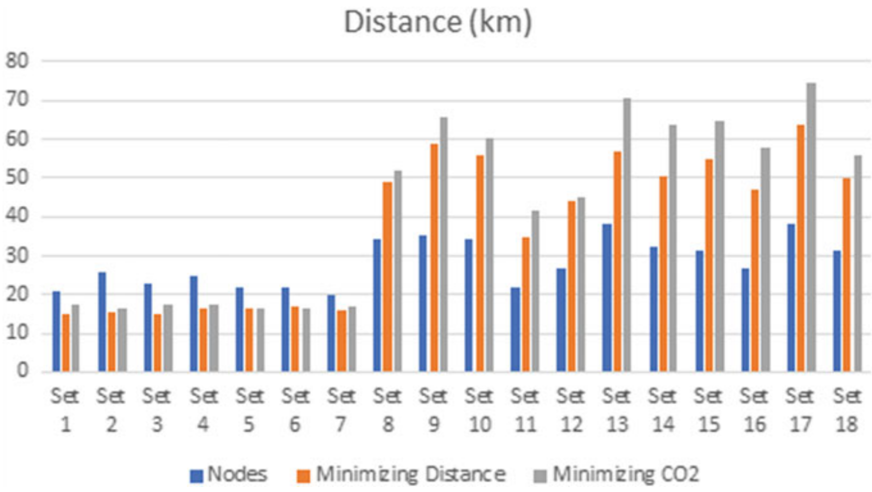

Fig. 49.2 Comparison of distances

policies grow apart. A set difference around 15% in CO_2 emissions can be appreciated in some sets, though some represent a smaller difference (3%).

49.5 Conclusions

A model to calculate CO_2 emissions, considering truckload, road gradient, and traffic is proposed. The API of Google Maps was utilized to get real data from the demand points of a department store in Mexico. Mexico City has an irregular topography, as other megacities in the world; a better delivery policy would optimize the overall fuel consumption of a fleet. The goal is to penalize the routes that consume more fuel to reduce the negative impact on the environment. These kinds of environmental-friendly projects help big companies innovate and gain certifications to enter new markets and reduce transportation costs, as well as gaining advantage over the competition.

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Chapter 50
Decisions to Invest in Waterway Terminals for Oil and Oil Products

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Abstract This paper proposes a methodology for evaluating investment decisions in waterway terminals, with the purpose of reducing logistics' costs. Based on a Brazilian terminal, in order to reduce excessive costs of demurrage, a project is evaluated through the Real Options Theory. The case study involves statistical data collection and interviews.

Keywords Demurrage · Investment analysis · Real options

50.1 Introduction

Some of the most relevant logistical costs of oil companies are observed in waterway terminals, where operations are carried out to move and store oil and oil products. In the largest terminal of a Brazilian company in terms of volume of products, there are some operational restrictions that generate significant expenses, especially related to costs of demurrage.

Monie [6] introduces an important relation between the time of waiting for the berth and the rate of occupation, showing how the wait grows exponentially when occupation is above 80% of the capacity. Barros et al. [1], Moura et al. [7], and Ribeiro et al. [8] present studies that show the concern of Brazilian organizations with the performance of terminals.

Investments in projects aimed at improving terminal performance involve the study of possible flexibilities in port planning. This issue has been discussed internationally over the last few years, mainly due to the fact that these investments are large and irreversible. Taneja et al. [10] propose the "Adaptive Port Planning" and the use of the real options approach to investment analysis. In Brazil, most of the works that use real options approach in oil and gas projects evaluate investments in offshore platforms and oil fields [2, 5].

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Some of the most relevant logistical costs of oil and gas companies are observed in waterway terminals, where operations are carried out to move and store oil and oil products. In the largest terminal of a Brazilian company, there are some operational restrictions that generate significant costs of demurrage. Several projects have been developed with the objective of eliminating these costs. If implemented, these projects could bring significant gains. In addition, by taking into account the managerial flexibilities involved, even greater gains are expected.

This article proposes a framework to select and evaluate investment projects in waterway terminals and applies the proposed step-by-step methodology to study possible investments in the chosen terminal, selecting one for economic valuation under the real options approach. It contributes to the literature with an innovative approach when analyzing a project of a Brazilian private waterway terminal. Based on the proposed case study, we intend to answer the following research questions: (i) "How should the company evaluate its investments in waterway terminals considering the uncertainties involved?"; (ii) "What is the impact of managerial flexibilities on the value of the selected project?"; (iii) "What are the main positive points observed with the use of the Real Options Theory in the project analysis?".

This work comprises four sections. The first is the introduction, followed by the methodology, which details the main models used for the proposed framework and the evaluation of the investment. The third section presents the case study and the results obtained. Finally, the conclusions are summarized, and the recommendations for future research are presented.

50.2 Methodology

For the construction of the proposed framework, two models of evaluation of investments with managerial flexibilities applied to port planning are taken as reference. In the model proposed by Salminen [9], a two-step approach is suggested. The first step focuses on identifying the investment. The second, divided into three phases, is focused on the selection and evaluation of different investment strategies, which include the real options approach. Taneja et al. [11] present a model that specifically addresses the step of investment analysis in a more general approach through six steps from the perspective of real options.

Based on the proposed the framework, a case study is carried out in the mentioned terminal. Once a project has been selected through a screening model, two investment scales are considered. Scale 1 consists of the project prioritized in the selection, and scale 2 is a composition of the scale 1 project and the second most suitable project for execution, since both together form a larger project that can be considered the complete improvement of the terminal's derivatives system. Scale 2 is approximately twice the scale 1. Thus, the investment analysis is proposed considering two real options: (i) the possibility of postponing the investment reflected in the option to wait; and (ii) the possibility of choosing between a larger or smaller size of the project, reflected in an option of scale. The main revenue considered for both cases is the reduction of costs of demurrage, and the gains are calculated incrementally.

A traditional valuation of the two scales is initially performed, using the discounted cash flow (DCF) method. However, the classical approach underestimates the value of the project since cash flows are treated as static expected values, without uncertainties being directly modeled. The real options approach allows the correct evaluation of managerial flexibilities, considering the three main characteristics of an investment decision: (i) irreversibility; (ii) decision of the optimal moment to invest; and (iii) uncertainties. The main uncertainties are represented by two variables: the demand for movement of oil derivatives in the terminal and the average cost of hire of derivatives ships. These uncertainties are modeled by an appropriate stochastic process, given by a mean-reversion process. The Ornstein–Uhlenbeck arithmetic mean-reversion model (OU-MRM) is defined as:

$$\mathrm{d}x = \eta(\bar{x} - x)\mathrm{d}t + \sigma\,\mathrm{d}z \tag{50.1}$$

where x is the stochastic variable, $\bar{x}$ is the mean-reversion level of long-run equilibrium, η is the speed of mean-reversion, σ is the volatility of the process, and dz is the standard Wiener process.

To perform the real simulation, the value of x_t at a future period t is given by:

$$x_t = x_{t-1}\mathrm{e}^{-\eta\Delta t} + \bar{x}\left(1 - \mathrm{e}^{-\eta\Delta t}\right) + \sigma\sqrt{\frac{1 - \mathrm{e}^{-2\eta\Delta t}}{2\eta}}N\,(0, 1) \tag{50.2}$$

The OU-MRM parameters can be estimated by the following linear regression:

$$x - x_{t-1} = a + (b - 1)x_{t-1} + \varepsilon_t \tag{50.3}$$

where

$$\eta = \frac{-\ln(b)}{\Delta t} \tag{50.4}$$

$$\bar{x} = -\frac{a}{(b - 1)} \tag{50.5}$$

$$\sigma = \sigma_\varepsilon\sqrt{\frac{2\ln(b)}{\left(b^2 - 1\right)\Delta t}} \tag{50.6}$$

where σ_ε is the standard deviation of the regression error.

Since in the OU-MRM both dx and x are normally distributed, Dias [3] points out that x can assume negative values. Therefore, it is more usual to model the logarithm of the variable. For example, for a variable P that represents an asset price, it is common to model $x = \mathrm{Ln}[P]$, where P presents lognormal distribution.

Once the stochastic processes are estimated, the project value can be simulated from its cash flow considering such uncertainties. In this work, the Monte Carlo simulation is performed using @RISK software. Considering a nontraded asset V, such as the present value of a project, there is no way to estimate its volatility through past data. In this case, the Market Asset Disclaimer (MAD) method can be adopted, where the best estimate for the initial asset value is the present value of its operating cash flows without flexibility. In addition, V has lognormal distribution so that it can be approximated by an MGB, regardless of the stochastic processes of the variables that define its value. Dias [4] proposes an adaptation in this model, here called modified MAD, in order to correct high volatility estimates from the original method.

The value of the investment postponement option $F(V)$ can be calculated using the contingent assets method. Since the investment does not have an expiration term, it corresponds to a perpetual option, whose ordinary differential equation (ODE) is given by:

$$\frac{1}{2}\sigma^2 V^2 \frac{\partial^2 F}{\partial V^2} + (r - \delta)\, V \frac{\partial F}{\partial V} - r\, F = 0 \tag{50.7}$$

where F is the derivative, V is the underlying asset, r is the risk-free rate, and δ is the cash flow distribution rate.

The boundary conditions for this ODE are given by:

$$F(0) = 0 \tag{50.8}$$

$$F\left(V^*\right) = V^* - I \tag{50.9}$$

$$\left.\frac{\partial F(V)}{\partial V}\right|_{V=V^*} = \left.\frac{\partial (V - I)}{\partial V}\right|_{V=V^*} = 1 \tag{50.10}$$

where I is the investment and V^* is the threshold, which is the value of the stochastic variable V in which the investor is indifferent to expect or invest immediately.

From these conditions, the solution of the ODE is given by Eq. (50.11), which represents the curve of the perpetual option value as a function of the asset value V and depends on the threshold V^* and the investment I.

$$\begin{array}{ll} F(V) = \left(\frac{V}{V^*}\right)^{\beta_1} (V^* - I) & \text{if } V < V^* \\ F(V) = V - I & \text{if } V \geq V^* \end{array} \tag{50.11}$$

The difference between $F(V)$ and the net present value (NPV) of the project without flexibility is the "waiting" premium, which, when greater than zero, indicates that the best decision is to wait for better market conditions to invest.

50.3 The Case Study

Based on Salminen [9] and Taneja et al. [11], the framework of Fig. 50.1 is proposed, comprising the phases of selection and analysis of investments in waterway terminals and focusing on the managerial flexibilities. The following key stages suggested here were adopted in the case study and are a proposal to be followed in future projects of the company.

At the terminal chosen for this case study, which has participation in both cabotage and long navigation, there are four berths located on two piers, called "North Pier" and "South Pier." The North Pier operates with oil and oil derivatives ships, while the South Pier only with oil ships. The main light derivatives traded in the terminal in the last five years represent 97% of the scales of the ships, being petrochemical naphtha, diesel oil with 10 parts per million (ppm) of sulfur, diesel oil with 500 ppm of sulfur, aviation kerosene, and gasoline.

As the first stage in the framework, a statistical analysis was performed based on two databases: (i) a database with the record of all the time spent by the ships operating in the terminal from 2013 to 2017; and (ii) a database with records of waiting times causes at all stages of the vessels operation, from before the occupation of the berth until the departure of the ship.

The profile of the occupation of the berths in the South Pier is remarkably different from the profile in the North Pier. Despite having a smaller number of scales, oil

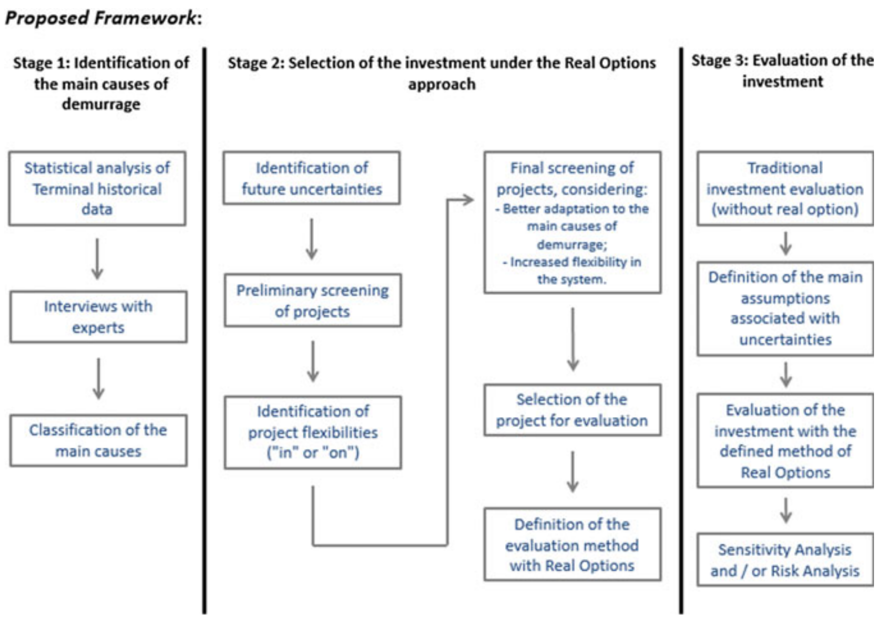

Fig. 50.1 Framework for selection and analysis of investments waterways terminals in the port sector proposed by this author

products' ships have greater demurrage, which results in greater average demurrage. However, due to the average lower hire cost, the average demurrage cost is equivalent to that of the oil vessels. These, in turn, feature higher number of stopovers and higher average hire, but lower average demurrage. The resulting average demurrage cost per scale and per year reaches similar levels for derivatives and oil vessels, suggesting that the different characteristics of the occupation profiles of each class are eventually compensated, which is reflected in costs of the same magnitude.

In order to highlight the main problems of the terminal, the events associated with the derivatives vessels, which stand out for the longest average demurrage, were classified according to their main causes during the year 2017. With the exception of the causes related to the piers (which are related to a static capacity problem) and the ones related to scheduling issues (which involves decision on stock policy and market service), the main causes of derivatives vessels demurrage are shown in Fig. 50.2.

Based on interviews with experts, some potential investments for the terminal were listed for screening. The information from the interviews showed results aligned with the quantitative analysis, pointing higher priority to the derivatives system, which suffered from the cancellation of projects in recent years. In a technical visit to the terminal, it was possible to verify the inferior condition of the superstructure of the North Pier compared to the South Pier.

As the second step of the second stage in the framework, nine projects were selected and detailed according to the following criteria: (i) benefits, restrictions, real options, and gains; (ii) relationship with the derivatives system and with the main causes of demurrage for association with the statistical analysis results; and (iii) expert opinion, which considered not only the relevance of the project, but also the analysis of real options.

The best-rated project was the "Installation of new loading arms in the North Pier," and the second was the "Installation of a new manifold in the North Pier and three

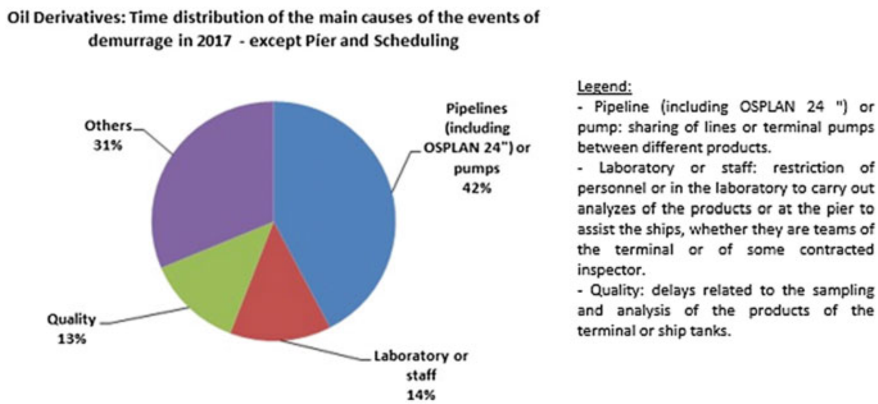

Fig. 50.2 Distribution of causes of demurrage events

new Booster pumps.” As these two projects together can be considered a greater one, this paper proposes the analysis of two different scales of this largest investment: (i) Scale 1 comprises the installation of new loading arms (already purchased) in the North Pier, as well as a new drainage system for the arms; and (ii) scale 2 includes, besides the installation of the new loading arms and a drainage system in the North Pier, a new manifold and three new booster pumps.

Finally, the investment decision was analyzed in the third stage of the framework. For the traditional investment analysis of the two different scales, the following assumptions were considered: (i) investment over 4 years; (ii) a risk-free rate of 6.5% p.a.; (iii) a 10% p.a. adjusted risk discount rate; (iv) present value of scale 2 investment (I_2) equals to 2.35 times the present investment value of scale 1 (I_1); (v) income and social contribution taxes: 34%; (vi) PIS/COFINS: 9.25%; (vii) ICMS: 14%; and (viii) 10-year linear depreciation with no residual value. The expected revenues for scale 1 are given by the gains from the reduction of demurrage due to the improvement in the discharge rate of ships from an average of 1600 m^3/h to an average of 3500 m^3/h, plus gains with reduction of costs with staff and maintenance. The expected revenues for scale 2 are the gains from scale 1 combined with gains from the reduction of demurrage due to the decrease of conflicting operations with the installation of three new booster pumps and the gains from reduction of product degradations. Both scales were economically feasible: (i) Scale 1 presented IRR = 17% p.a. and $V_1/I_1 = 1.49$; and (ii) scale 2, IRR = 12% p.a. and $V_2/I_2 = 1.05$.

To proceed with the real option analysis, the stochastic processes for the demand and cost of hire were estimated, both representing the uncertainties in the cash flow. The demand series was seasonally adjusted, and hire series was deflated from the IGP-DI. The Dickey–Fuller unit root test rejected the geometric Brownian motion hypothesis for the two variables, indicating mean-reversion properties in both cases. The parameters for both variables were estimated based on OU-MRM as in Eq. (50.1). For the demand, however, an adaptation was necessary, given the difficulty faced in working with its high speed of reversion. The main parameters obtained for the two series were: (i) for the demand, $\sigma = 16.42\%$ p.a. and $\eta = 0.20675$; and (ii) for the hire, $\sigma = 63.33\%$ p.a. and $\eta = 3.99684$.

Considering the two different scales, the project parameters and the option value for each case were calculated. From modified MAD method, the aggregate volatility and the cash flow distribution rate obtained for scale 1 were, respectively, $\sigma_v = 17.83\%$ p.a. and $\delta_v = 5.50\%$ p.a. For scale 2, $\sigma_v = 13.79\%$ p.a. and $\delta_v = 5.28\%$ p.a. The curves of the waiting option value $F(V)$, given by Eq. (50.11), and of the immediate exercise value, both normalized by the value of the investment, as functions of the normalized value of the project, are shown in Fig. 50.3 for both scales.

The value of the option to wait exceeds the NPV, given its value at $t = 0$, in both cases. With respect to scale 1, the threshold is $V_1{*} = 1.82\, I_1$, greater than $V_1 = 1.49\, I_1$. In this case, the “waiting” premium is 7.7% of the NPV. With respect to scale 2, the threshold is $V_2{*} = 1.68\, I_2$, greater than $V_2 = 1.05\, I_2$, and the “waiting” premium is 299.0% of the NPV.

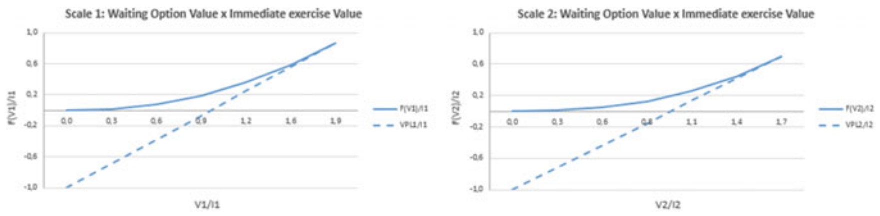

Fig. 50.3 Waiting option value and immediate exercise value for scales 1 and 2

The curves of the option to wait for the two scales can also be analyzed simultaneously, as shown in Fig. 50.4. In this case, however, the option value curve is given by the maximum value between the two options curves and compared with the maximum NPV between the two scales. Under this approach, it is not worth investing in scale 1, but only in scale 2 if its value is greater than or equal to its threshold ($V_2 \geq 1.68\, I_2$).

Sensitivity analysis was performed in order to verify the impacts of changes in the investment values and in the estimated parameters. With a variation of −10% for investment in scale 1 and +20% for investment in scale 2, for example, the NPV of scale 1 grows 13% in the traditional approach, while the NPV of scale 2 falls 97%, but still resulting in viability for this scale. In this case, when considering the existing options, there are two disconnected sets of exercise, with the thresholds $V_1{}^* = 1.82\, I_1$ for scale 1 and $V_2{}^* = 1.70\, I_2$ for scale 2. Therefore, it would be worth investing in scale 1 for a significant range of values ($1.82\, I_1 \leq V_1 < 2.93\, I_1$), having a short interval where it would be worth waiting to invest in scale 2 ($2.93\, I_1 \leq V_1 < 3.08\, I_1$ or $1.61\, I_2 \leq V_2 < 1.70\, I_2$), until the investment in scale 2 becomes more attractive ($V_2 \geq 1.70\, I_2$).

As for demand volatility, when its value is increased by 50% (from 16.42 to 32.84%), for example, there is a growth of 741% in the “waiting” premium of scale 1

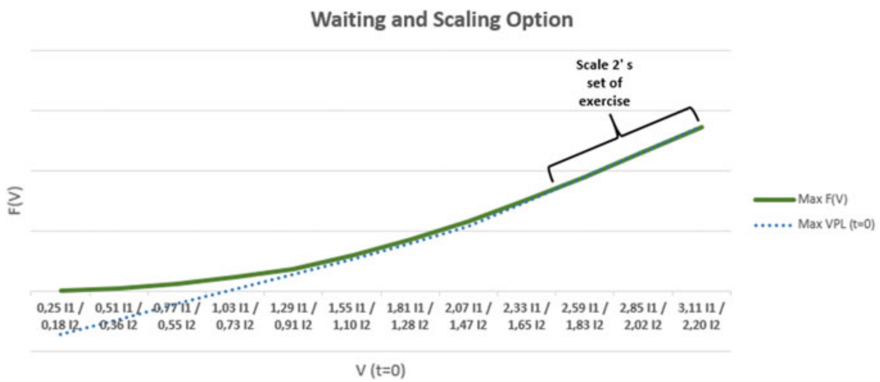

Fig. 50.4 Waiting and scaling options

and 389% in the "waiting" premium of scale 2. These results show the high impact of this parameter on the option values, confirming the importance of reliable estimates.

50.4 Conclusions and Future Research

This article proposes a methodology for the selection and evaluation of investments in waterway terminals subject to restrictions that cause high demurrage costs to their operation. Following the steps outlined in the proposed framework, the results from the case study provided information on (i) the relation between the occupation of the terminal berths and the queue average time; (ii) the possibility of improving the productivity of the terminal through other ways than the construction of new berths; (iii) the range of uncertainties involved in port planning and the difficulty of translating them into real options; and (iv) the importance of a correct definition of the stochastic processes of the variables with randomness.

Given the multiple variables involved in port planning, it is of great importance that the company adopts a flexibility approach in its investment valuations regarding waterway terminals, in order to extend the economic life of its projects. These evaluations can be enriched by quantifying the existing real options. Some seemingly simple options, such as the option to wait or the option of scale, significantly improve project values. The main advantage observed with the application of the Real Options Theory in the evaluated project was precisely the possibility of quantifying unobserved gains in the traditional valuation.

As future work, the direct modeling of the variable "time between ship arrivals" as uncertainty and a broader sensitivity analysis can bring additional gains to the valuation process.

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Chapter 51
Evaluation of the Effects Produced by the Commissioning Procedures on Offshore Oil Platform Operability

Alexandre Rocha do Nascimento and Andréa Regina Nunes de Carvalho

Abstract Research indicates that the average operability (production/capacity) of an oil platform is 80% against the target of 90%. This ex post facto case study of an oil platform in its first year of operation reveals that 75% of production losses are related to the commissioning of the platform.

Keywords Capital projects · Oil and gas sector · Commissioning

51.1 Introduction

The oil and gas industry requires high investments in capital projects for the development of new oil fields. In this context, there are a number of issues that contribute to financial losses (e.g., oil price fluctuation, exchange rate variations, low reservoir performance, inoperative wells, or lifting systems) concerning these projects. The return on their investments occurs only when the platforms start the operation. The operability (i.e., the ratio between oil production and platform capacity) is one of the main performance measures in terms of project quality [12]. It may also be defined as the percentage of time that the platform operates in a secure mode [17, 18]. Recent studies show that the average operability of oil platforms in their first year of operation is in the 80% range compared to a 90% expectation of the project sponsors [10].

The commissioning process, within a project, intends to improve the operability of an asset aiming at the return of its investment and the guarantee of its sustainability [4]. Its objective is to guarantee the operability of installation and carry out tests that verify its full functioning after construction and assembly activities [1]. Therefore, the effective implementation of a commissioning process in platforms projects is a possible solution to guarantee the planned operational goals.

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Despite the recognized importance of commissioning, there is a need for more scientific studies that correlate statistically and reliably the influence of commissioning on the operability of an asset. In this sense, this ex post facto case study aims to evaluate, with the aid of reliability, availability, and maintainability (RAM) analysis, the effects produced by the commissioning procedures on the operability of an offshore oil platform in its first year of operation.

This article is organized into five sections. Section 51.2 presents the theoretical background and Sect. 51.3 describes the methodology. Section 51.4 presents the studied context and the results obtained from this research. The conclusions are presented in the last section.

51.2 Theoretical Background

The development of a capital project, when it involves high cost and complexity, occurs through successive waves of planning. This type of planning consists of several cycles of information collection and analysis, decision making, and updating of the project baseline [16].

According to Merrow [10], the oil and gas projects generally adopt systematic three phases for planning, one phase for execution, and the last one for evaluation. The planning stages, submitted to decision gates, are known as front-end loading (FEL). Phase 1 consists of identifying a business need, generating ideas, analyzing market demand, business sustainability, and the availability of process technology in order to obtain sponsorship for the project. Phase 2 aims at defining which engineering solution should be delivered to meet the business need. In this phase, the operability of the plant is an input to establish an economic feasibility analysis of the project, and hence, the presence of the operation and maintenance teams in the definition of the conceptual project are necessary. Phase 3 aims to design a project that allows a quantitative estimation of costs and execution time and establish the operability of the platform. Phase 4 (execution) comprises the executive design, manufacturing, logistics, construction, assembly and commissioning of the facility. Phase 5 refers to the demobilization of the project and the first year of operation of the facility, evaluation of the project outcomes, and recording improvement opportunities for future projects. The operability of the platform is one of the evaluated results.

The commissioning process, which generally begins in phase 3, comprises production assurance, throughout the development of an investment project, in order to deliver all the operational systems to the operator without pending issues. Brito et al. [2] suggest that commissioning is a project driver that complements the scope definition and its alignment with the organization's strategic objectives. Coyner and Kramer [5] highlight that commissioning is a shipbuilding term that describes the process of ensuring that an organization can sustainably receive and operate a new facility. Adolphe [1] states that the mission of commissioning is to prove that the systems work in accordance with the design.

The earlier operational issues are considered within the project design, and greater are the chances of obtaining a better production performance. O'Connor et al. [14] emphasize the importance of considering the start-up of the facilities since phase 1. The planning of the project execution should consider a schedule aligned with the start of the process plant. O'Brien et al. [13] states that in phase 3, the commissioning team should divide the plant into operational systems and establish a precedence network as input for project execution planning.

The performance of an investment project may be assessed under various criteria (such as operability, reliability, and maintainability) along the life cycle of the projected installation and the commissioning process plays an import role within this context. Mugnaini et al. [11] states that anticipating the inauguration of installation without properly commissioning can affect the reliability of the equipment. Carrasco and Lima [3] define operability as the possibility of a process plant to reach production capacity. Jung et al. [8] describe the term operability as the efficiency of logistics within a vessel. In a sense, operability depends on the reliability of the equipment (specified within the project) and the maintainability (provided by the operational area).

In terms of operability benchmarking, data relative to oil platform production are generally collected between the 7th and 12th month after commissioning. This is done to exclude recurring faults at the beginning of production of an industrial plant, as described in Fig. 51.1 which presents the "bathtub curve." As seen, the operability increases as the failure rate decreases at the beginning of the production. Within this research study, operability of a platform is defined as the ratio between oil production and the production potential of the oil wells.

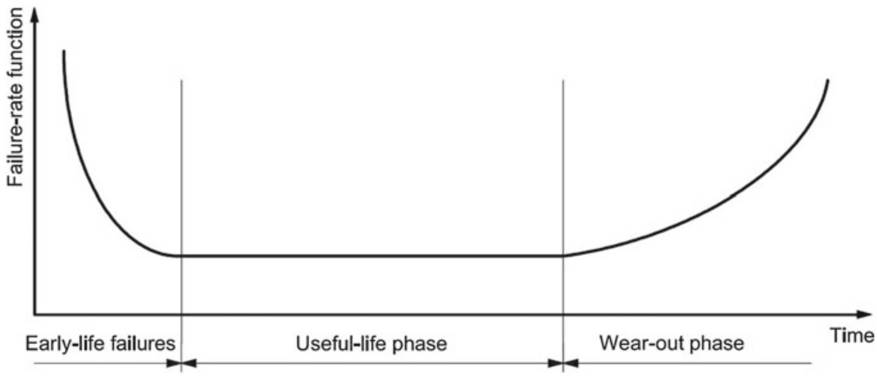

Fig. 51.1 Bathtub curve *Source* [9]

51.3 Method

The present research is an ex post facto case study regarding the first year of operation of an FPSO platform, the DAMI Platform. According to Yin [19], the use of the case study is typical for the study of complex social phenomena, allowing a holistic and real-world view. On the other hand, it is an ex post facto research, since there is no control over the variables since the experience has already occurred according to Gil [7].

Through documentary research and unstructured interviews with professionals involved in the design of the platform under study, it was possible to identify critical issues regarding the management of its commissioning process. In addition, through an internal management system, data referring to production losses were gathered relative to the first eleven months of operation of this platform. These historical losses were categorized by cause (i.e., loss due to commissioning failure or loss due to operation failure).

In order to estimate the effects of these historical losses on the operability of the platform, a statistical method was used, based on RAM analysis. Therefore, the DAMI platform was represented by a model whose operation was simulated using MAROS 9.0 software provided by DNV-GL [6]. Different scenarios were simulated and, according to the results, the effects of the commissioning process (i.e., losses from commissioning) on the operability of the platform were quantified. Subsequently, several issues were discussed not only regarding these numerical results but also the management of commissioning in the company.

51.4 Case Study

In the DAMI Platform, 66 production loss events were registered in its first year of operation. Moreover, 21 of these events were classified as losses originated from the commissioning process and 11 of them, considered of greater severity, required a process which included the registration, analysis, and treatment of the anomalies.

To calculate the effect of these losses on the operability of this platform, a process flow diagram (i.e., a graph that represents the production flows in an installation or system) of the studied platform is designed using the MAROS tool, as shown in Fig. 51.2. According to this diagram, the oil comes from the wells to the platform, where it passes through a three-phase separation vessel, generating three process streams (oil, water, and gas).

Subsequently, a reliability block diagram (RBD) is assigned for each equipment. This diagram contains the mean time between failure and the mean time to repair, the probability distribution parameters for maintenance events, the impact of maintenance events and breakdowns on production output, and the precedence relations among equipment (i.e., if equipment stops, others may also stop). The RBD is essential in the MAROS tool to realize the reliability analysis which calculates the

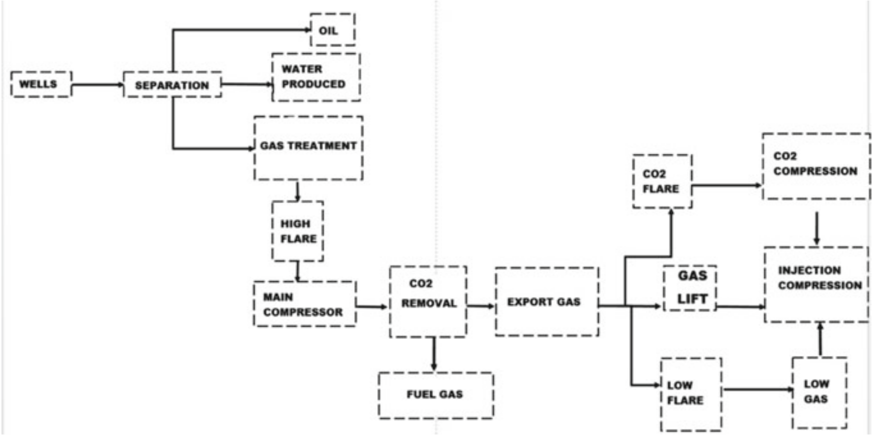

Fig. 51.2 DAMI platform process flow diagram

availability and production losses due to equipment failures and maintenance in a given time. Within this process, a Monte Carlo simulation generates random faults in the equipment to calculate the rate of system availability. After a customized number of simulations, a report is generated to present the availability of equipment and systems, production losses, and which faults and maintenance activities have caused the greatest impact on availability and production losses. The results of these simulation runs generate an estimation of the platform operability and the relative contribution of each system and equipment to the production losses, identifying the bad actors to be treated.

Using MAROS tool, three scenarios were simulated for the DAMI platform: (i) the baseline (original data, based on theoretical random failures), (ii) the realistic scenario (based on the historical losses), and (iii) the adjusted scenario (considering only the most probable loss occurrences according to specialists). Scenario 1 refers to original plan, developed during phase 4 of the DAMI platform project. This scenario only uses the random/probabilistic reliability failure rates extracted from the OREDA [15] (i.e., a consortium made up of global oil and gas companies, dedicated to the collection and sharing of reliability data and equipment maintenance) Handbook. Figure 51.3 shows the variation of operability along 12 months for scenario 1. In this case, the platform production is adherent to the oil production curve.

Scenario 2 (the realistic one) takes into account the historical failures of the DAMI platform in its first year of operation. This scenario considers the random/probabilistic reliability failure rates extracted from the OREDA Handbook and the real failures that caused production loss in the first 12 months of operation. Figure 51.4 presents the variation of operability in this scenario and a significant production loss within the analyzed period.

Scenario 3 (adjusted scenario) is an estimate of the production of future platforms. Professionals with engineering and operational knowledge analyzed the deterministic failures of the DAMI platform and indicated which failures can be avoided. In this

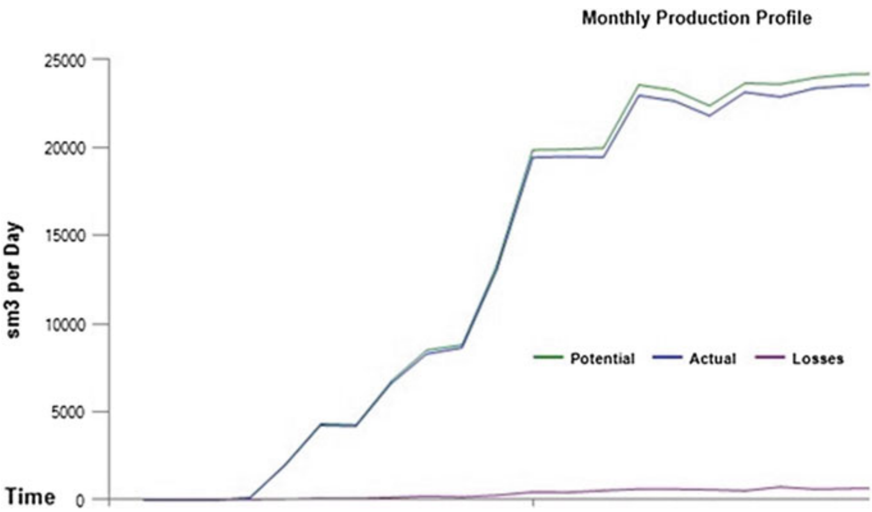

Fig. 51.3 Potential, production, and loss in scenario 1

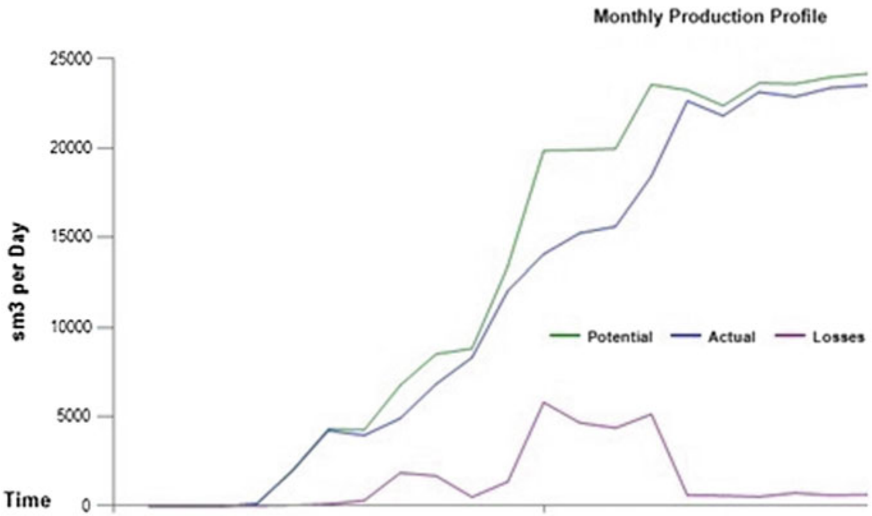

Fig. 51.4 Potential, production, and loss in scenario 2

case, only the most probable loss occurrences from the historical data were considered. Figure 51.5 shows the variation of the operability along the initial 12 months according to this scenario. A significant reduction in production losses, comparing to the previous scenario, can be observed. This is due to the adoption of corrective actions, recommended by these professionals.

Table 51.1 offers a summary of the three scenarios by presenting the simulated platform losses (in million barrels), the operability rate calculated (%) and the financial losses (in million dollars) after the Monte Carlo simulation considering 500 iterations.

In the 12 month period, considering the deterministic failures (realistic scenario), there was a 17.4 percentage points decrease in the platform's operability compared to the baseline scenario, which represented a loss of 4.37 million barrels of oil. Considering the value of the barrel at 70 dollars, there was an increase in losses of about 306 million dollars. Commissioning alone contributes to a loss of 13 percentage points in operability and 3.28 million barrels of oil or 229 million dollars. The deterministic failures of equipment contribute with a loss of 4.3 percentage points

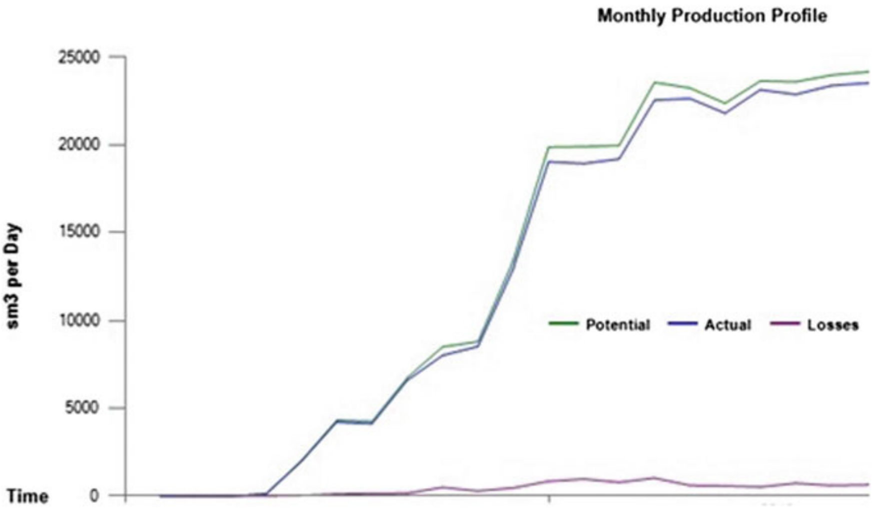

Fig. 51.5 Potential, production, and loss in scenario 3

Table 51.1 Comparison loss scenarios for the initial twelve months of operation

Scenarios	12 months		
	Losses (million barrels)	Operability rate (%)	Financial losses (million dollars)
1 (Baseline)	0.56	97.8	39.2
2 (Realistic)	4.93	80.4	345.1
3 (Adjusted)	1.00	96.0	70.0

and 1.09 million barrels of oil or 76 million dollars. Scenario 3 shows that the employment of corrective actions, recommended by specialists, would avoid 90% of the losses estimated in scenario 2, resulting in a gain of 275 million dollars. In scenario 3, random failures considered at the baseline are again responsible for the largest share of production loss (87%), and commissioning failures account for only 4% of losses.

This simulation study was extended to a 21-year period for scenarios 1 (Fig. 51.6) and 2 (Fig. 51.7). In Fig. 51.6, the platform presents a high operability performance since the beginning of the operation, when the operability should be increasing due to the gradual reduction of the failure rate, as illustrated by the bathtube curve (Fig. 51.1). Additionally, according to DAMI's historical database, the mechanical failures at the start of the operation decrease and do not follow the OREDA database assumptions of constant failure rates, creating an optimistic expectation for the start of production. On the other hand, Fig. 51.7, based on the realistic scenario, shows a

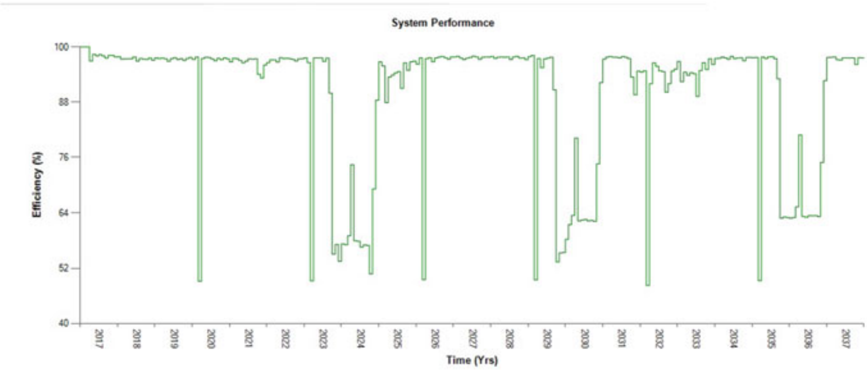

Fig. 51.6 Scenario 1—21 years of operation

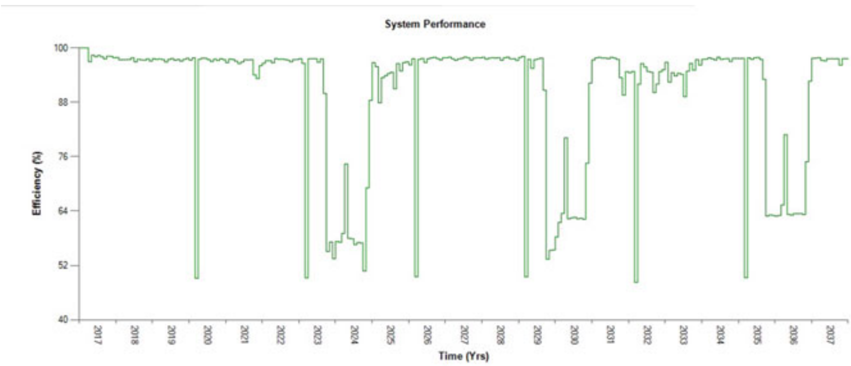

Fig. 51.7 Scenario 2—21 years of operation

significant failure rate at the beginning of production, which is more consistent with the bathtube curve.

51.5 Conclusion

This research refers to an ex post facto case study, related to the first year of operation of an FPSO platform. The main objective is to evaluate the effects of the commissioning process on the operability of this platform during this period. Therefore, data relative to the production losses occurred during this first year of operation were collected and classified as operational errors or failures resulting from the commissioning process. In order to estimate the effects of these historical losses on the operability of the platform, a statistical method was used, based on RAM analysis. When comparing the planned operational efficiency (97.8%) with the operability based on the historical data collected during the 12 months (80.4%), it was concluded that this difference refers to additional losses due to commissioning failures (75%) and to losses initially not considered in the simulation model (25%). This reinforces the need to revise the operability baselines in order to reveal the decreasing rate of failures at the beginning of the operation and, finally, to undertake improvement actions in the commissioning process. This study also shows that the adoption of comprehensive actions, indicated by experts, could reduce this volume of losses by 90%. In summary, it is concluded that the actions of the commissioning process have a high impact on the operability of the platform in the first year of operation, and its effective implementation constitutes a critical factor for the success of the project. Finally, this study contributes to literature as it presents a new method for estimation of operability, with the aid of reliability analysis and data obtained from production losses.

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Chapter 52
Stock Management of Asphalt: Applications in a Brazilian Oil Company

Giuseppe Ventoso Neto

Abstract This paper proposes and applies a model of inventory management of asphalt in a large oil company in Brazil. Results are compared with the current practices and show positive gains in terms of measurement and safety stock cost avoidance. Practical implications and suggestions for the future research close the study.

Keywords Safety stock · Inventory costs

52.1 Introduction

Brazil concentrates on a great part of the transportation of products and passengers in the modal road, and nevertheless, only about 12% of its highways are paved [6]. Well-paved roads ensure a more efficient, cheap, and safe flow and distribution of products.

Faced with this scenario of great potential but uncertain demand, there is a need to improve inventory management practices in order to guarantee the supply to the market and the continuity of the works and at the same time to avoid financial losses, either by lost sales or by high maintenance costs.

In this context, this chapter aims to propose a model of asphalt stock management, based on the calculations and academic foundations, to replace the current management that is made just based on employee expertise. The work analyzed the reality of production and delivery of a refinery producing asphalts, highlighting the difficulties and uncertainties in the processes. The proposed model has as main results: calculation of the theoretical safety stock and a comparison between the costs of realized and theoretical stocks.

The chapter is divided into four sections. In Sect. 52.2, the theoretical reference, containing the main topics relevant to planning, sizing, and inventory control, will be presented. Section 52.3 briefly details the methodology used in the case study.

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In Sect. 52.4, the case is developed and the results are presented. Finally, Sect. 52.5 presents the conclusions and recommendations.

52.2 Literature Overview

The scope of this study is very extensive in the literature. Numerous studies can be found searching for terms such as inventory management, safety stock, inventory control, and inventory costs. In the following topics, the main concepts that underlie this study will be presented.

52.2.1 Definitions

The stocks can be classified according to the type of use, the main types being highlighted by Silver et al. [9] and Ballou [2]:

- Cyclic stock (Q) or cycle stock: It is the necessary stock, produced or ordered, to meet the demand during the period between successive requirements.
- Transit stock (TS): It is the amount in transit between facilities or orders not yet received.
- Speculative stock: It occurs as a result of purchases prior to a real need due to possible exchange rate variations or promotional discounts, for example.
- Safety stock (SS): It is the stock required to cover uncertainties. This type of inventory is the focus of this chapter and will be better detailed in Item 2.2.
- Average inventory (Sm): It consists of half of the cyclical stock plus the safety stock and more in transit inventory. These symbologies and denominations will be adopted from now on in this chapter. The mathematical formula for the calculation of the average stock is represented in Eq. (52.1).

$$\mathrm{Sm} = \frac{Q}{2} + \mathrm{SS} + \mathrm{TS} \tag{52.1}$$

52.2.2 Safety Stock

For Silver et al. [9], the safety stock is the stock held to meet a demand that exceeds the amount forecast for a given period. Schmitd et al. [8] defend the existence of the safety stock for the maintenance of the delivery requirements due to the volatility of demand, time, and spare volume. According to Ballou [2], the safety stock dimensioning is related to two determining factors: uncertainties in demand and resupply and level of customer service desired.

In this context, a formula stands out due to a large number of references in the literature and its great application in the industry. The calculation method relates a safety factor (Z), based on the desired level of service, with the standard deviation of the uncertainties (S). However, it should be noted that the use is valid for demands that follow a normal distribution. The calculation formula is given in Eq. (52.2).

$$\mathrm{SS} = Z \cdot S \tag{52.2}$$

Z It is the number of standard deviations of the average of the demand distribution, which represents the probability of inventory presence during the period of resupply, that is, the level of service desired.
S It represents the standard deviation of the uncertainties considered.

It is commonly found in the literature, for example, in Ballou [2] and Bowersox et al. [3], a simplified formula combining the standard deviations of two random variables, in this case demand and lead time. From this formula, we arrive at the final expression for the calculation of the safety stock considering the uncertainties of the demand and resupply time (Eq. 52.3):

$$\mathrm{SS} = Z \cdot \sqrt{\mathrm{LT} \times S_D^2 + D^2 \times S_{\mathrm{LT}}^2} \tag{52.3}$$

LT It is the lead time.
S_D It is the demand standard deviation.
D It is the demand.
S_{LT} It is the lead time standard deviation.

52.2.3 Inventory Costs

Inventory maintenance costs are those costs associated with maintaining products, whether finished or intermediate in processing, in the stock. These expenses are calculated taking into account the average stock [5]. The main costs highlighted by Bowersox et al. [3] and Waller and Esper [10] are as follows:

- Weighted average cost of capital (WACC): It is the opportunity cost of capital. It takes into account the required return on the equity of the company and the degree of indebtedness; that is, it would be like an investment left to do to prioritize the maintenance of the stocks.
- Insurance: This cost is calculated based on the estimated risk of loss from the product.
- Obsolescence: This cost is related to the deterioration of the products during the period of storage.

- Storage: All expenses are associated with special facilities and care for the maintenance of products in the stock.

Among all the costs presented, what most impacts the cost of inventory is the WACC, so it has become the most used to represent the financial value spent on inventories. Silver et al. [9] adopt Eq. (52.4) to calculate the cost of the loading stock:

$$SC = I \cdot V \cdot \mathrm{Sm} \tag{52.4}$$

SC It is the stock cost.
I It is the weighted average cost of capital (WACC) rate.
V It is the unit value of the item in the stock.

52.3 Methodology

According to Yin [11], the use of the case study is indicated when the objective of the research is to investigate a contemporary phenomenon in its natural environment, considering multiple sources of evidence, without control or manipulation of variables. These definitions were fundamental to characterize this work as a case study, since it fully meets the above requirements.

The analysis unit of this study is an oil refinery of Petrobras, capable of producing asphalts. Petrobras is an integrated energy company with more than 60,000 employees, which has 13 refineries and 120 oil production plants in operation in Brazil and other 18 countries. One of its main activities is the production of petroleum products, which include asphalts.

The development of this case study was based on the following sequence:

- Mapping of the current inventory management;
- Search by theoretical reference;
- Data collection;
- Analysis of the collected data: The analyses were performed using the statistical tools of Microsoft Excel and through the application of the fundamentals addressed in the theoretical framework.

52.4 Case Study

This chapter will be devoted to the case presentation and analysis of results.

Table 52.1 Asphalt demand sample statistics by quarters (t)

	Jan–Mar	Abr–Jun	Jul–Set	Out–Dez
Mean	25.254	29.104	35.513	26.834
Standard deviation	9.060	11.667	11.519	10.455

52.4.1 Production, Delivery, and Storage Capacities

According to the refinery's production experts, the current monthly production capacity is 40,000 t and the delivery capacity can reach up to 41,000 t/month.

Currently, the refinery has four operational tanks, each of them with capacity to store 4,000 t. In this tank configuration, only two tanks have the potential to store the product as a safety stock, since one is dedicated to dispatch product to the loading nozzles and another is available to receive production. In this context, the maximum safety stock capacity is 8000 t.

52.4.2 Demand Analysis

At this stage, sales data from 10 years (2008–2017) at the refinery were considered. Due to the seasonality of the demand, the study proposed the decomposition of the year in quarters, and therefore, different safety stocks will also be calculated for each of these periods. Thus, about 30 data were observed for each period, expurgating data from refinery stops, when the demand was forcibly repressed. The results of the average demands of the quarters and the respective standard deviations are given in Table 52.1.

As expected, the period of greatest consumption is the period from July to September, since in the coldest months the lowest rainfall occurs, a fact that contributes directly to the construction of paving works, and the smaller ones are the first and the last months of the year, months with higher incidence of rainfall. When all data compiled annually, the mean/month performed was 29,216 t and the standard deviation was 11,160 t.

52.4.3 Production Time Analysis

In order to analyze the asphalt production time, data were collected from two months of 2017, with a total of 10 tanks produced. The mean verified was 4.54 days, and the standard deviation was 0.15 days.

52.4.4 Calculation of Safety Stocks Based on Historical Demand Data

This study used Eq. (52.3) to calculate different safety stocks according to the quarters of the year. Due to the importance of the product for the development of the country's logistics infrastructure, which is essentially road, the level of asphalt delivery service must be high. When the asphalt is not delivered, a fundamental raw material for paving, the works are interrupted, causing delays and damages for the construction companies and the country. Thus, four service-level scenarios (92.5, 95, 97.5, and 99.99%) were simulated in order to show the difference in the safety stock dimensioning and in the maintenance cost of stocks.

Considering the normally distributed demand and using the normal table, we obtain the Zs as indicated in Table 52.2, for each level of service.

Using the Zs of each scenario and the statistical data of demand and production time and with the calculations from Eq. (52.3), the results represented in Table 52.3 were obtained for SS.

As given in Table 52.3, a service level of approximately 100% requires practically double the safety stock than the target level of 97.50%, for example.

At this point it is important to note that the refinery could not operate in the 99.99% scenario and 97.50% only in the first and last quarter of the year due to the safety stock capacity being at most 8000 t. The scenario of 95% could be fulfilled throughout the year, as well as the scenario of 92.5%.

As shown in Item 4.2, for sensitivity purposes, Table 52.4 presents the safety stocks when the data are compiled annually.

Table 52.2 Z for different service levels

	99.99%	97.50%	95.00%	92.50%
Z	3.70	1.96	1.65	1.34

Table 52.3 Calculated safety stocks compiled by quarters (t)

SL (%)	Jan–Mar	Abr–Jun	Jul–Set	Out–Dez
99.99	13.471	17.237	17.246	15.470
97.50	7.136	9.131	9.136	8.195
95.00	6.007	7.687	7.691	6.899
92.50	4.879	6.243	6.246	5.603

Table 52.4 Calculated safety stocks compiled annually (t)

SL (%)	99.99	97.50	95.00	92.50
SS	16.530	8.757	7.372	5.987

With the calculation of the single safety stock for the year, for the restricted tank reason, the only viable scenarios would be those of 95 and 92.5%.

52.4.5 Comparison of Maintenance Costs

In order to make a comparison between realized and theoretical inventory costs, the theoretical average inventories were calculated from the scenarios with quarterly safety inventories using Eq. (52.1). The cyclic stock (Q) is the production lot size, which is the capacity of the tank (4000 t). The stock in transit is represented by the tank in production and was considered, for the calculation purposes, the same as the average cyclic stock, since production and delivery have similar rates. The safety stocks (ES) were calculated in Sect. 54.4. The average inventories collected for comparison were the years of 2015 and 2016, years in which the refinery had the same current tank capacity. Once the average inventories were calculated, inventory costs were calculated based on Eq. (52.4). The values of the item in the stock (V) and the rate (I) are fixed and are 1000 R $/t and 9.38%, respectively. The sale price, because it is confidential, was divided by a constant, but it is in the same order of magnitude and does not significantly change the cost value. The rate of 9.38% was used because it is the average of companies in the oil and gas sectors [7]. The results are shown in the graph in Fig. 52.1.

In the case analyzed, considering that the refinery had the capacity to store the asphalt quantity indicated in the 99.99% service-level scenario, the annual cost of inventory could reach a high of 1.9 million reais, about 42% more than the achievements of 2015 and 2016 and about 45% compared to the target scenario of 95%. The scenario of 92.5% would save about 10% from the 95% scenario, but at the expense of a below-expected level of service for a product critical to the country's

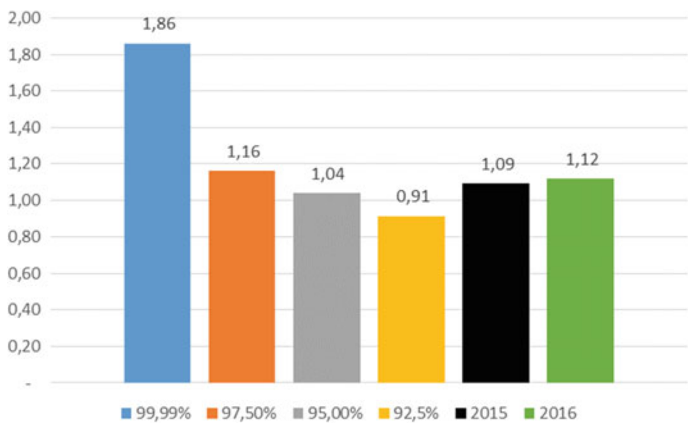

Fig. 52.1 Comparative chart of theoretical costs x realized (Mi R $/year)

development. As previously seen in the calculation of safety stocks, the maintenance costs also differ when considering the quarterly division. Only by adopting the said division, the reduction of costs with the maintenance of inventories is in the order of 5% compared to the use of the security inventory in a single period.

52.5 Conclusions

Based on the concepts included in the theoretical reference and the analysis of the data collected, it was possible to achieve the purpose of the study that was to develop an asphalt inventory management model based on literature concepts, to replace the current scenario, where management is made based on the experience of the collaborators who work in the area. The study fulfilled its objectives, and the main results highlighted are as follows:

- Calculation of the safety stock: The results showed to be adherent to the operational reality of the refinery analyzed, but improvements were presented, such as the division of the safety stock in quarters, which in all scenarios was favorable in terms of inventory costs in relation to working with single safety stock throughout the year, with cost reductions around 3%. Due to the relevance and criticality of the product in the national scenario, together with the current storage, the study recommends that the operation should occur according to the scenario of 95% service level.
- Comparison of inventory costs: The costs of each scenario were evaluated according to the average stock/year of each one and a comparative analysis with the realization data. The 99.99 and 97.5% service-level scenarios proved to be incompatible with both the operational reality and the financial reality of the company, so they were not considered as possible scenarios for the implementation. On the other hand, the 95% showed adherence to the operational and financial reality of the company, being the most appropriate to operate in practice.

The study, although achieving the proposed objective, presents a limitation, covering only one producing refinery. This fact appears as an opportunity to continue the development of the same model on other fronts. The main one would be to follow up this work by applying it to other asphalt producing units.

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Chapter 53
Industry 4.0: Lessons Learned from the German Industry

Hannes Winkler and Luiz Felipe Scavarda

Abstract Interest in Industry 4.0 has grown significantly in both academic and industrial societies. However, there are still many challenges and barriers to move from concept to reality. This paper addresses this research-practice gap by analysing the development of Industry 4.0 within the German industry highlighting the main lessons learned.

Keywords Digital factory · Maturity model · VDMA toolbox

53.1 Introduction

Industry 4.0 became a very fast-growing topic, attracting attention from academics and practitioners with significant impact for different industry sectors in the near future [5, 7, 14]. The term "Industry 4.0" first emerged at the Hannover Trade Fair in Germany in 2011, presented by a group of government officials, industry leaders and academics. The idea was to develop the German industry and to maintain its competitive advantage [21, 39]. For the German government, it is crucial that German manufacturing industry keeps its competitive edge, as industrial manufacturing accounts for about 25% of all jobs in Germany [15]. The term Industry 4.0 quickly became widely used and the focus of attention of companies and their leaders. The 2016 World Economic Forum Annual Meeting in Davos was being held under the theme "Mastering the Fourth Industrial Revolution" [34]. Industry 4.0 also quickly gained growing attention among researchers worldwide [16, 25].

The goal of this paper is to show three current Industry 4.0 applications in the German Industry and to highlight the challenge to analyse a current as-is state of a company as well as the desired to-be state. Therefore, an overview of current maturity models for Industry 4.0 is presented. One of the most prominent maturity models

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in Germany, the VDMA Toolbox, is used to analyse the maturity level of the three toy-cases, to test the applicability of the model and evaluate their current level. The difficulties of the application are described, and a research agenda is presented.

The paper is organized into five sections, being this first one this introduction. Section two provides a theoretical background on the subject, focusing on the stages of the industrial revolution and on the available maturity models. Section three provides an overview of current Industry 4.0 applications in Germany, focusing on three toy-cases. Section four evaluates the cases according to their maturity levels based on the VDMA Toolbox model. Finally, the last section offers the author's main conclusions and an outlook for future research.

53.2 Theoretical Background

53.2.1 The Four Stages of the Industrial Revolution

An industrial revolution can be considered as a "system of macro inventions that generates events that change the society in a definitive and pragmatic way" [16, 28]. The First Industrial Revolution ("power generation") was initiated with the introduction of the power loom in 1784 and the mechanization of production and transportation processes using water and steam power [13]. The Second Industrial Revolution ("electrification and industrialization") was initiated by the adaption of electrical power to industrial machines, replacing steam-powered systems. The first assembly line was implemented, not at Ford Motor Company, but in a slaughterhouse in 1870 [29]. The Third Industrial Revolution ("electronic automation") started with the appearance of the first programmable logic controller (PLC) in 1969. In the following years, electronics, computers and information and communication technology (ICT) were applied to automate production processes and robotic systems replaced manual work [31].

The Fourth Industrial Revolution is characterized by the "advanced digitalization and integration of industrial manufacturing and logistics processes, and the use of internet and "smart" objects (machines and products)" [16], merging the physical and virtual worlds, in what is called the cyber-physical production systems (CPPSs) that communicate between themselves via a network.

As the term Industry 4.0 is quite recent, there is still no complete consensus on this concept, as some authors might call it Advanced Manufacturing, Smart Manufacturing, Smart Factory, Internet of Things, Internet of Everything, or Industrial Internet to express the same concept [16]. Shafiq et al. [36] define Industry 4.0 as a combination of "intelligent machines, systems production and processes to form a sophisticated network". In such a network, the units are linked and interconnected and form a large network of "centralized information systems". This network creates a virtual model of the real world [26, 36]. At the same time, Industry 4.0 can be seen as an inheritor to current mechatronic and automated systems [2, 26].

Industry 4.0 can enable the management and control of entire value creation networks throughout the full product life cycle. The focus lies on the satisfaction of increasingly demanding customers, their growing customization requirements as well as on the creation of new business models worldwide [24, 26]. The central component is the linkage of digital worlds and physical systems with cyber-physical systems [1]. It is expected that such highly integrated and interconnected factories, machines and products will be able to interact in an intelligent and partly autonomous manner with minimal manual intervention [27, 33]. Industry 4.0 is believed to change drastically the classical human and production organization systems, and the organizational business models, impacting the overall society and the environment [21].

53.2.2 Opportunities and Challenges for Industry 4.0 Implementations

Expectations for the potential of Industry 4.0 are high. Studies estimated the potential of Industry 4.0 at between 100 and 150 billion Euros for the German economy alone over the next few years [9]. Therefore, many companies launched initiatives to prepare their business for Industry 4.0 and the challenges and opportunities to come [32]. One of the first questions for industrial companies, when starting an Industry 4.0 initiative or a pilot project is "where are we today?" and "where do we want to go?" These questions are not easy to answer. Companies have difficulties for evaluating their current state of Industry 4.0 as well as describing their vision and identifying specific fields of action, programs and projects [33]. Uncertainties about the actual capabilities and the structural impact on value chains are impeding the implementation of Industry 4.0 [19]. Another difficulty for organizations is to estimate the necessary investment in new technology and the consequences on their current and future business model [33]. The individual orientation as well as the interconnection of the various technologies in different stages of development make Industry 4.0 a complex undertaking and it is crucially important for companies to be aware of their own position relative to future versions of Industry 4.0 and to play an active role in change by developing disruptive business models [19].

To overcome the uncertainty in manufacturing companies in terms of Industry 4.0, new tools and methods are necessary to guide and support the alignment of business strategies and operations [33]. To provide an objective performance assessment of a company's current capabilities and future challenges, several models to access the Industry 4.0 maturity or Industry 4.0 readiness and to show possible "next levels" of maturity have emerged over the last years. These models are employed to derive a systematic plan to progressively enhance performance based on the analysis of a company [19].

53.2.3 Maturity Models of Industry 4.0

The term “maturity” indicates a “state of being complete, perfect or ready” [37]. Maturity also implies a certain progress in a system development [33]. That means that maturing systems (technological, but also organizational or biological) step up their ability to perform over time towards a desired to-be condition. Maturity models are tools to develop and to evaluate the maturity of a company or a process with reference to a defined goal [33]. Equivalents to maturity models are “readiness models” [33]. Kese and Terstegen [22] published a comparison of 14 different, mainly German, maturity and readiness assessments. Most of them are set up as online or offline questionnaires to self-assess the Industry 4.0 maturity of a company. For these self-assessments, the time effort varies between 10 and 20 min. Some other models use a workshop approach with duration of up to 3 weeks, to analyse the company, assess its maturity and establish individual goals and next steps towards Industry 4.0. Apart from data capturing and time effort for each maturity model, Kese and Terstegen [22] provide only a short comparison of the main areas/topics and departments analysed, as well as a short overview on the structure of each maturity model (number of categories and number of maturity levels).

Another possibility to structure current state and future goals of a company regarding Industry 4.0 is a step-by-step process analysis using a morphological box as suggested by Winkler and Krajcevic [40]. Each single step along an industrial process is mapped as a row in a morphological box, the first process step being the first row and the last process step being the last row in the matrix. The technical possibilities for every single process step are described as options/variants in the columns. For example, a single-process step like “confirm next assembly step” can be implemented using different high-tech and low-tech solutions, like, for example, “manual confirmation via button”, “manual confirmation via barcode scan”, “automatic confirmation via RFID”, “automatic confirmation via intelligent camera”, “automatic confirmation via ultrasound sensor”, etc. These process steps and technical options define the solution space. For each technical option, the effort (e.g. time, investment and training) and the benefit (e.g. improvements in cost, quality, flexibility, speed) can be compared. Different scenarios can be defined as combinations of different technical options. As some technical solutions of a chosen scenario might depend on each other (e.g. installation of Wi-Fi, software, camera module), a timeline for implementation, investment and benefits can be established.

53.2.4 Maturity Model “VDMA Toolbox”

One of the first and widely accepted models to help analysing the current state and possible future steps of a company’s Industry 4.0 journey is the “VDMA Toolbox Industry 4.0” [3]. VDMA is the German Mechanical Engineering Industry Association (Verband Deutscher Maschinen- und Anlagenbau). With more than 3200 member companies in the SME-dominated mechanical and systems engineering industry, VDMA is Europe's largest Industry Association, based in Frankfurt am Main [38]. The Toolbox Industry 4.0 was one of the first models to measure maturity and was published in 2015 by Anderl et al. [3]. It is regarded as a suitable tool to analyse status quo and to set future goals, as well as to "break down the huge subject of Industry 4.0 into manageable parts" [6]. Several researchers and practitioners used the model to analyse the current as-is state and the future to-be state in industrial companies over the last years [4, 20, 23].

The VDMA Toolbox Industry 4.0 groups several application areas of Industry 4.0 with five technical levels of implementation each, into the main areas "product" and "production". The Toolbox aims at helping companies to generate new Industry 4.0 business models and ideas. The area of analysis is the product and the manufacturing process itself, which are used to identify a particular company's Industry 4.0 capabilities [3, 19]. The toolbox is used during an analysis phase and a workshop and is intended to be a "continuously evolving impulse generator" [3, 19]. To improve a company's position regarding Industry 4.0, the goal is to move from the "earlier stages" on the left side of the table to the "more advanced stages" on the right side of the table [4, 20, 23].

53.3 Current Industry 4.0 Applications in the German Industry

Germany is considered the frontrunner in Industry 4.0 [8]. Many German companies have initiated pilot projects or demonstrators to experiment and learn from industry 4.0 applications. Many examples are published on the so-called Plattform Industrie 4.0. The platform is steered and led by the federal minister for economic affairs and energy, the federal minister of education and research, and high-ranking representatives from industry, science and the trade unions. The platform currently lists more than 350 German Industry 4.0 applications, being developed and implemented by companies and research institutions [10]. Out of these applications, the current section offers three toy-cases, all realized in the south of Germany, but each with a very different approach and technology.

53.3.1 Toy-Case 1: BOSCH REXROTH—Industry 4.0 Production Line

Bosch Rexroth has implemented an Industry 4.0 production line, where every work piece carrier is equipped with a RFID tag. The production line consists of automatic and manual elements. Via automatical reading of the RFID chips, a scanner in the automatic production modules always perceives which product variant has to be produced. At the first station, a heat-conducting paste is automatically applied by a handling system. The RFID tag is read again and at the next production step, a robot assembles the circuit board. The board is fitted with a heat sink and passed on to another robot. This second robot screws the individual board into place [10, 11]. The installation of RFID chips on the work piece carriers enables them to connect with process data. This allows the technical departments a correlation of process data with the work piece carrier used. Data of every component in the process can be connected with each other, saved and analysed in the Manufacturing Execution System (MES). For every process, the ID of the used tool, the parameters of the process, as well as the ID of the work piece carrier are documented. This way is it possible to analyse data over a period of several months with several thousand produced units and to identify sources of error [10, 12]. For complex manual tasks, workers can be supported by the Bosch Rexroth ActiveAssist workstation. ActiveAssist displays the next necessary process steps via short movies and indicating lights. ActiveAssist can even prevent errors by controlling the correct positioning of a tool or the position of the worker's hand [12]. At the end of the production and assembly line, all electronic elements are checked and the functionality is tested. To diagnose possible failures, all information from the previous production and assembly steps are compared with the outcome of the tests. All data gathered from production, assembly, machines and sensors are presented in nearly real time. Irregular incidents are identified and informed to the employee in charge. He is able to access all data at all times—on the machine, on a shop floor dashboard or alternatively on a tablet or his mobile phone. Maintenance tasks can be carried out directly via the terminals. These data gathering, testing and control processes not only improve the product quality and reduce scrap but also decrease downtimes of the production and assembly components [10, 11].

53.3.2 Toy-Case 2: WÜRTH—Intelligent Bin "iBin"

Würth Industrie Service developed an "intelligent bin" (iBin) for C-Parts, using an optical ordering system, where the quantity, number and ordering information for an item can be obtained at bin level via a built-in camera with image recognition. Several times during the day, a picture is taken and analysed automatically. Image recognition software can derive item quantities in the bin from the picture. If a defined residual quantity is reached, an automatic replenishment order is transmitted to the ERP system, without human intervention. This guarantees transparency of the bin content and an automated triggering for replenishment, regardless of whether the bin is located on a rack or on the production line [41]. The iBin works via a wireless system and can be implemented without changing processes, rack systems and infrastructure.

53.3.3 HERE THE CHAPTER THEN HAS TO BE 53.3.3 Toy-Case 3: SEW EURODRIVE—Mobile Handling Assistant

At the SEW Eurodrive production and assembly plant, mobile assembly assistants act as workbenches and can assist employees with interactive instructions for the assembly sequences. These mobile, autonomous and cooperative assistance systems are also used for various additional tasks and support different working steps such as material logistics, workpiece transport, assembly and joining processes as well as loading and unloading of machines [35]. The mobile handling assistants travel autonomously to the individual workstations and adapt to the work height. The robots are even able to pick random pieces out of a box, using a software (bp3—Bin Picking 3D) developed at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA [18]. The software is capable of localizing the workpieces in a crate and allows them to be picked by a robot. Localization of the items is possible by means of a stereo camera and a specially developed algorithm based on the CAD model of the item. As localization alone is not sufficient for reliable picking of the workpiece, the software additionally features collision-free gripping point determination and path planning. This allows a reliable picking of workpieces even in difficult positions, such as near the bottom of the crate [17].

53.4 Maturity Evaluation

This section evaluates the maturity of the three toy-cases from the perspective of the VDMA toolbox, in order to test its applicability for different current Industry 4.0 applications. In a first step, the toy-cases are categorized in the VDMA table. Then, the “next steps of improvement” according to the VDMA table for each toy-case are evaluated.

The Bosch Rexroth “Industry 4.0 Production Line” is situated in the “production category”. It could be classified as “analysing data for process monitoring” with partial “automatic process planning/control”. Other fitting categories are “use of mobile user interfaces” and “component-driven, flexible production of modular products within the company”. The ActiveAssist features are difficult to classify in the VDMA Toolbox (worker assistance, quality control via recognition of tool and worker position). The man–machine interface could be considered “centralized/decentralized production monitoring/control” as well as “use of mobile user interfaces”. The next evolutionary steps according to the VDMA model would be, for example, “augmented and assisted reality” or “component-driven, modular production in value-adding networks”.

The Wuerth Intelligent Bin “iBin” could be categorized on the “product side” of the VDMA table as a product with “integrated sensors” where the product “independently responds based on the gained data”. “Data and information exchange” are also an "integral part" of the iBin. In these two stages, the iBin already reached the highest possible Industry 4.0 evolutionary stage. So, the VDMA model does not provide a recommendation for next steps. In connectivity terms, the iBin does not access the Internet, but the intranet/ERP System. This connection occurs wireless, not via Ethernet. There is no classification for this in the VDMA model. The category "monitoring" cannot be clearly categorized, as the iBin does not really monitor its own "condition" in terms of "failures", but the quantity of items in the bin. The "production criteria" is hard to apply to the iBin, as it is part of the supply system but not a "machine", where the category "man–machine interface" or "machine-to-machine" communication would fit. If considered a "machine" or part of the "production process", the iBin could be categorized as "automatic process planning/control" as it controls the quantity of the items, as well as "automated information exchange" as it triggers replenishment orders automatically.

The SEW Eurodrive "Mobile Handling Assistant" can be classified on the "production" side of the table. In the category "efficiency with small batches", the maturity stage "component-driven, flexible production of modular products within the company" seems to fit the application. In this category, the next level of maturity would be "component-driven, modular production in value-adding networks". It is not clear, why this next level necessarily would be an improvement and a goal for the company. Several other characteristics of the SEW Eurodrive example are difficult to match in the VDMA Toolbox, for example, the flexible use of the assistant, the intelligent image interpretation with 3D cameras or the automatic height adaption for the worker. The "man–machine interface" could be categorized in "centralized/decentralized production monitoring/control", as the mobile handling assistants autonomously search for their next task and instructions. Why the proposed next stage "use of mobile user interfaces" and "augmented and assisted reality" would necessarily make sense for SEW Eurodrive is not clear.

53.5 Conclusions and Outlook

Only a few years after the introduction of the term "Industry 4.0", both industry and academia are highly interested and invested in the subject. Many companies have started pilot projects in many different areas of Industry 4.0. As the term can be interpreted very broadly and the options to develop applications and use cases for Industry 4.0 are manifold, the emerging of many "maturity/readiness models" to guide companies in the definition of their status quo and the next steps helped companies to get some guidance on their path to become a "leader" in Industry 4.0. Nevertheless, the pure number of different maturity models and their different approaches show that it is still not easy for a company to find the "right path" towards Industry 4.0. The presentation of three different and current applications in German companies showed how different the ideas, products and services in Industry 4.0 can be and that the application of a widely used maturity model, as the VDMA toolbox, is not an easy task and the results and recommendations are not comprehensive. Several technologies and applications cannot be grasped by the current

VDMA model, for example, the use of image capturing/recognition (Wuerth, SEW Eurodrive), the use of videos/projections to support workers and to control quality (Bosch Rexroth), automatic height adjustment to assist workers (SEW Eurodrive) or flexible and autonomous handling assistants (SEW Eurodrive). When applying the VDMA model to current industry examples, it is also not clear, why the "next stage" in each category is necessarily an improvement for customers or the company.

As further research to close this gap between research and industry, we recommend a much more detailed comparison of the many existing maturity models, analysing further its strengths and weaknesses, and a more structured approach in which context to use which model as well as an exemplifications of the models with current (pilot) projects in the manufacturing industry, to test the practical usability. Ideally, the models also should be tested over time, to re-evaluate its results and recommendations after a few years.

Perhaps the most important criteria to define success or failure of Industry 4.0 applications are the ability (in short or long term) to increase turnover and/or to reduce costs for a company. These financial aspects have to be included in an evaluation of technologies and applications in Industry 4.0, as each technical improvement, digitalization or new connectivity should serve one or both of these aims.

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Chapter 54
Influence of the Petroleum Stock on the Stay of Oil Tankers at Onshore Terminals

Pércio Pereira Ferrer, Gustavo Souto dos Santos Diz and Eugenio Kahn Epprecht

Abstract We analyze, through regression analysis, the influence of the petroleum stock (and other variables) on the stay of oil tankers in a large onshore terminal, to support the decision of the total stock to work within a planning cycle, so as to minimize costs for the company.

Keywords Transportation costs · Oil inventory · Multiple regression

54.1 Introduction

The petroleum supply chain involves production, storage in platforms and onshore terminals, transportation to refineries and distribution and commercialization of the refined products (and of crude oil) [3]. Since the storage capacity of offshore platforms is limited, the oil produced needs to be regularly transferred to onshore terminals, from which it is sent by pipelines to the refineries [1]. For an efficient control of this supply chain, the total oil stock should be within specified limits, in order to avoid, on the one hand, lack of oil in the refineries and, on the other hand, excessive inventory costs or even lack of storage space, which would require interrupting the production [5].

Because of natural fluctuations in the volumes of oil produced and refined, adjustments are periodically made in the import and export amounts ordered so as to keep the projected stock within the limits established. Projections are updated weekly and for a 100-day horizon. The target inventory limits are established considering the inventory maintenance costs and the service level specified for the supply of the refineries and offloading of the oil produced in the platforms. We propose, however, that an additional factor should be considered, namely the effect of the inventory

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level in the total cost of maritime transportation. This is the motivation of the present work.

Indeed, part of the transportation costs is due to the stay of tankers at onshore terminals, including the period while the ship waits for docking. Stays longer than the international standard of 36 h bring substantial additional costs [8]. In the company studied, in the year 2017, the idle time of tankers waiting for docking was responsible for total 20% of the cost of oil transportation between platforms and onshore terminals. So, a deeper knowledge of the factors that affect the stay (and excess of stay) of tankers at onshore terminals can help supporting tactical decisions with the aim of reducing such costs.

With this in mind, we pose ourselves the following questions:

- What are the factors that explain the length of stay of tankers at onshore terminals?
- In particular, does the oil stock level affect the length of stay? (in the case of the company studied and its supply chain).
- Would it be possible, through adjustments in the target stock level (i.e., the upper and lower limits), to increase the efficiency of the maritime transportation and have an economy in costs?

To answer these questions, we performed a regression analysis [2, 7], using as independent (response) variable the length of stay. The results confirm our thesis. The analysis and results are detailed in the next sections of this paper.

54.2 Company Context and Data Collected

The company in analysis is a multinational one, operating in over 25 countries. Since its capacities of production and refining are of a same order of magnitude, the company has a flexibility to decide, on financial/economic grounds, based on each month's specific scenario, the amount of oil to be refined and the amount to be exported. Importing crude oil is also possible if necessary in order to meet the refineries' needs to supply the market of refined products. In other words, since the company acts in all stages from the production of crude oil to the distribution of refined products and exportation, it can decide the total inventory target and limits, in order to optimize its operations in an integrated manner, as a whole system. The company's most important oil terminal, used to supply four refineries that represent more than 40% of the country's refining capacity, was chosen for the study.

The data for the analysis were obtained from the company's system, for every day from January 1, 2016, to December 31, 2017, and comprised the following variables:

Dependent variable (unit: ships):

Tankers_waiting: A number of tankers, in day i, waiting for docking at the terminal are studied. The contribution of each tanker for the summation is proportional to the part of the day it waited (a tanker that, in a given day i, waited only half of that day counts as 0.5 for this variable in day i).

Independent variables (all of them in cubic meters and daily):

- **TotalStock**: Available oil stock in all refineries, terminals, platforms and tankers of the company in day *i*;
- **Stock_Term**: Oil stock in the terminal studied in day *i*;
- **Stock_Ref_Term**: Oil stock in the refineries and terminals served by the terminal studied in day i;
- **Production**: Total volume produced (in all platforms of the company) in day *i*;
- **Refining**: Total volume refined in the refineries of the company in day *i*;
- **Sale**: Volume of crude oil sold that was shipped in day *i*;
- **Purchase**: Volume of crude oil bought by the company that was delivered in day *i*.

After collection, the data underwent consistency and validity checks: For instance, operations of tankers that did not carry oil but, for instance, oily water or residuals, were excluded. Also excluded were operations with missing data. This resulted in excluding 137 out of 897 operations of tankers; the analysis was then performed with the remaining 760 operations.

54.3 Analysis of the Data and Final Model

Initially, the correlations between all the variables (dependent and independent) were estimated. The estimated correlation between **TotalStock** and **Tankers waiting** was of 0.61. A correlation of 0.29 was also estimated between **Production** and **Tankers waiting**. The other correlations were much smaller, except between **Stock_Ref_Term** and **Stock_Term** (0.58), and between **Stock_Ref_Term** and **TotalStock** (0.45).

A linear regression model was fitted of the response variable **Tankers_waiting** on all the independent variables. The *p*-value obtained was highly significant: 1.93×10^{-102}. The coefficient of determination was $R^2 = 0.494$. So, looking for a possible better model for the relationship between the independent variables and the number of tankers waiting, transformations were tried, namely the logarithmic transformation and the inverse. They were applied to the response (maintaining the dependent variables untransformed), and next, they were applied to the dependent variables (and maintaining the response untransformed). That is, we applied the regression of the transformed response to the original variables and also the regression of the original response to the transformed variables. There has been no improvement, on the contrary; so the analysis continued with the original variables.

A characteristic feature of the data is that problems in the platforms produce abrupt changes in the production, as problems in terminals prevent tankers from discharging, extending their stay; failures in refineries reduce the processing of crude oil, making the crude oil stock to increase; the concentrated arrival of importations or simultaneous shipping of exportations generates a substantial noise in these variables. The use of smoothed data may therefore result in more precise estimates and a regression model with higher explanatory power. Toward this end, we tried replacing all variables, dependent and independent, by their moving averages. Moving averages of 10, 15, 30, 45 and 60 days were tried. The coefficient of determination increased from 0.494 to (respectively) 0.685, 0.732, 0.770, 0.836, 0.903 and 0.937. However, using moving averages produced a large autocorrelation of the errors, which invalidates the results obtained. Thus, it was decided to use the dynamic regression to model the problem with the averages of 7, 10, 20 and 30 days of the data. The results were evaluated using the parameters: adjusted R^2, mean absolute percentage error (MAPE) and Bayesian information criterion (BIC), and are presented in Table 54.1. All the details can be found in Ferrer [6].

As the best results were obtained with the regression with a mean of 20 days, this was the model chosen. The final model obtained is presented in Eq. (54.1)

$$\hat{y} = 0.381625y_{t-1} + 0.002015x_1 - 0.016553x_2 - 0.001945x_3 - 3.820474 \quad (54.1)$$

where $\hat{y}$ is the estimate of the tankers waiting for docking, y_{t-1} is the number of tankers waiting for docking in the previous period, x_1 is the **TotalStock**, x_2 is the **Refining**, and x_3 is the **Stock_Ref_Term** (x_1, x_2 and x_3 in thousand cubic meters).

The autocorrelation error function (FAC error) of the selected model, presented in Fig. 54.1, shows that the residues do not present serial autocorrelation.

Table 54.1 Dynamic regression results

Dynamic regression made with	Adjusted R^2	MAPE	BIC
7 days average of the data	0.7224	0.3779	0.9002
10 days average of the data	0.6850	0.3960	0.9486
15 days average of the data	0.7893	0.3560	0.7917
20 days average of the data	0.8013	0.3322	0.7726
30 days average of the data	0.7061	0.3451	0.8309

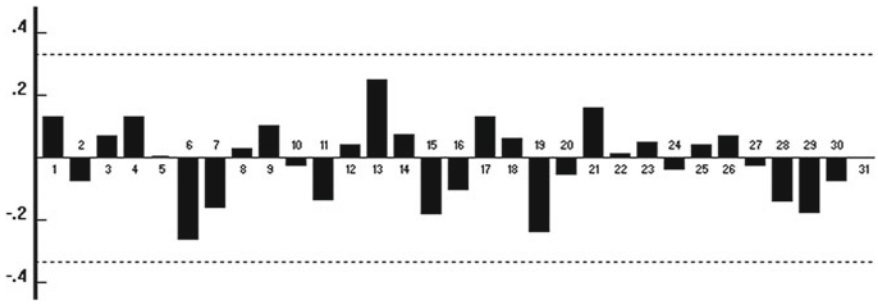

Fig. 54.1 Selected model—autocorrelation error function

54.4 Practical Implications: Use of the Regression Equation and Economy of Costs

It may not be clear for the reader that Eq. (54.1) implies that the planned inventory levels affect the waiting time (or a number of tankers waiting) and not the other way around. The reader might reason that more tankers discharging at the terminal will make the oil stock increase, and that it is the stock level that should be the dependent variable [4]. The answer to this question should consider the real context of the company. Our point is that, even if the production of crude oil in the platforms is continuous, the company is able to decide (on economic grounds) how much to stock, refine, export and import; in fact, the stock levels are planned, and the planned volumes of oil to be stocked, refined, exported and imported are revised dynamically so as to keep the inventory levels within the planned limits. As a consequence, it is possible to take into account the effect of the stock on the excess of stay of tankers (through Eq. 54.1) when optimizing the oil stocks for maximizing the company profit.

For illustration, suppose (hypothetically) a reduction of 500,000 m^3 in the target average stock (variable x_1) (without changes in the other variables); Eq. (54.1) shows that this will reduce $\hat{y}$ (30 days moving an average of the number of tankers waiting per day) in $0.002015 \times 500 = 1.0075$, that is, approximately one unit.

Now, let us compare the cost of excess of stay (SE), given by Eq. (54.2), with the cost of carrying items in inventory (IC), given by Eq. (54.3) [9],

$$\mathrm{SE} = H \times d \tag{54.2}$$

where H is the hire (cost per day) of a ship in the terminal and d is the duration of the stay excess per tanker in days,

$$\mathrm{IC} = i \times V \times S \tag{54.3}$$

where i is the average capital cost rate, V is the value per unit of the item in stock, and S is the average stock.

Considering that $H = 50{,}000$ US$/day, $i = 0.8\%$ per month, $V = 341.23$ US$/m^3, corresponding to 54.25 US$/barrel and the average price of Brent crude oil in 2017 [10], the increase of 500,000 m^3 in S will produce an increase of 1.511 million of dollars per month in the cost of excess of stay and an additional inventory cost of 1.365 million of dollars per month. So, the additional cost of excess of stay is 10.7% larger than the additional inventory cost. This shows the relevance of considering the cost of excess of stay in the planning.

54.5 Conclusions

The analysis confirmed our hypothesis that the crude oil inventory level affects the excess of stay of tankers in onshore terminals. The higher the former, the higher the latter is. The cost of excess of stay is far from negligible: As a matter of fact, the cost of excess of stay produced by an increase in the inventory level is almost 11% higher than the additional inventory cost. We then propose that the cost of excess of stay be considered, as part of the total cost to be minimized when defining the target average inventory level limits. There is a bulk of the literature on the minimization of the transportation costs, but to the best of our knowledge this is the first work to consider the stock levels as a factor for the cost of excess of stay of tankers.

Reducing the target average stock is feasible for the company, because it produces, transports, refines and sells for the internal market its own crude oil and refined products, as well as can export and import crude oil. Adequately setting the inventory level targets may result in an economy of several tenths of millions of dollars per year.

There is opportunity for follow-up research, for refining the model, in particular (although not exclusively) examining in more detail the role of the other variates (independent variables) identified, especially the ones that are moderately correlated with the total stock, and also investigating the possibility of (and/or validity conditions for) generalizing the results and conclusions to other onshore terminals of the company and to oil companies in general.

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Chapter 55
The Broker as a Distribution Channel Model in the Perception of Retail Customers

Antonio José de Sousa Filho, Monalyza Teles Teixeira, Matheus Nogueira Leopoldino and Tonny Kerley de Alencar Rodrigues

Abstract This research aims to investigate the preferences of retail customers related to the Broker distribution system. The results demonstrated the delivery time and customer response time as variables that influence the most in the customers' preference for the Broker in comparison with the other types of distribution channels.

Keywords Broker · Supply chain · Distribution channels · Retail customers

55.1 Introduction

Industry in general has sought to invest increasingly in alternative distribution channels to those traditionally used in the past years. These alternative logistics service providers are identified as entities outside the company, mainly focused on the industry logistics operation, establishing a strategic partnership to reduce the logistics costs and increase market reach levels [23]. An example of the strategy adopted by several business segments is the formation of a partnership with the Broker distributor, defined as an alternative distribution channel which operates as an extension of the industry [8]. In this sense, Broker is responsible not only for providing distribution services but also for the sale of products, advice on merchandising in the stores and even collection of debts from its retail customers [2, 8, 23].

Based on these premises, it is realized that insertion of the Broker in the supply chain as an intermediary agent between the industry and the retail requires an effective integration among the stakeholders involved in this process. Thus, it is fundamental that directors and managers, both the Broker's and the supplier's that contracts it, are constantly concerned with the information flow management, considered fundamental to the level of performance of organizational processes [8]. Based on the

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perception of retail customers, what aspects does the Broker distribution system have that could be applied in the other categories of distribution channels? As an attempt to solve this problem, this research aims to investigate the preferences of retail customers related to the Broker distribution system compared to traditional distribution channels.

55.2 Theoretical Base

The competitiveness of the current economic scenario requires that organizations are progressively focused on the search for new strategies that distinguish them from other competitors. Among the innumerable strategies developed by company managers, the ones related to supply chain management (SCM) stand out. In fact, the competitive advantages provided by the SCM are characterized as unique, since they are integrated into the planning and management of all the activities carried out in the company [11, 12]. All this significance attributed to SCM arises from its purpose of managing an interconnected network of companies. In this way, the results are not restricted to those achieved by a unilateral effort, but by an effort that involves all the stakeholders that are part of the chain. Based on the proposed concepts SCM and the need for an efficient flow of operations, information technologies become fundamental to ensure better integration between processes by allowing the sharing of information along the supply chain [7, 9, 12].

There are several concepts that help define the term distribution channel, among which the following stand out: the flow of a product, from its production to consumption; transfer of ownership of goods between producers, intermediaries and final consumers; or the alliance of companies to carry out exchanges [6, 5]. Taking into account the evolution of these concepts over time and from more recent theoretical descriptions, it is possible to define a distribution channel as an organized network/system, composed of intermediary agents, which are responsible for providing a link between manufacturers and final consumers, ensuring the availability of the goods under the most favorable conditions possible [18, 5].

Traditional distribution channels have lost market space for alternative distribution modes such as agent Brokers. This agent is a provider of the logistics services or entities outside the supplier/producer, which establishes strategic partnerships in view of the greatest possible market reach, combined with the reduction of costs of the logistics operation. By following the trends of outsourcing or forming strategic partnerships, the industry delegates attributions to these agents while directing their efforts and resources to production activities and the process of developing new products [19].

Broker agent, in general, can be considered an institution, contracted by the manufacturers as a form of sales forces outsourcing, defined as a logistic and sales operator. Thus, this alternative channel operates as an extension of the industry, not only accompanying its distribution services, but also performing product sales, warehousing, delivery, merchandising advice at retail and wholesale points of sale, collection and post-sale, however, without assuming ownership of the marketed merchandise [4, 19]. From these conceptualizations, it is perceptible Broker's insertion in the supply chain, as a sales agent, through which the free market system performs the transfer of ownership of products. Therefore, it required the existence of an integration among all the supply chain components. Thus, it is extremely relevant, in this stakeholder integration process, that there is an effective flow of information to increase the logistics system performance, which directly influences the other activities developed by the Broker [3, 4, 13, 17, 25].

55.3 Method

The present research was constructed from field research and participant, having as instrument of data collection a script of semi-structured interview. The script was not intended to obtain simple and predictable answers, but to understand the participants' perception related to the Broker distribution. In addition, it was applied with the main criterion of inclusion of the participants in the research: to be a retail client of the distribution channel Broker.

The research was developed in the Broker's customer service department in Teresina, PI, during the period from June to August 2018. The research was based on a qualitative approach in the collection and analysis of data aiming to investigate the preferences of retail clients related to the Broker distribution system compared to traditional distribution channels.

As for the technical procedures, the literature review technique was carried out. The purpose was to find theoretical and epistemological support regarding works related to the theme [18]. This bibliographical research sought a general overview of materials which had already received analytical treatment on the main books of classical authors of the area and articles of quality journals (high Qualis/Capes or impact factor), preferably researches of the last five years; however, we also used those from previous years because they were studies with reference to the research area.

Still on the field survey, the interviews collected (25) contained information related to the provision of services by the Broker to the companies' retail clients. However, the interviews select (16) only contained information that is related to the distribution system performed by the distributor agent under the retail vision, as described in Table 55.1.

55.4 Results and Discussion

Based on the a priori category selection and the content of the internal management documents, the analysis was divided into three topics related to the Broker's delivery conditions, which proved to be important contributions to the study objective:

Table 55.1 Performance profiles of retail customers

Retail channel	Number collected	Number of orders June/August 2018 (average)	Preference for DC Broker
Pharmacy	05 channels	04 orders	03 channels
Grocery store	10 channels	12 orders	06 channels
Bakery	03 channels	25 orders	02 channels
Snack bar	03 channels	18 orders	02 channels
Pet shop	04 channels	18 orders	03 channels
Subtotal	25 channels	15 orders	16 channels

fulfillment of the order delivery period by the Broker; conformity of the products ordered; and frequency of visits as loyalty process.

One of the first free associations that emerged from the analysis of interviews collected to evaluate the Broker distribution system by the retail customers was related to the waiting time between the order and the arrival of the products at the store. As in some theoretical contribution findings, the "time preference" was defined as a fundamental variable for retail satisfaction due to the fact that the delivery of goods delays implies a lack of the inventory level control, directly reflecting in the availability and, consequently, in the sales of products at the sales point [1, 22, 5].

In this context, the concept of commodity availability emerges, which is achieved through an efficient inventory management. Thereunto, it is extremely necessary to have an efficient demand planning for goods and an excellent programming of purchases to carefully follow the procedure in order to ensure that the products are always available to the final consumer [21]. Since there are delays in the products purchased and delivery by the retailer–supplier, their merchandise management in stock is impaired, implying the lack of products on the sales shelves, resulting in the reduction of products marketed by retailers.

Based on the data collected and considering the concept of customer *lead time*, which, in general, can be determined from the measurement time from the product request to its delivery, the waiting time is one of the variables that impact the most on customer satisfaction levels described [24]. This is basically because the longer it takes to reach the retail outlet, the greater the likelihood that there will be no availability of products to the final consumer, causing retailer dissatisfaction, and may even induce them to buy the same products with other suppliers in competing distribution channels, according to the information in Table 55.2.

Conformity of the products was another preference found in the survey findings, in which dissatisfactions related to the divergent goods were declared regarding both the mix of products and the quantity requested in the order by the retail public. Thus, the Broker was given the responsibility for the additions and substitutions of products during the marketing and delivery processes, causing retail dissatisfaction when the products arrive at the points of sale.

Table 55.2 Customer profile (grocery store B)

Channel	Frequency of care	Is there timely delivery?	Do you want to place the order?	Do you have any complaints/suggestions?	Comments
Grocery B	Biweekly	No	No	Yes	The customer complains about the implications of delays in sales. He/she also says that in these cases, he/she buys the same products with competition regardless of the price offered

However, taking into account the Broker's marketing process, it is known that the responsibility for generating and finalizing the order in the specialized system and, concurrently, inclusion of the products in the order is attributed to the commercial representative, whose activity of typing of requested goods by the customer requires attention and caution in order to avoid non-compliance with requests and future problems stemming from the retail public dissatisfaction. In this way, the Broker management is the more detailed follow-up of occurrences of this nature directly with the sellers inserted in that context to avoid customer frustrations (Table 55.3).

For the satisfaction of any client, it is ideal that could offer products according to the real needs [22]. That is to say, when the products arrive at the point of sale, it must comply with the requested quantity, price and characterization of the order. In case of nonconformities related to the order, the customer has the total right to not accept the merchandise, causing damages to both the retail and the distributor. This is what happens in cases of orders arriving at the point of sale with prices different from the one informed after the order is entered by the seller, implying the indicators of return (KPIs) for nonconformities of the products (Table 55.4).

Based on these statements, it is perceived that the relationship between the product preferences directly implies the return order indicators made by Broker's customers. This is due to the fact that, when they receive their orders, retail customers, when they perceive differences in the ordered products with the delivered orders, have the total right to not accept the merchandise and return it to the distributor. These factors

Table 55.3 The customer reports about the disagreement of arrived products with those requested in the order with the seller and claims that products come in excess of what is requested

Channel	Frequency of care	Is there timely delivery?	Do you want to place the order?	Do you have any complaints/suggestions?	Comments
Pet shop C	Biweekly	No	No	Yes	The customer reports about products that arrive in disagreement with those requested in the order with the seller and claims that products come in excess of what is requested

Table 55.4 The customer complains about the divergence of the products requested with the products that arrive at the establishment and also states that when this happens, he/she never accepts the merchandise

Channel	Frequency of care	Is there timely delivery?	Do you want to place the order?	Do you have any complaints/suggestions?	Comments
Snack bar B	Biweekly	Yes	No	Yes	The customer complains about the divergence of the products requested with the products that arrive at the establishment and also states that when this happens, he/she never accepts it

Table 55.5 The customer complains about the absence of the seller at the points of sale. He/she affirms that buys in the rival provider because the seller does not give adequate support

Channel	Frequency of care	Is there timely delivery?	Do you want to place the order?	Do you have any complaints/suggestions?	Comments
Pet shop A	Weekly	Yes	No	Yes	The customer complains about the absence of the seller at the points of sale. He/she affirms that because the seller does not give adequate support

also imply buying retail customers from competing suppliers once they return the merchandise and need the products in stock.

Another factor of fundamental importance for the satisfaction of retail customers was related to the frequency of the visits of the sales representative at the point of sale. It was declared that the visits at the points of sale by sellers should always happen because there are daily emergencies that must be resolved (Table 55.5).

The frequency of visits is defined based on the needs of each customer, and this service from the seller directly to the point of sale, as well as serving as a support for customers, is also a way of maintaining a close relationship between the distributor and the retailer. This customer loyalty can be characterized as a gradual process and requires frequent monitoring and attention to their needs [5, 22]. In order to be loyal to retail customers, it is necessary for the sales representative to offer service whenever necessary and for this purpose weekly or biweekly routines of direct visits are made to the retail customer, so that this becomes a loyal buyer. In cases of non-visits, the seller opens up loopholes for the customer to buy products with competing distributors, causing billing losses to the Broker.

55.5 Conclusion

Based on the bibliographical and field research and analysis of the data collected, through a semi-structured interview script, the research aimed to investigate the preferences of retail clients related to the Broker distribution system in comparison with the traditional distribution channels. From this investigation, one can understand the factors that influence the most in the retail customers' satisfaction and what makes Broker a channel of distribution differentiated from the others. The identified variables allow retail customer satisfaction levels to be established, the factors that most influence the loyalty process.

The identified variables allow retail customer satisfaction levels to be established and the factors that influence the loyalty process the most. By analyzing the product waiting time influence, it is possible to notice that the Broker differentiates itself from its competitors because it excludes more bureaucratic processes from its system, focusing its responsibilities only on the distribution of products and reducing the delivery time as a consequence. Still, waiting time directly interferes with order invoicing, since delivery delays induce customers to purchase the same products from other vendors in competing distribution channels because of the unavailability of products in stock.

The aspects related to the representative attendance, regarding both the reliability of information and the frequency of attendance to the stores, reflect not only the satisfaction but also the number of orders made by retail and in the indicators of return of orders. In spite of the shortcomings in the quality of service, Broker stands out for the fact that its main activities are focused on improving the services of the representative to the clients, through constant training and establishment of visit routines that must be fulfilled and evaluated. However, when these two preferences are not met, the retailer is dissatisfied with the Broker service, implying in returns of goods and purchase of the same products in competing channels regardless of the price.

It is expected that the results of this model, coupled with the peculiarities of the distribution system that surrounds the Broker supply chain, will ensure new theoretical contributions from this research. To reach the expectations, starting from this initial part of a more detailed study about the preferences of the retail clients with respect to the Broker distribution system, it is suggested for future studies both qualitative and quantitative that the information of other channels can be investigated, for example attacked or whole retail for comparisons of the findings. In addition, the research can be focused on the quantitative implications of the preferences found in the billing and key performance indicators (KPIs), making a more in-depth analysis of the costs involved in choosing between the different distribution channels.

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Chapter 56
Using Lean Six Sigma for the Optimization of Inventory Management—A Case of a Lubricating Oil Factory

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Abstract This paper presents a Lean Six Sigma (LSS) application in a lubricating oil factory to reduce the excessive inventory of an additive. This was achieved through implementing a periodic review policy and of the DMAIC methodological approach used to decrease the lead time and consequently the safety stock.

Keywords Lean Six Sigma (LSS) · Inventory management · DMAIC

56.1 Introduction

Waste generates unnecessary costs, which are represented by efforts or initiatives that do not add value to the product or service, i.e., which the client does not recognize as activities that should be paid for [11]. In this context, for Ohno [8] the lean manufacturing philosophy refers exactly to the elimination of waste and unnecessary elements to reduce costs, and it focuses on the production of what is needed at the right time and in the required quantity. It means that lean production is a management philosophy based on the elimination of non-value-added (NVA) activities [16]. For Kaushik and Kumar [5, p. 145], "Six Sigma is the concept of improving the quality by reducing process variations, making continuous improvements, reducing defect rates and improving the processes. Initially, the concept of Six Sigma focused on defect reduction, cost reduction and value addition. Fundamentally, the basic idea of Six Sigma is to improve the process-capability and making the process more reliable along with reducing wastes within industries. Evaluation the implication of applying Six Sigma over the small and medium-sized enterprises is the main purpose of this research work taking a particular case of automobile industries".

Traditionally, Lean and Six Sigma (LSS) are implemented separately, but recently the two theories have being deployed together by some organizations; this new

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integrated approach is called Lean Six Sigma [18]. Tohidi and Liraviasl [15] state that the methodology combines two improvement trends: working better (using Six Sigma) and working faster (using lean manufacturing). According to Supriyanto and Maftuhah [14, p. 498] "LSS is an approach that has been proven and applied in many on manufacturing floors. Initiated in the automotive industry, continuous improvement was implemented to improve the manufacturing process change."

Shokri [12] conducted a survey in the literature of the last two decades around three practices of business improvement, Lean, Six Sigma and Lean Six Sigma (LSS). In all papers with a focus on the supply chain and logistics, only 12% used LSS, while the most used were Lean (54%) and Six Sigma (34%), showing the opportunity of new studies with this new method of improvement.

The reduction of production lead time and the decrease work in process inventory are the benefits of the LSS methodology [14, p. 498]. Inventory management has a significant role in Supply Chain and your optimization, can help to reduce costs and permit a considerably improve the performance indicators of the organization [1, p. 221].

The objective of this paper is to reduce the excessive inventory of an input, called AI AP, at the company, a lubricating oil producer in Brazil. This paper is structured in five sections: Sect. 56.1 presents the introduction, Sect. 56.2 presents a literature review, Sect. 56.3 provides the methodology overview, Sect. 56.4 gives the results and discussion, and finally, Sect. 56.5 provides the conclusions and future research.

Based on the general objective of this work, a secondary objective was defined: How does the first gap in the supply chain (time to receive the additive) influence the receipt lead time and the safety stock. It should be noted that the item AI AP was chosen as the object of study and the company as the unit of analysis. In addition, it was the position of the AI AP item on the ABC curve of the average closing inventory during the period from May 2016 to April 2017, which led to its choice.

56.2 Literature Review

The Toyota Production System focuses mainly on the identification and subsequent elimination of waste to reduce costs, increase quality and speed up the delivery of products to customers. One of the elements of the Six Sigma infrastructure is the establishment of teams to execute projects that contribute strongly to the achievement of the company's strategic goals [17]. The development of these projects is carried out based on a method called Define, Measure, Analyze, Improve and Control (DMAIC). Werkema [17] defines the five steps of the DMAIC method as: definition, or accurately defining the scope of the project; measurement, or determining the location or focus of the problem; analysis, or determining the causes of each priority problem; improvement, or proposing, evaluating and implementing solutions to each priority problem; and control, or ensuring that the achievement of the goal is maintained in the long term.

After the definition step, a value stream map (VSM) is used, which, according to Supriyanto and Maftuhah [14, p. 498], is one of the lean tools used to recognize and to reveal problem lean, such as the sources of waste and find the hidden waste. VSM describes all activities of the process, both value-added and non-value-added activity. In the measurement step, on the other hand, the ABC analysis is a prioritization tool based on the Pareto principle that can be used by different processes and systems. ABC analysis is one of the techniques used comprehensively in manufacturing industries for inventory classification. The ABC inventory classification technique has an efficient control on a huge amount of inventory items. The ABC inventory classification approach categorizes inventory items as A, B and C classes according to their annual consumption value to direct and control the inventory items more proficiently [10]. A typical ABC classification of inventory items has a configuration in which 20% of the items are considered A, and these correspond to 65% of the value of demand or annual consumption, which is the focus of this work.

In the improvement step, the inventory is the focus. This logistics activity plays an important role to enhance the efficiency and competitiveness among manufacturing industries [6]. Maintaining appropriate inventory levels has been an essential task for a firm since high inventory levels and increases the responsiveness to customers while increasing the cost, whereas low inventory levels might cause shortages, which consequently impairs the firm's reputation [3, p. 979]. Ballou [2] classifies the sales-forecast-based inventory policy as a push inventory control system, and he adds that this approach is reasonable for inventory control.

The same author divides the inventory control classification into two different types: push inventory control and pull inventory control systems. Ballou [2] states that pull systems result in reduced inventory levels at points of storage because they react to demand conditions and specific costs. To ensure the premise of the company's strategy regarding customer service, the same author points to the advanced pull inventory control system as an alternative. In these cases, there is a need to maintain an inventory—even if at a low level—to meet demand fluctuations, the so-called buffer stock.

Puchkova et al. [9] assume that a hybrid push–pull strategy can mitigate the risks and improve the robustness of the push–pull strategy. The location and number of pulling points are optimized using a mixed integer programming model with cost minimization objective function.

According to Silver et al. [13], the stock control policy depends on how often it determines the review interval, which can be between two types, the continuous review method that the stock quantity is always known and the periodic review method that the stock is known only after a time interval of R units. According to the same author, the main advantages related to the existence of an inventory are the improvement in the level of service offered to the customer and a reduction of the process costs.

According to Montgomery [7], the analysis of the results of the Cp and Cpk indicators is the key points for the analysis of the process' capability in the improvement phase. After finishing the solution implementation step for the identified problem in the improvement phase, the next step of the DMAIC method is to control these improvements in the day-to-day life of the system. Werkema [17] refers to the control step as the application of the proposed solution in the large-scale implementation phase, the control of the process' performance over time and the standardization of changes made in the process with the adoption of the proposed solutions.

56.3 Methodology Overview

The method chosen for the study was the case study because of the intention of preserving the unitary character of the object under study, i.e., a description of a situation in the context in which a certain investigation and formulation of hypotheses are being made [4]. The qualitative–quantitative research approach was used. A bibliographic research was employed for the literature review, and documentary research was used for the data that gave rise to the results. Direct observation was used as a data collection technique since no interviews were carried out to collect the data.

Based on this data collection step, time and contact measurements were used by the people involved in the development of the value stream map of the most sold products by the company, in terms of historical sales volume and revenue. The next step was the identification of the existing gaps during the process, and based on the work of Werkema [17], the DMAIC methodology was applied in the development of the projects in the company's area under study in order to reduce the input inventories. Based on the collected samples, it was possible to obtain sufficient data to make use of the Minitab software. One of the main functions of this software is to evaluate the stability and the capability of a particular process. Based on the analysis collected through the Minitab results, the main points of impact in relation to the time of receipt of the input were identified. To this end, the total time of the receipt process was divided into subgroups of activities, which were associated with their respective times, reducing the time of receipt, which would lead to a reduction in inventory.

56.4 Results and Discussion

The company chosen for the case study is one of the largest producers and suppliers of lubricating oil in Brazil. The company counts with just a single industrial plant, located in Rio de Janeiro, which is responsible for servicing the average demand of 18 million l per month throughout Brazil. This case study seeks to address one of the biggest problems currently facing the plant: a large quantity of stored raw material. The inventory policy adopted by the company has been the same for nine years and has remained this way because of concerns regarding the cost associated with the productive capacity.

The process was investigated based on Werkema's [17] Define, Measure, Analyze, Improve and Control (DMAIC) methodology and its stages. The productive process was defined in the definition step and would serve as a foundation for the study—and subsequent steps of this process were then addressed (scope of the project). Two criteria defined by the company were considered as key points of the business: the financial impact to the company if the product was out of stock and the sales volume of the product.

After defining the specific product to be analyzed, a value stream map (VSM) was used as a tool to map and understand the fluidity of the process and to identify the flow of material and information in the system. It was then decided to start prioritizing the gaps related to the inventory of the supply chain and, subsequently, to give continuity to the other gaps, since no other project on this subject had ever been raised by the company's project department. For this reason, this study will be focused on eliminating the first gap concerning inventories identified in the VSM, the excessive inventory of raw materials, in particular of packaged additives.

When analyzing the total inventory of additives in November 2016 in the measurement step, it was found that the volume at closing was equal to 967 tonnes, which could be divided between packaged additives (570 tonnes) and additives in bulk (397 tonnes). The first number (570 tonnes) includes 138 SKUs of additives, where 95% of these items are national packaged additives and 5% are imported packaged additives. When assessing the volume of each type of packaged additive at the closing of the inventory as well as the involved cost, it was found that national packaged additives had a share of 73% and imported packaged additives 23%, for a total of R$11,755,667.00.

The chosen item AI AP had the largest share of the additive iStock for the month of November/2016 and is the main input, in percentage terms, used in the manufacturing process of company. Furthermore, another point that reaffirmed the choice for AI AP as the pilot additive in this case study was its position on the ABC curve of the average closing inventory during the period from May 2016 to April 2017, as can be seen in Fig. 56.1.

At the analysis stage, it is important to reflect on what has been measured previously and to identify the causes that contribute to the low performance of the pro-

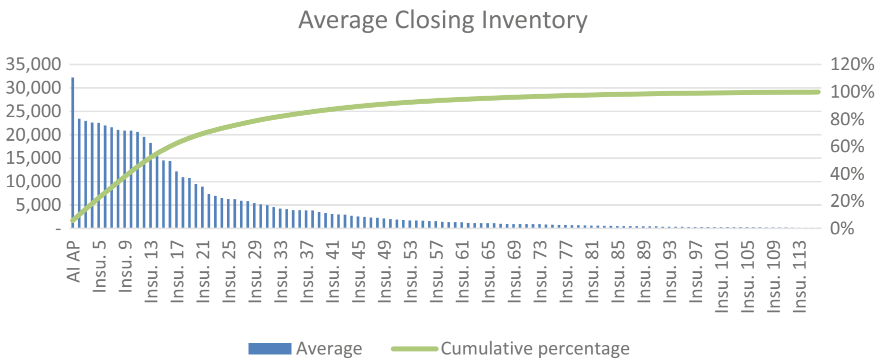

Fig. 56.1 Average closing of the monthly stock from May 2016 to April 2017 in kilograms

cess. The average closing inventory during the period from May/2016 to April/2017 was 32,217 kg, a value that exceeded the buffer stock informed by the company (24,000 kg). The causes of this excessive inventory were analyzed with the Ishikawa diagram tool, and after this data was surveyed, the five whys tool was used. One of the root causes found was the lack of update of the adopted inventory calculation policy.

Currently, the company bases its inventory policy on sales forecasting. The packaged additive inventory is seized by the company with the following inputs: the sales forecast for the following month, the available inventory of the previous month (information passed through the closing inventory indicator) and the buffer stock (defined as 15 days of average daily consumption for national products and 60 days of average daily consumption for imported products). With this information provided by the company, a survey could be conducted of the average quantity in stock for a given input throughout the month. This metric is important because it allows you to calculate the total cost of inventory or opportunity cost, as can be seen in Fig. 56.2.

As such, the average stock for the period under analysis was 61,379 kg. With this information, it is possible to calculate the cost of the inventory during the observed period, which is equal to the average inventory multiplied by the cost per kilogram of AI AP (R$24.58). The value of the inventory in the period from May/2016 to April/2017 was equal to R$1,508,679.99.

In the improvement phase, it is important that the improvements to the gaps that were identified in the system are implemented. According to Ballou's [2] classification, the company has a policy based on push inventory control to ensure coverage of the variations in demand through its prediction.

In this case study and taking some constraints and priorities of the company into consideration, the periodic review method was found to be more adaptable to the already existing internal structures, especially because of the reduced number of employees and the frequency of control of the item's inventory, as can be seen in

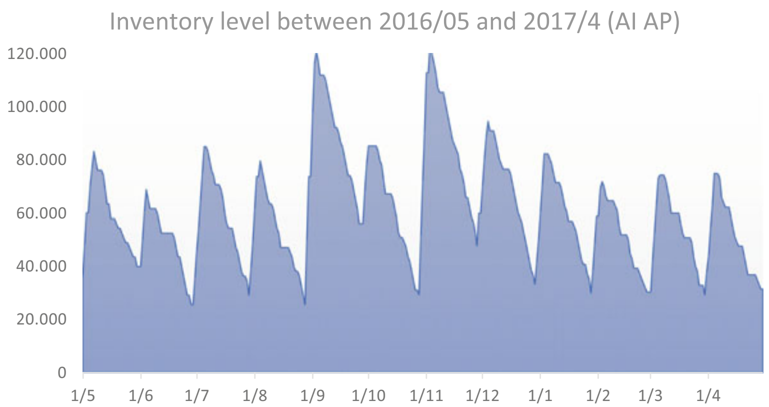

Fig. 56.2 Amount of AI AP inventory daily during the period from May 2016 to April 2017

Ballou [2]. The necessary variables were then calculated based on the collected data (Table 56.1) to model the inventory control, according to the periodic review model (Table 56.2).

According to the collected information, the inventory of the AI AP input was 20,665 kg, which would be equal to an inventory cost of R$507,945.70, considering the cost per kilogram of AI AP (R$24.58). The cost reduction in the inventory in the current conditions of the company when compared to the cost of the proposed inventory of this case study would be R$1,000,734.29.

In addition to the gains observed through the changes in relation to the use of the adequate inventory policy, other improvements can also be deployed to ensure that there is an even greater reduction in the inventory cost. The internal variable that directly influences the calculation of the safety stock is the input receipt lead time, which is related to the total time since the entry of the delivery truck at the factory to the moment of entry of the input in the system.

By looking at the times of entry of the trucks in the factory and the time when the inputs were available in the system, it was possible to take a sample of 44 AI AP unloadings that occurred over the period of May/2016 and April/2017. Based on the collected samples, it was possible to obtain sufficient data to make use of the Minitab software. One of the main functions of this software is to evaluate the stability and

Table 56.1 Data for the AI AP input for the periodic review model

Case study data	Value
Demand (D): Average daily demand from May 2016 to April 2017	2092 kg
Procurement cost per order (S)	R$1256.00
Inventory cost (IC): $I = 25\%$ per year and $C =$ R$24.58	R$0.02 per day
Lead time (LT): Cycle time of supplier (3 days) more receiving time in facility (1.1 day)	4.1 days
Standard deviation of demand (SD)	1724.58 kg
Probability (P) of no stock-out per replenishment	98%

Table 56.2 Results of the periodic review model

Replenishment policy	Formula	Value
Economic order	$Q = \sqrt{2DS/IC}$	$Q = 16{,}210$ kg
Order interval	$T = Q/D$	$T = 8$ days
Demand during lead time plus cycle time	$s'_d = s_d\sqrt{LT + T}$	$s'_d = 5999$ kg
Maximum level	$M^* = d(T + LT) + z(s'_d)$	$M^* = 37{,}611$ kg
Average level	$AIL = (dT^*/2) + z(s'_d)$	AIL = 20,665 kg

the capability of a particular process, as can be seen in Fig. 56.3, which shows the process analysis graphs.

Based on Montgomery [7], the value assessed in this case study was less than 1.33 for both indicators, which indicates an incapability of the process; i.e., the process needs improvements in the common causes so the average and the variations are reduced so as to make the process capability.

Based on these data, the times of each input receipt activity and its major gaps were gathered, totaling an average of 1.10 days. As such, some improvements were proposed, such as the creation of a responsibility matrix for the invoice clerks, a change in the physical location of the invoice clerk receiving the input invoices to avoid unnecessary movements, the collection of samples performed by the supplier, among others. After the implementation of the suggested changes, the average time of the process should in theory be reduced to 6 h and 42 min (0.257 days).

Considering the new time of receipt, a new value for the variable lead time is obtained (3.257 days) in the periodic inventory review model. Under these conditions, the inventory of the AI AP input would be 20,225.75 kg, which would be equal to an inventory cost of R$497,148.94.

In the control stage, as seen in the review by Werkema [17], it is important to ensure the control of the proposed solutions and the performance of these solutions. For this last stage of the DMAIC tool, actions were proposed to ensure the control of

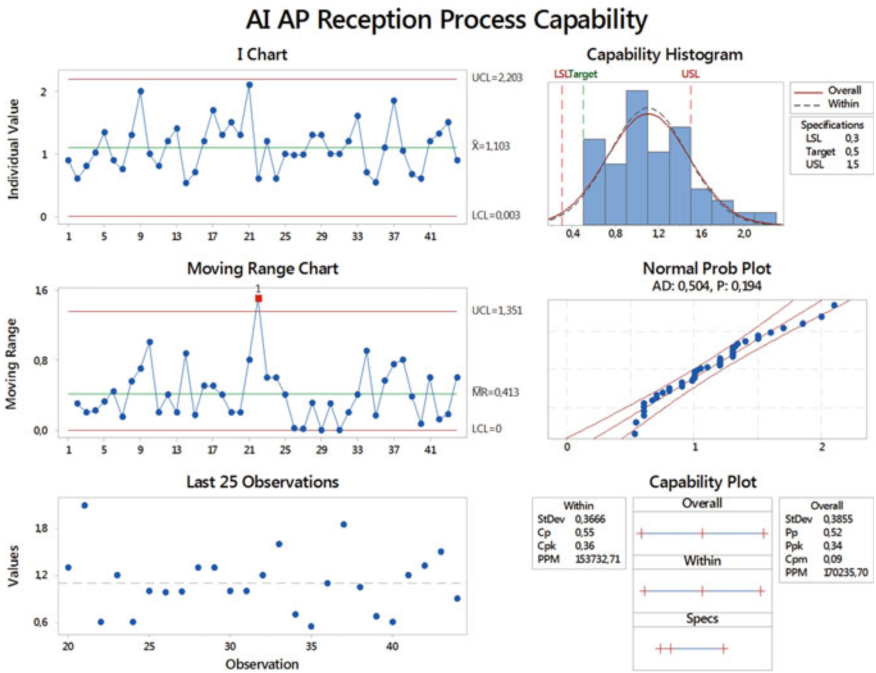

Fig. 56.3 Capability and stability report of the AI AP receipt process

the implemented process: deployment of an action plan for the implementation of the proposed activities; documentation of the new system employed; training to those involved in the new system; monitoring of the system through indicators; expansion of knowledge to the other relevant departments; and celebration of the achievements.

56.5 Conclusions and Future Research

There are two panoramas regarding the financial results of this case study. The current situation has an inventory policy based on sales forecasting, push inventory, the calculation of inventories based on strategic sales targets, an input receipt process lead time of 4.1 days, 100% of service to production, an average inventory during the analyzed period of 61.379 kg and a capital linked to the inventory of R$1,508,679.99. The proposed situation has an inventory policy based on the periodic review method, pull inventory, the calculation of inventories based on the consumption of the internal customer (production), an input receipt process lead time of 3.257 days, 100% of service to production, an average inventory during the analyzed period of 20,225.75 kg and a capital linked to the inventory of R$497,148.94. The expected reduction of capital employed with the inventory, considering only the implementation of this case study for the input AI AP, is of R$1,011,531.05 per year.

In addition to the financial gains involved in the results, other gains can be made that are not accounted for in a quantitative manner, but which should be taken into consideration, such as: satisfaction of the billing employees, who now have defined priorities and responsibilities; satisfaction of suppliers with the reduced input unloading time; satisfaction of operators for not having space problems to store the inputs and for having greater ease in finding an input in inventory to send to production; reduction of the risk of accidents because of the reduction of material inside the building as well as less handling by forklifts and operators.

The LSS methodology used for the reduction of waste and to generate greater profits is therefore corroborated by this study. The lean production concept and the tools used to generate this change of attitude in production are also suited for lean inventories.

The reductions in the inventory levels can generate some financially advantageous situations in the current time of crisis experienced by Brazil. The reduction in capital makes room for investment in other more profitable businesses for the company. In addition, it is important to emphasize that no significant investments are required for the proposed improvements and that the problems can often be solved by studies and changes in the flow of activities alone. The idea is to seek improvements and new adaptations and not to stick to a flow just because it has been carried out in the same way for a long time.

Suggestions for future work include: inventory management/policy and the Lean Six Sigma methodology. Regarding the inventory management/policy subject, it is important to highlight that there are other ways to manage inventories. Regarding LSS, this case study is restricted to waste and the variations related to the inventory level criticized by the methodology, but there are other types of waste and other changes relating to other logistics processes or other industrial processes that can be studied and attacked.

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Chapter 57
SCM Evolution: A Bibliometric Study on the Past 3 Decades

J. M. Benedetto

Abstract Supply Chain Management is a thriving research arena, with 9525 articles in WoS. A bibliometric approach was used to understand the evolution of the main research streams as an update of Charvet et al. (J Bus Logistics 29(1):47–73, 2008 [1]) work. Six streams have been identified, with late entrant Green SC reclaiming the biggest share.

Keywords Supply Chain Management · Bibliometric study · SCM

57.1 Introduction

Supply Chain Management is on a long journey to become a discipline within its own right. Harland et al. [2] concluded it to be an emergent discipline back in 2006, and more recently, Stentoft and Rajkumar [11] called it a young discipline.

Discipline or not, the field attracts much attention from researchers. A search for the term “Supply Chain Management” on the Web of Science website found 9525 published articles, between 1945 and 2018. The growth on publications has been steady since 1990, with a peak in recent years. The year 2017 only saw 1147 published articles.

Charvet et al. [1] studied SCM evolution in 2008 through a bibliometric study. Their research was based on co-citation analysis and sought to map the intellectual structure of the field. The bibliometric approach is mainly quantitative, reading trends on the number of published papers and the relation between papers, authors and journals.

Following the lead of Charvet et al. [1] to try and make sense of this exciting and always expanding body of knowledge, this paper performs another bibliometric study on the topic. My intent is to contribute with a snapshot of the field development enabling comparisons between similar studies. Despite the choice of a direct citation

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network analysis instead of a co-citation analysis, the method followed here was quite similar to Charvet et al. [1].

I also borrowed two of the four Charvet et al. [1] research questions to drive this new study: what are the Journals that publish SCM papers; can one identify major stream of research within the SCM literature?

This paper is organized as follows: Sect. 57.2 describes the data collection and preparation phases. Section 57.3 presents the analysis and compares it against the results from Charvet et al. [1]. Finally, the paper ends with a conclusion session, which includes a discussion on its limitations and possible pathways.

57.2 Data Collection and Preparation

Articles search was based on the term "Supply Chain Management" in WoS. Title, abstract, authors' keywords and keywords plus have been searched, limited to academic articles but not on the publications' year. This query resulted in 9525 articles.

Data preparation was performed in two steps. The first step consisted of building the direct citation network in CitNetExplorer, which included clustering. The second step went about organizing the bibliometric data on a format that could be more easily consumed by Tableau (the data visualization software of choice), using Data Science Studio, from Dataiku.

As this work does not intend to identify micro-tendencies or micro-streams of though, isolated articles should not be a central concern. To focus on the more prominent work, I used the core publications feature from CitNetExplorer. From van Eck and Waltman [12], "a core publication is defined as a publication that has at least a certain minimum number of citation relations with other core publications." More information on the mathematical base (K-cores) can be found on Seidman [10]. Applying the feature with a parameter of ten (at least ten citations between core publications), a group of 2248 core publications was identified.

The software uses two dimensions to locate articles within the citation network: time (vertical axis) and closeness (horizontal axis). Lines represent citations and go always downstream. The time dimension is self-explanatory: articles are positioned based on their year of publication. The closeness dimension is a bit harder to calculate. From van Eck and Waltman [12], "essentially the closeness of publications i and j equals the probability that a random walk starting from publication i will end at publication j." So, publications that share many direct or indirect links are closer than the ones that do not. The exact formulae can be found in van Eck and Waltman [12].

This new network was passed through the clustering algorithm offered by CitNetExplorer. The algorithm is a variant of the modularity function proposed by Newman and Girvan [8] and Newman [7] (apud van Eck and Waltman [12]). More details about it can be found at Waltman and van Eck [13] (apud van Eck and Waltman [12]). As our interest is with the big research themes inside SCM, clusters with less than 100 articles have been merged with another cluster. Six stable clusters were identified.

CitNetExplorer enriched the article data with the group or cluster number. This data went to the second preparation step in Data Science Studio from Dataiku. With that, data was finally ready for analysis using Tableau.

57.3 Analysis and Results

As one of my goals for this research paper was to understand how SCM evolved through time, whenever possible a comparison with Charvet et al. [1] findings has been drawn.

57.3.1 A view from the entire pool of articles

The field growth is quite impressive and shows no hint of decline (Fig. 57.1). The trend had already been identified by Charvet et al. [1], as one can see when comparing both analyses (Fig. 57.2).

Articles were spread throughout 1297 different journals, but the concentration is high. Twenty-three journals have published 50% of all articles (Fig. 57.3). As with Charvet et al. [1] (Fig. 57.4), most part of the journals are from Operations, Logistics or Supply Chain fields.

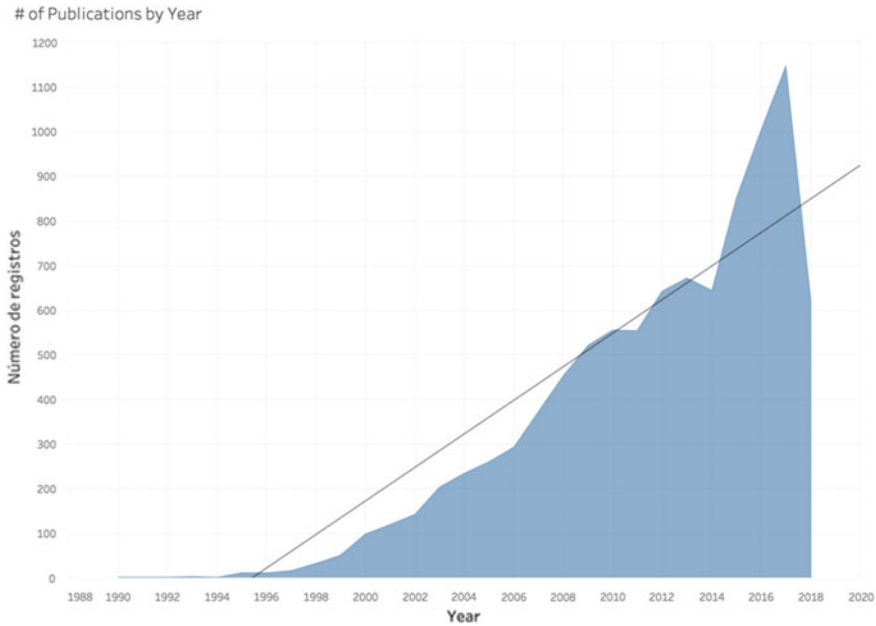


Fig. 57.1 Number of publications by year

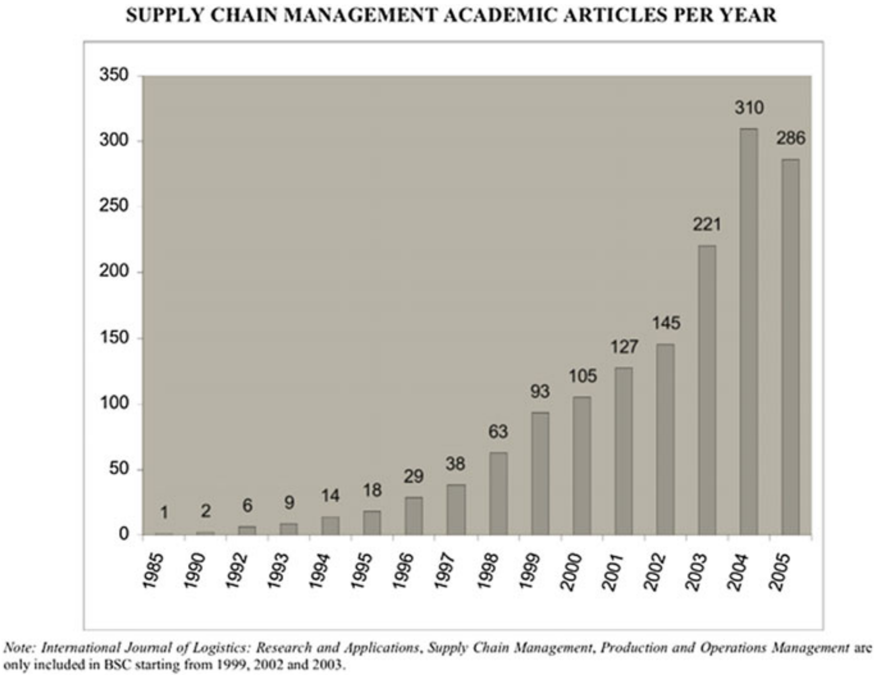


Fig. 57.2 Supply Chain Management academic articles per year (1995–2005). Extracted from Charvet et al. [1]

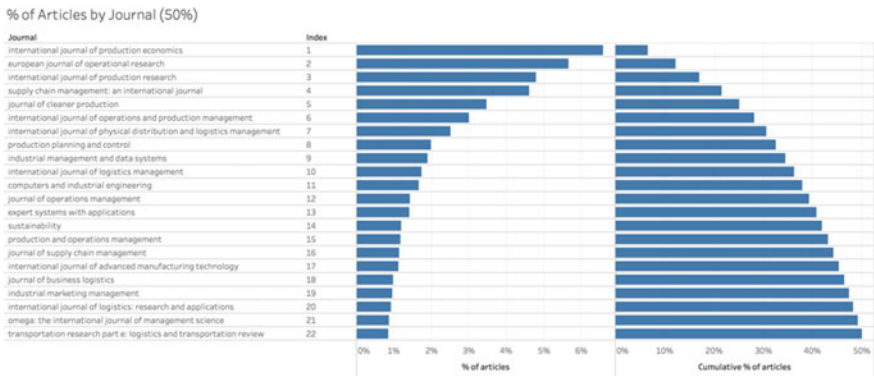


Fig. 57.3 Frequency and cumulative distribution of journals, top 50%

TOP 28 JOURNALS (915 'SCM' HITS IN BSC)

Journal Title	Abbreviation	Total Hits	1995-2004 Hits	Hits per Article (%)	Hits per Article 1995-04	Times Cited	Cites per Hit
Management Science	*MS*	40	39	1.6	3.2	330	8.3
International Journal of Physical Distribution & Logistics Management	*IJPDLM*	85	58	18.2	14.9	249	2.9
The International Journal of Logistics Management	*IJLM*	64	47	25.6	29.7	249	3.9
Journal of Business Logistics	*JBL*	38	31	9.2	15.0	193	5.1
Decision Sciences	*DS*	25	22	2.7	6.3	185	7.4
European Journal of Operational Research	*EJOR*	67	54	1.0	1.4	152	2.3
Industrial Marketing Management	*IMM*	24	21	2.4	3.9	113	4.7
International Journal of Production Economics	*IJPE*	77	60	3.7	4.0	92	1.2
International Journal of Operations & Production Management	*IJOPM*	57	44	4.3	5.9	85	1.5
Journal of Operations Management	*JOM*	30	22	5.4	6.6	84	2.8
Industrial Management & Data Systems	*IMDS*	24	18	4.3	4.1	78	3.3
Interfaces	*IF*	18	17	1.5	3.4	69	3.8
Production Planning & Control	*PPL*	37	31	3.7	4.3	56	1.5
International Journal of Production Research	*IJPR*	42	20	1.1	0.9	44	1.0
Production & Operations Management	*POM*	23	20	22.5	21.1	32	1.4
Production & Inventory Management Journal	*PIMJ*	14	14	1.6	4.3	30	2.1
Communications of the ACM	*CACM*	12	9	0.5	0.6	26	2.2
Transportation Journal	*TJ*	11	10	2.7	6.1	17	1.5
International Journal of Logistics: Research & Applications	*IJLRA*	28	21	20.4	18.4	13	0.5
IIE Solutions	*IIES*	31	31	7.9	7.9	5	0.2
Transportation Research: Part E	*TRE*	12	7	6.4	4.5	5	0.4
Journal of Supply Chain Management: A Global Review of Purchasing & Supply	*JSCM*	27	25	20.1	21.2	3	0.1
Electronic Markets	*EM*	11	9	4.8	4.7	3	0.3
Risk Management[1]	*RM*	41	32	3.0	4.3	0	0.0
Management Services[1]	*MSV*	31	27	3.1	6.8	0	0.0
Supply Chain Management	*SCM*	25	17	33.3	28.3	0	0.0
International Journal of Automotive Technology & Management[1]	*IJATM*	11	8	23.9	36.4	0	0.0
Industrial Engineer: IE	*IE*	10	5	6.8	4.9	0	0.0

[1] *RM*, *MS* and *IJATM* were included in BSC, but are clearly not academic journals. Since we further employ a cut-off based on the number of citations, this does not affect our results.

Fig. 57.4 Top 28 journals from Charvet et al. [1]

Another pathway is to analyze the evolution through time. Grouping the articles based on their publication date in five years bin, there is movement on the ranking of top ten journals (Fig. 57.5). It seems that Sustainability and Environmental Journals are getting their fair share of publications, with two journals in this category for 2015–2020. As an example, the number of articles published by the Journal of Cleaner Production, already surpassed any other journal on a five years base.

57.3.2 A Deep Dive into the Core Articles

The work from Charvet et al. [1] was based on 33 articles. They defined a core article as receiving ten or more citations from other articles in their database, but also sharing citations with 25% of other core articles. In their case, eight citations links were required. Part of the restriction was practical: the data base would have to be manually built.

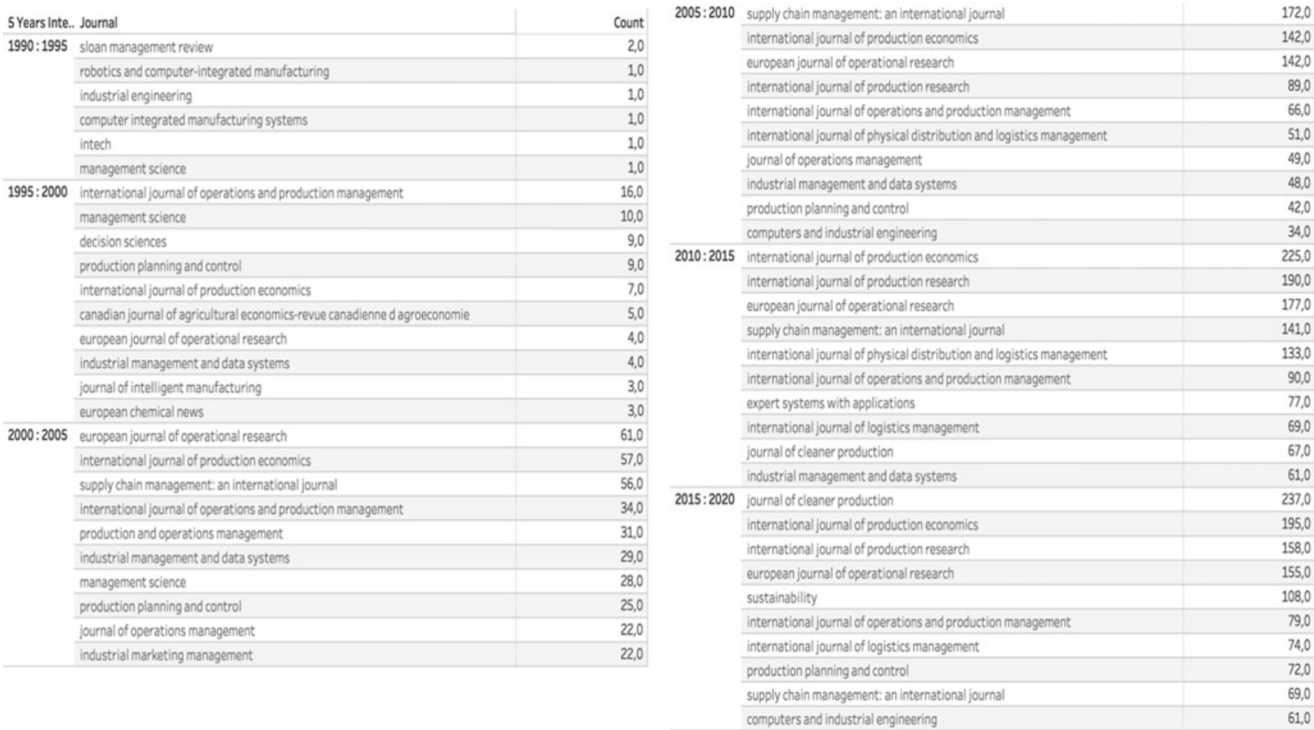
For the current paper, I opted to reduce the constraint and allow for more articles inside the core group. Core articles were defined as sharing at least ten citations link with each other. No exigence on the number of receiving citations. One expected impact is to have more recent articles on the core group, as they would not have had time to be cited but are citing many others.

The 2248 core articles followed the same pattern we saw on the complete sample. The list of the most important journals does not change much if one considers only the number of articles published. However, if one measures the impact using the number of citations as a proxy, the order changes quite a bit. Two remarkable changes are Management Science (from position 24 as for number of articles to six considering impact) and Sustainability (from position 13 as for number of articles to 24 considering impact).

If we go into a more detailed level and compare the list of 33 articles from Charvet et al. [1] (Fig. 57.6) with an updated version, (Fig. 57.7) only four articles remain. They are Lee et al. [4], Lee et al. [5], Lambert and Cooper [3] and Narasimhan and Jayaram [6]. The top journals were quite stable but not the top articles.

57.3.3 Clusters' Overview

Six clusters have been identified by CitNetExplorer algorithm. An initial analysis of a sample of titles from each cluster allowed the identification of its main subjects. Cluster 1 deals with Green Supply Chain, Social Responsibility and Sustainability. Cluster 2 was harder to classify. It is interested by Supply Chain Integration, Performance, Lean, Strategy. Cluster 3 studies Supply Chain Risk Management, Resilience and Humanitarian Supply Chain. Cluster 4 is all about Inventory Management, Information Sharing and Coordination. Cluster 5 is interested in the Buyer–Supplier Rela-



5 Years Inte..	Journal	Count
1990 : 1995	sloan management review	2,0
	robotics and computer-integrated manufacturing	1,0
	industrial engineering	1,0
	computer integrated manufacturing systems	1,0
	intech	1,0
	management science	1,0
1995 : 2000	international journal of operations and production management	16,0
	management science	10,0
	decision sciences	9,0
	production planning and control	9,0
	international journal of production economics	7,0
	canadian journal of agricultural economics-revue canadienne d agroeconomie	5,0
	european journal of operational research	4,0
	industrial management and data systems	4,0
	journal of intelligent manufacturing	3,0
	european chemical news	3,0
2000 : 2005	european journal of operational research	61,0
	international journal of production economics	57,0
	supply chain management: an international journal	56,0
	international journal of operations and production management	34,0
	production and operations management	31,0
	industrial management and data systems	29,0
	management science	28,0
	production planning and control	25,0
	journal of operations management	22,0
	industrial marketing management	22,0
2005 : 2010	supply chain management: an international journal	172,0
	international journal of production economics	142,0
	european journal of operational research	142,0
	international journal of production research	89,0
	international journal of operations and production management	66,0
	international journal of physical distribution and logistics management	51,0
	journal of operations management	49,0
	industrial management and data systems	48,0
	production planning and control	42,0
	computers and industrial engineering	34,0
2010 : 2015	international journal of production economics	225,0
	international journal of production research	190,0
	european journal of operational research	177,0
	supply chain management: an international journal	141,0
	international journal of physical distribution and logistics management	133,0
	international journal of operations and production management	90,0
	expert systems with applications	77,0
	international journal of logistics management	69,0
	journal of cleaner production	67,0
	industrial management and data systems	61,0
2015 : 2020	journal of cleaner production	237,0
	international journal of production economics	195,0
	international journal of production research	158,0
	european journal of operational research	155,0
	sustainability	108,0
	international journal of operations and production management	79,0
	international journal of logistics management	74,0
	production planning and control	72,0
	supply chain management: an international journal	69,0
	computers and industrial engineering	61,0

Fig. 57.5 Evolution of the top ten journals through time

33 CORE ARTICLES

Article	Journal	Cited	Article	Journal	Cited
Lee et al. (1997)	MS	159	Tarn et al. (2002)	IMDS	17
Cooper et al. (1997a)	IJLM	74	Lee and Wang (1999)	MS	16
Thomas and Griffin (1996)	EJOR	51	Aviv (2001)	MS	15
Arntzen et al. (1995)	IF	49	Raghunathan (2001)	MS	15
Lambert and Cooper (2000)	IMM	44	Sahin and Robinson (2002)	DS	15
Mentzer et al. (2001)	JBL	35	Lamming et al. (2000)	IJOPM	14
Lee et al. (2000)	MS	30	Lambert and Pohlen (2001)	IJLM	13
Narasimhan and Jayaram (1998)	DS	30	Lamming (1996)	IJOPM	12
Monczka et al. (1998)	DS	27	Bhaskaran (1998)	DS	12
Swaminathan et al. (1998)	DS	24	Lummus et al. (1998)	PIMJ	12
Stank et al. (2001)	JBL	24	Tsay (1999)	MS	12
Mabert and Venkataramanan (1998)	DS	24	Croxton et al. (2001)	IJLM	12
Bechtel and Jayaram (1997)	IJLM	22	Tan et al. (1999)	IJOPM	12
Cooper et al. (1997b)	JBL	21	Krause et al. (1998)	JOM	12
Brewer and Speh (2000)	JBL	21	Scannell et al. (2000)	JBL	11
Maloni and Benton (1997)	EJOR	20	Raghunathan (1999)	DS	11
Lambert et al. (1998)	IJLM	20			

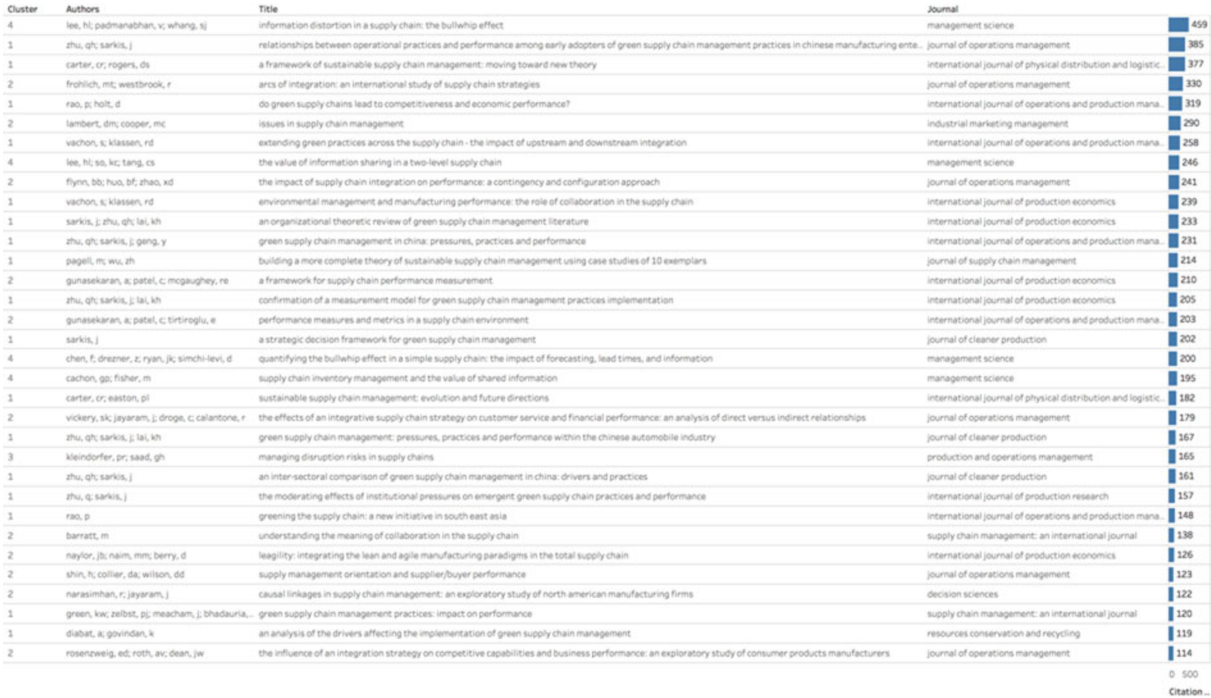
Fig. 57.6 Top 33 articles from Charvet et al. [1]

tionship, Power and Contracts. Finally, Cluster 6 mixes Analytical modeling and Supplier Selection. Figure 57.8 shows the direct citation network clustered.

The SCM theme started with Cluster 2 (Supply Chain Management Practice) in our sample, around 1992. Until 1997, it was the only stream of research, when Cluster 4 (Information Sharing) started. Until 2012, it was the biggest cluster, but it was displaced by Cluster 1. The rest of the clusters started around the year 2000 and followed the general development curve. Please refer to Fig. 57.9 for a detailed view of this evolution.

What one can see checking the clusters' keywords and journal names, an analysis of the journal field makes even more explicit. The concentration in Operations and Technology is astonishing. One question that arouses is about the multidisciplinary nature of Supply Chain. Should not we see a more democratic contribution from fields like marketing and strategy? The same concentration was perceived by Charvet et al. [1].

Another question is on the asymmetry between the weight of Green Supply Chain topic versus the small contribution from Regional Studies, Planning and Environment field. Researchers are writing hundreds of articles on Green Supply Chain and publishing these papers in classical Operations Management or Supply Chain specialized journals.



Cluster	Authors	Title	Journal	Citation ..
4	lee, hl; padmanabhan, v; whang, sj	information distortion in a supply chain: the bullwhip effect	management science	459
1	zhu, qh; sarkis, j	relationships between operational practices and performance among early adopters of green supply chain management practices in chinese manufacturing ente..	journal of operations management	385
1	carter, cr; rogers, ds	a framework of sustainable supply chain management: moving toward new theory	international journal of physical distribution and logistic..	377
2	frohlich, mt; westbrook, r	arcs of integration: an international study of supply chain strategies	journal of operations management	330
1	rao, p; holt, d	do green supply chains lead to competitiveness and economic performance?	international journal of operations and production mana..	319
2	lambert, dm; cooper, mc	issues in supply chain management	industrial marketing management	290
1	vachon, s; klassen, rd	extending green practices across the supply chain - the impact of upstream and downstream integration	international journal of operations and production mana..	258
4	lee, hl; so, kc; tang, cs	the value of information sharing in a two-level supply chain	management science	246
2	flynn, bb; huo, bf; zhao, xd	the impact of supply chain integration on performance: a contingency and configuration approach	journal of operations management	241
1	vachon, s; klassen, rd	environmental management and manufacturing performance: the role of collaboration in the supply chain	international journal of production economics	239
1	sarkis, j; zhu, qh; lai, kh	an organizational theoretic review of green supply chain management literature	international journal of production economics	233
1	zhu, qh; sarkis, j; geng, y	green supply chain management in china: pressures, practices and performance	international journal of operations and production mana..	231
1	pagell, m; wu, zh	building a more complete theory of sustainable supply chain management using case studies of 10 exemplars	journal of supply chain management	214
2	gunasekaran, a; patel, c; mcgaughey, re	a framework for supply chain performance measurement	international journal of production economics	210
1	zhu, qh; sarkis, j; lai, kh	confirmation of a measurement model for green supply chain management practices implementation	international journal of production economics	205
2	gunasekaran, a; patel, c; tirtiroglu, e	performance measures and metrics in a supply chain environment	international journal of operations and production mana..	203
1	sarkis, j	a strategic decision framework for green supply chain management	journal of cleaner production	202
4	chen, f; drezner, z; ryan, jk; simchi-levi, d	quantifying the bullwhip effect in a simple supply chain: the impact of forecasting, lead times, and information	management science	200
4	cachon, gp; fisher, m	supply chain inventory management and the value of shared information	management science	195
1	carter, cr; easton, pl	sustainable supply chain management: evolution and future directions	international journal of physical distribution and logistic..	182
2	vickery, sk; jayaram, j; droge, c; calantone, r	the effects of an integrative supply chain strategy on customer service and financial performance: an analysis of direct versus indirect relationships	journal of operations management	179
1	zhu, qh; sarkis, j; lai, kh	green supply chain management: pressures, practices and performance within the chinese automobile industry	journal of cleaner production	167
3	kleindorfer, pr; saad, gh	managing disruption risks in supply chains	production and operations management	165
1	zhu, qh; sarkis, j	an inter-sectoral comparison of green supply chain management in china: drivers and practices	journal of cleaner production	161
1	zhu, q; sarkis, j	the moderating effects of institutional pressures on emergent green supply chain practices and performance	international journal of production research	157
1	rao, p	greening the supply chain: a new initiative in south east asia	international journal of operations and production mana..	148
2	barratt, m	understanding the meaning of collaboration in the supply chain	supply chain management: an international journal	138
2	naylor, jb; naim, mm; berry, d	leagility: integrating the lean and agile manufacturing paradigms in the total supply chain	international journal of production economics	126
2	shin, h; collier, da; wilson, dd	supply management orientation and supplier/buyer performance	journal of operations management	123
2	narasimhan, r; jayaram, j	causal linkages in supply chain management: an exploratory study of north american manufacturing firms	decision sciences	122
1	green, kw; zelbst, pj; meacham, j; bhadauria,..	green supply chain management practices: impact on performance	supply chain management: an international journal	120
1	diabat, a; govindan, k	an analysis of the drivers affecting the implementation of green supply chain management	resources conservation and recycling	119
2	rosenzweig, ed; roth, av; dean, jw	the influence of an integration strategy on competitive capabilities and business performance: an exploratory study of consumer products manufacturers	journal of operations management	114

Fig. 57.7 Top 33 articles with greater impact up to date

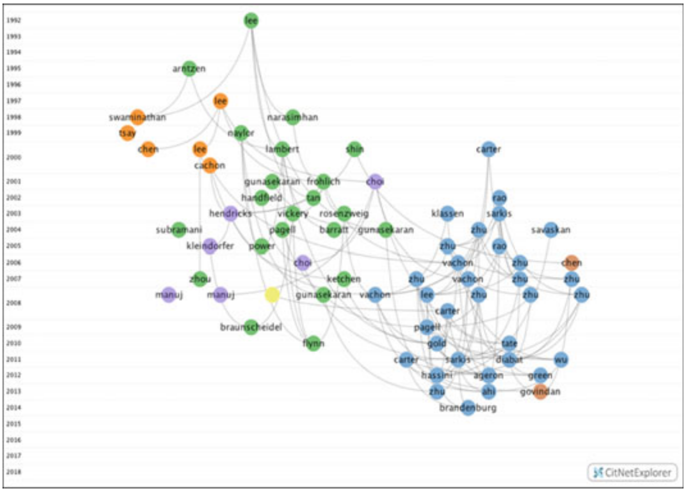


Fig. 57.8 Core articles clustering

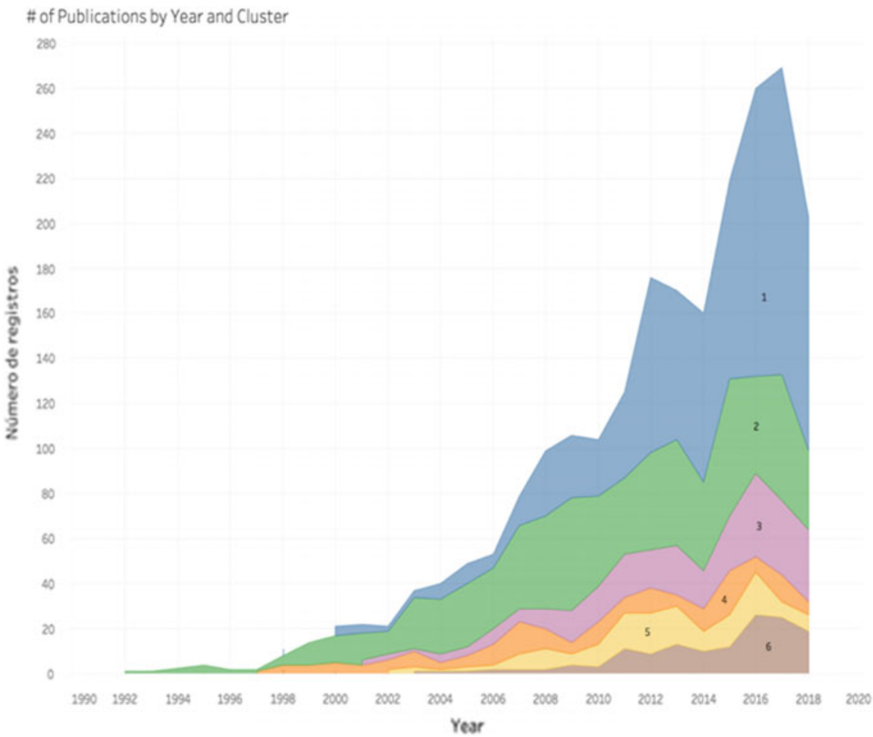


Fig. 57.9 Growth of clusters trough time

57.4 Conclusion

This paper tried to answer the two research questions below, through a bibliometric study:

1. What are the Journals that publish SCM papers?
2. Can one identify major streams of research within the SCM literature?

Fifty-eight percent of the core articles studied have been published in Operations and Technology Management Journals. However, during the past three years, two journals from Regional Studies, Planning and Environment field gained traction and entered the top ten list. This shift is probably related to the explosive growth in articles dealing with Green Supply Chain, CSR and Sustainability.

Using a clustering algorithm, six major clusters or streams of research have been identified: Green Supply Chain, SCM Practice, SCRM, Information Sharing, Dyadic Relationship, Analytical Models. The SCM practice stream was the first one to appear (1992) and stayed dominant until 2012. After that, the Green SC had an explosive growth and became the major stream of research (846 articles).

The field is growing faster and faster in number of articles. The relative size of the research streams changed considerably between 2000 and 2018, but all topics were already there.

This work had some major limitations. First, as I diverged in research method from Charvet et al. [1], differences in findings could be attributed to differences in methods. Another study, repeating the method and protocol of Charvet et al. [1] would be interesting to control for the methodological variable.

Second, the definition of each cluster theme or themes had a great deal of subjectivity. Only the papers title was considered. A text mining technique would be preferable, faster and more precise. Also, the choice of parameters and clustering algorithm plays an important role on the number and constitution of clusters. Different algorithms should be tried to test the clusters stability [9].

I am convinced by the utility of the citation network analysis. Hopefully, this paper will illustrate its use and encourage more essays (Fig. 57.10).

Journal	Ajg 2018	1	2	3	4	5	6	Total ger..
international journal of production economics	3	76	65	28	15	4	13	201
supply chain management: an international journal	3	61	90	30	5	7	3	196
journal of cleaner production	2	134	1	3			25	163
international journal of operations and production management	4	38	94	13	2	11	2	160
international journal of production research	3	35	34	35	13	2	7	126
journal of operations management	4*	10	44	10	7	32		103
international journal of physical distribution and logistics management	2	39	27	22	5	9		102
international journal of logistics management	1	14	34	16	2	11		77
journal of supply chain management	3	21	6	4	1	36		68
production planning and control	3	25	22	7	1	1	4	60
industrial management and data systems	2	14	31	3	3		3	54
european journal of operational research	4	6	7	4	21		6	44
sustainability	Nulo	29	3	2			7	41
industrial marketing management	3	12	24			3		39
journal of business logistics	2	5	9	11	3	6		34
benchmarking: an international journal	1	11	13	3			1	28
resources conservation and recycling	Nulo	22	2				4	28
journal of purchasing and supply management	2	18	1	4		3		26
transportation research part e: logistics and transportation review	3	15	3	2	4		2	26
business strategy and the environment	3	24					1	25
computers and industrial engineering	2	4	5	7	2		7	25
omega: the international journal of management science	3	7	8	1	5		3	24
international journal of logistics: research and applications	1	5	9	7	1		1	23
management science	4*	2	1	1	18			22
journal of manufacturing technology management	Nulo	8	9	4				21
Total geral		635	542	217	108	125	89	1.716

Fig. 57.10 Number of articles by journal and cluster (top 25 journals)

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Chapter 58
A Conceptual Model to Guide the Redesign of Performance Measurement Systems

Joana Rocha, Luiz Felipe Scavarda and Patricia Renata Carvalho de Mendonça

Abstract The purpose of this paper is to present an overview of the literature on performance measurement systems (PMS) focused on the redesign phase. Therefore, the study also aims to propose a conceptual model guideline for the redesign of existing performance measurement systems based on the literature studied.

Keywords Literature review · Conceptual model

58.1 Introduction

Performance measurement system (PMS) has gained prominence in the academic and corporate world. It has also been widely used by managers to support the decision-making process [1]. According to Kaplan et al. [2], it supports the implementation of the strategy at various levels of the organization. PMS incorporates a set of metrics used to quantify the effectiveness and efficiency of actions [3]. Process, people and information systems are also part of PMS [1]. In this sense, academics and practitioners are interested in understanding how organizations are measured and how value can be extracted from information [4]. According to Gutierrez et al. [5], the studies identified in the literature are mostly related to the design of new systems, with a lack on studies focused on redesign and implementation or the complete life cycle. The empirical studies identified deal mostly with case studies or surveys. Although there are many discussions about criteria and requirements that measurement systems must have, there is no consensus about what is really sufficient and/or necessary for its elaboration, illustrating only one of the challenges of designing it [4]. The balance between the number of indicators and the information needed for the monitoring of the process and assistance in decision making is fundamental [6].

This paper aims to propose a conceptual model focused on the redesign, verification of PMS effectiveness and subsequent implementation. The work follows the definition of the conceptual model proposed by Meredith [7] that consists in

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accomplishing the simplification of the fact or abstraction, maintaining connection with reality. The model should present the relevant elements and propositions that describe the phenomenon (event, reality or process) [7]. The first phase of the research consists of mapping and verifying the adequacy of existing models in the literature and existing gaps. The proposed framework is developed based on the "Discovery-Oriented Approach" approach by Menon et al. [8]. It aims not only to suggest good practices regarding redesign but also to facilitate the PMS redesign implementation. Although the importance of supply chain influenced PMS with the arrival of many trends as outsourcing [9], reinforcing the importance of PMS for supply chain management [10], the proposed framework does not include directly at the moment the supply chain view for PMS, being a research limitation of this study.

This article is organized in five sections: Introduction, Theoretical Background, Methodology, Conceptual Model and Conclusion.

58.2 Theoretical Background

This section offers a background on PMS, conceptual models and barriers to the use of performance measurement systems.

58.2.1 Performance Measurement System (PMS)

Since the 1980s, actions have been taken to measure organizational performance through metrics, which contributes to the achievement of objectives [11]. According to Neely et al. [3], the measurement of performance allows quantifying the efficiency and effectiveness of actions. The measure of performance is a metric used to quantify process and to make it possible to compare with established goals [3]. Even systems models that were not only focused on measuring performance were driven by management needs. One of the challenges of this research area is to provide systems that include performance management and not just measurement.

Although performance measurement systems have become relevant since the late 1980s, only nowadays it has gained relevance in the field of management. In this sense, the use of the systems reduces decision making based on intuition or only with a financial bias [12].

The main causes of adopting a PMS are: to plan, monitor, evaluate, control and communicate financial and operational activities; help decision making; maximize profit by increasing profitability; allow alignment with goals, objectives and organizational strategy; reward and discipline employees and leadership; make predictions about the future [11]. As a result, systems are no longer limited to generating metrics and measuring results, but they need to focus on managing those results.

Most of the studies found in the literature are focused on the design of new systems and a few are oriented to the analysis of the implementation and continuous updating of systems [11, 13].

58.2.2 Conceptual Models

Traditional PMS was developed to monitor costs and accounting systems [14]. In order to provide a more balanced view of the processes, Keegan et al. [15] proposed a model considers in addition to the internal processes, the external ones, encompassing the financial and non-financial views. Another model widely known in the literature is the one proposed by Kaplan et al. [2] which addresses the four perspectives of the balanced scorecard.

According to Bourne et al. [13], new frameworks oriented to PMS review focused, for the most part, on answering questions about which types of measurement a company should adopt, but did not provide a detailed guide on how to carry out its implementation. The systematic proposed by Bourne et al. [13] and Gutierrez et al. [5] addresses the stage of implementation in a more concise way.

The proposed procedural model is divided into four stages: design, implementation, use and revision (Fig. 58.1).

The initial phase is the identification of the main objectives and the design of the indicators. At this stage, it is necessary to develop a systematic to review the final set of metrics. These measures should be defined on the basis of the strategy and considering the customers and stakeholder requirements [13].

The implementation phase consists of aligning systems and procedures, ensuring that measurements are made regularly according to the proposed design [13]. Effective implementation requires the alignment of the organizational structure and systems, being a work phase and involving additional costs with developments of, for example, systems.

The last phase of the system, before the start of the review cycle, the use phase is a prerequisite to any evolution [16]. The use phase is a prerequisite to any evolution [16]. At this stage, it is important to update and improve PMS [13].

Despite providing adequate performance information and analyzing the results, the PMS should be periodically reviewed in order to maintain its relevance to the

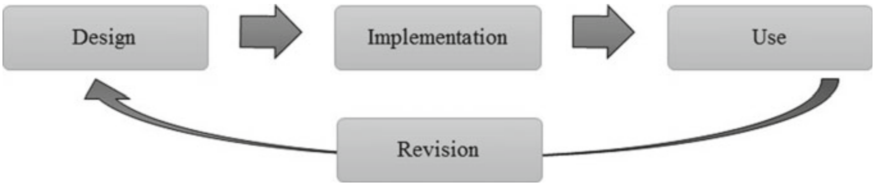

Fig. 58.1 Conceptual model Bourne et al. [13] and Gutierrez et al. [5]. *Source* Adapted from Bourne et al. [13] and Gutierrez et al. [5]

strategy [17]. Thus, a systematic should be conducted to periodically review the entire set of measures according to changes in the competitive environment and strategy, including mechanisms to review indicators and enable continuous improvement [5]. There are different uses of PMS, one of which is to evaluate the implementation of the strategy [5, 13].

At the stage of the redesign, interesting proposals were presented as Dixon et al. [18] propose the use of questionnaires to identify strengths and weaknesses in current PMSs and workshops to carry out such redesign. Kaplan et al. [2] propose interviews with senior management.

58.2.3 Barriers to the Use of Performance Measurement Systems

According to Goshu and Kitaw [4], the success of a performance measurement system is linked to the following characteristics: simplicity, balancing, accuracy, adequate number of indicators and cost.

According to Van Camp and Braet [11], publications on the subject of PMS increased significantly, with 100,000 studies published between 1994 and 2011. Nevertheless, few studies were published focused on the lessons learned, incorporating analyzes of practical problems found [11].

According to Van Camp and Braet [11], the literature has failed to incorporate into the proposed models flaws encountered during deployment in real systems. Van Camp and Braet [11] identified after a systematic review fourteen reasons that may lead to the failure of the design and implementation process of a PMS, which are:

(1) Lack of managerial involvement;
(2) Lack of alignment with strategy;
(3) Lack of formal procedure;
(4) Insufficient frequency;
(5) Lack of reward system;
(6) Lack of financial support;
(7) Lack of human capital;
(8) Lack of IT support;
(9) Lack of user involvement;
(10) Cultural obstacles;
(11) Lack of reactive/proactive actions;
(12) High number of stakeholders;
(13) Decisions taken by the group over decisions based on data analysis;
(14) Pressure in relation to time.

Kennerley and Neely [16] suggest that the various barriers that may hinder the functioning of the evolutionary cycle of PMS can be overcome if the evolutionary cycle is designed with clear triggers, with a specific process of revision, modification and implementation of measures, availability of the skills needed to use, reflect, modify and implement measures, have flexible systems that enable appropriate data collection, analysis and reporting, consolidate a measurement culture within the organization, ensuring that the measurement value and importance of maintaining relevant measures appropriate.

58.3 Methodology

The proposed conceptual model was elaborated based on the "Discovery-Oriented Approach" approach by Menon et al. [8]. This approach contemplates three dimensions: academic view, related to the literature reference available; industrial concepts, linked to practical concepts related to the subject and can be obtained through primary data (interviews with experts and executives related to the area) or by direct observation of these practices in industry; and the third and last dimension that is based on knowledge generated from association and analysis of the two dimensions previously mentioned [8].

This research incorporated the first two dimensions: academic, through the identification in the literature of gaps related to the implantation phase; and the industrial view translated by the view of the industry obtained through non-structured interviews with respondents tied to the problem. The third view was not analyzed herein and its incorporation is recommended for the future studies.

58.4 Conceptual Model Implementation

The literature on PMS still does not have consensus as to what are the necessary and sufficient conditions for a system to be successful or what factors must support its elaboration. Therefore, the usage/revision step is relevant in order that the improvement of the systems is based on the process of trial, error and readjustment [4].

Figure 58.2 offers the proposed conceptual model aims to improve the proposed by Bourne et al. [13] and Gutierrez et al. [5] including a pilot stage before implementation itself.

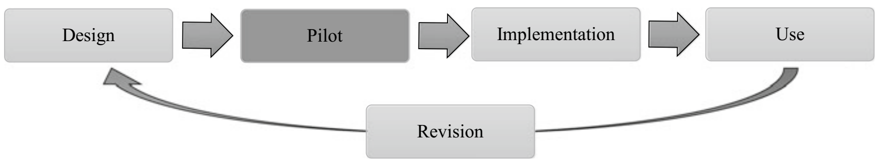

Fig. 58.2 Conceptual model Bourne et al. [13] and Gutierrez et al. [5] adapted. *Source* Author

The proposed stage of the inclusion of the pilot phase aims to ensure that the indicators proposed in the project stage are adherent to the reality of the company, avoiding unnecessary financial expenses and efforts. During the pilot phase, the indicators should be tested and evaluated in a short period in order to evaluate the effectiveness of the proposed measurements. The test can be performed in a reduced scope within an organization as a specific area or region, in order to restrict the effort employed.

For each of the objective problems identified by Van Camp and Braet [11], it was assessed whether the inclusion of the pilot stage can contribute to the process. Table 58.1 presents the results obtained through the adoption of the first two dimensions of the "Discovery-Oriented Approach" approach by Menon et al. [8].

Table 58.1 How can the pilot step help mitigate/reduce failure?—industrial view

#	Cause of failure—academic view	Can the pilot stage mitigate/reduce this failure?	How can the pilot step help mitigate/reduce failure?—industrial view
1	Lack of managerial involvement	Yes	Managers have the opportunity to follow in a practical way the benefits that a PMS deployment can bring, facilitating engagement. In this phase, they have the opening to propose improvements/adjustments in the model that can be implemented more immediately
2	Lack of alignment with strategy	Yes	It allows to verify if the measurements made are in line with the strategy's proposals and to make possible adjustments before spending with software development, for example
3	Lack of formal procedure	Yes	At this point, it is possible to verify if the procedures elaborated in the project phase are adequate and to make possible adjustments
4	Insufficient frequency	Yes	In this step, adjustments can be made in relation to the measurement frequency, evaluating effort × benefits of the update with greater frequency

(continued)

Table 58.1 (continued)

#	Cause of failure—academic view	Can the pilot stage mitigate/reduce this failure?	How can the pilot step help mitigate/reduce failure?—industrial view
5	Lack of reward system	Yes	The pilot stage assesses the effectiveness of the reward system against existing indicators and, if necessary, makes this adjustment in the short term in reward systems or in the PMS (including or withdrawing indicators)
6	Lack of financial support	No	–
7	Lack of human capital	No	–
8	Lack of IT support	No	The step can help in avoiding unnecessary developments for the deployment phase but does not reduce the necessary IT support
9	Lack of user involvement	Yes	Users have the opportunity to conveniently follow the benefits that PMS deployment can provide, facilitating engagement. In this phase, they have the opening to propose improvements/adjustments in the model that can be implemented more immediately
10	Cultural obstacles	No	–
11	Lack of reactive/proactive actions	No	–
12	High number of stakeholders involved	No	–
13	Decisions taken by the group over decisions based on data analysis	Yes	The pilot phase aims to evaluate the effectiveness of the PMS proposed in the decision support
14	Pressure over time	No	This step can also extend deployment time

Source Author

Analyzing Table 58.1, it is possible to assume that according to the industrial view, seven of the fourteen problems identified by Van Camp and Braet [11] can be mitigated with the implementation of the pilot phase.

58.5 Conclusion

Although there are several studies focused on PMS analysis, few are focused on the review/implementation phase [5]. Using the approached offered in Menon et al. [8], this research practice gap was analyzed under the academic and industrial views.

Regarding the academic view, a study carried out by Van Camp and Braet [11] was used as a base, which through a systematic review of the literature identified 14 failure factors associated with the PMS implementation phase.

After this step, an adaptation was proposed in the framework proposed by Bourne et al. [13] and Gutierrez et al. [5], including the pilot stage. For each of the gaps identified previously, it was analyzed, with the inclusion of industry data, how the pilot stage could mitigate the problems identified using the industrial view. Of the 14 reported problems, seven can be mitigated by including this new step.

Despite the methodology proposed by Menon et al. [8] have three views, only two were contemplated in the study, the third being proposed as the future studies. This could be achieved by applying the proposed conceptual model in a case study.

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Chapter 59
The Social Dimension and Indicators of Sustainability in Agrifood Supply Chains

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Abstract This paper aims to identify, in the international literature, the state-of-the-art research related to social sustainability in agrifood supply chains. To achieve this goal, a systematic literature review covering papers published in the ScienceDirect, Directory of Open Access Journals and Emerald Insight databases, was carried out.

Keywords Agrifood supply chain · Social sustainability · Social indicators · Sustainability

59.1 Introduction

The scientific production related to the social dimension of sustainability in agrifood supply chains has been growing among the authors of several areas of academic knowledge, because it is a multidisciplinary theme that involves several actions and practices along the supply chain. As pointed out by Hall and Matos [14], the fight against social exclusion through the insertion of impoverished communities into sustainable supply chains has been debated by scholars and it is growing.

In order to achieve sustainability in supply chains, the process should not be confined to just one organization, but consider the various actors involved and extrapolate issues that go beyond the environmental ones. The concerns with the social issues in effect, preserving the conditions of the workers in supplier companies and forming collective partnerships for social development as a whole, should be considered [16, 23].

Thus, the companies are subsidizing efforts to search for mutual gains in the supply chain by adding value to social inclusion in order to gain new markets through innovative mechanisms and a balance of power in the relations.

Distinguishing and identifying what actions and practices are related to social sustainability are challenges, since many academic works end up encompassing several research fields jointly, not delimiting the boundaries between the dimensions

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of financial, social or environmental sustainability. Therefore, this hinders an in-depth analysis of the characteristics and application fields of social issues in a sustainable supply chain management.

So, summarizing indicators of social sustainability can expose the most studied characteristics in the academic environment, verifying the most explored areas and research gaps in still incipient investigation fields, are fundamental, since it can trace characteristic elements of social sustainability present in publications, guide potential themes in researches and disseminate practices and experiences to the business community. Some indicators of social sustainability proposed by Labuschagne and Brent [17] provide a categorization structure containing social indicators observed in sustainable supply chains, which are subdivided into four spheres of action: internal human resources, external population, stakeholder participation and macro-social performance.

Assuming that collective actions among members are essential to the management of sustainable supply chains with a view to achieving social gains and mutual benefits, it is elementary to expect that cooperative or more complex practices, such as collaborative practices, are present in the relations between the members that make up the supply chains and their related partners. Identifying these arrangements aims to consolidate the understanding of these concepts in relation to the social sustainability practices used and illustrates the academic approach taken by the researchers regarding cooperation and collaboration to improve social issues.

In agrifood chains, implementing a sustainable management is complex, since it encompasses a great variety of specificities that compose this type of relationship and entails different social aspects when it comes to raw material suppliers, especially when they are small impoverished rural producers. Maloni and Brown [19] highlight that these supply chains are complex because they involve sensitive elements external to the business and also require labor-intensive applications at all stages of the chain.

In order to obtain subsidies for studies related to social sustainability in agrifood supply chains and existing collective arrangements, the objective of this paper is to identify in the literature the state-of-the-art research that operates under the social sustainability dimension, identifying related indicators and vital cooperative or collaborative practices. For this purpose, it carried out a descriptive, exploratory and qualitative research through the systematic literature review technique. The systematic review was based on the Cronin et al. [7] protocol, through database searches on the ScienceDirect, Directory of Open Access Journals and Emerald Insight Web sites, using descriptors related to social sustainability in agrifood chains.

The result of the research indicates that the academic production of research related to social sustainability in the agrifood supply chain is still scarce, although it has shown a significant growth in recent years. Among the indicators of social sustainability that are less present in publications, macro-social issues related to regional or national impacts were the least considered by the authors. This paper demonstrates that the collaborative arrangements related to infrastructure sharing and the integration of the productive processes among the agrifood supply chain are also few studied. The results also demonstrate that collective actions are more exploited when related to cooperation than collaborative arrangements.

59.1.1 Methods and Research Techniques

In order to guarantee adequate reliability and validity of the literature review, the author must specify the criteria used in the research, following the subsequent steps: (i) Formulate the research question; (ii) define inclusion or exclusion criteria; (iii) select and access the literature; (iv) evaluate the quality of the literature included in the evaluation; (v) analyze, synthesize and disseminate the results [7]. Thus, the criteria and filtering process used for this systematic literature review are presented:

Definition of the research question: What are and what is the approach of the current studies related to social sustainability indicators in the sustainable management of the agrifood supply chain, and what collective and integrative actions are identified?

Definition of the inclusion and exclusion criteria: The criteria are keywords associated with Boolean operators, scientific databases, publication period and types of articles. As the proposed study deals with a multidisciplinary theme, there may be periodicals in several areas of knowledge, such as: administration, production engineering, process engineering, sociology, law, environmental engineering, agronomy, among others. This article was delimited for scientific research: ScienceDirect, Directory of Open Access Journals and Emerald Insight. The use of various collection databases aims to broaden the variety of studies and later to use objective criteria for refinement and selection of the most representative ones. After choosing the scientific bases for research, we defined the period of publication that considered the last 10 years, covering from 2006 to 2016. The keywords were defined for the search of factors that are part of the social dimension and were delimited under the book Cannibals with Forks by Elkington [10], considering the combined descriptors, preserving, in all combinations, the term supply chain as the base axis for the search in the databases. The search combinations were: (a) supply chain, social development, food; (b) supply chain, social development, agriculture; (c) supply chain, social development, agrifood; (d) supply chain, social responsibility, food; (e) supply chain, social responsibility, agriculture; (f) supply chain, social responsibility, agrifood; (g) supply chain, social sustainability, food; (h) supply chain, social sustainability, agriculture; (i) supply chain, social sustainability, agrifood; (j) supply chain, social justice, food; (l) supply chain, social justice, agriculture; (m) supply chain, social justice, agrifood; (n) supply chain, social truth, food; (o) supply chain, social truth, agriculture; (p) supply chain, social truth, agrifood; (q) supply chain, ethic, food; (r) supply chain, ethic, agriculture; and (s) supply chain, ethic, agrifood.

Regarding the selected articles, it was defined that only articles published in periodicals would be considered, excluding those published in annals of events, patents, quotations and chapters. The Boolean operator used was the AND, excluding the OR and NOT operators, since the results should reflect articles related to the social sustainability of agrifood supply chain.

Literature selection and access: Overall results using keyword combinations in the ScienceDirect, Directory of Open Access Journals and Emerald Insight databases, totaled 63 publications. Considering the established exclusion criteria, 12 publications were excluded from this population, since they were related to events and chapters, and 7 were repeated publications of articles already collected in the research bases when the combined descriptors were applied. Thus, 44 articles were selected for further analysis and verification for inclusion in the sample.

Evaluation of the literature quality included in the review: Considering the ScienceDirect database, 18 articles were selected applying the descriptors and the exclusion criteria, but only 10 were selected to compose the sample, since 8 were eliminated because the topics, after analysis of the summary and introduction of each publication, were not related to the proposed study and were excluded due to their content. At the Directory of Open Access Journals database, of the ten studies selected after the first exclusion criteria, only six were selected for the sample and the others were excluded because they did not align to the proposed objective after analyzing the abstracts published in the portal. Finally, with respect to Emerald Insight, 16 articles were selected and 13 included in the sample, since these were aligned with the objectives proposed by this article. Considering the exclusion criteria applied, the sample that will compose the analysis totalizes 29 articles.

Analysis, synthesis and dissemination of results: This step demonstrates the analysis for each selected article considering the contents of the articles housed in the portals ScienceDirect, Directory of Open Access Journals and Emerald Insight. Thus, the data were tabulated in electronic spreadsheets and classified with the respective authors by: social sustainability indicators, classified according to the Labuschagne et al. [18] criteria; cooperative actions, identified according to the Britto [5] classifications; collaborative actions and scope classifications, according to the dimensions of Barrat [1]; research design; collaborative relationships among members of the supply chain; and predominant research design.

59.2 Presentation, Analysis and Discussion of Data

Indicators related to social sustainability were identified in the articles that compose the sample collected, taking into account the criteria established by Labuschagne et al. [18] and were classified according to the dimensions established by the same authors. It should be emphasized that indicators play a mutable and evolving role in response to the aspirations of society and the conceptual evolution of the understandings and can be developed in the future moments as organizations actually evaluate their net contributions to the real generation of social wealth to the society [10].

Table 59.1 presents the results of the indicators present in the articles analyzed and correspond to each author of the publications. In it, the classification of indicators identified in light of the analysis of the articles is placed, as well as the sphere of the indicators to which they belong.

Analyzing Table 59.1, it is possible to observe, in the majority, social sustainability indicators related to the external population (25), followed by the stakeholder participation (20), internal human resources (11) and, lastly, indicators related to the macro-social performance (6). These results already demonstrate a greater academic

Table 59.1 Social sustainability indicators in agrifood supply chains

Authors	Internal human resources	External population	Stakeholder participation	Macro-social performance
Manning et al. [21]	Health and safety, employment practices	Human capital	Information provision, stakeholder influence	
Rimmington et al. [25]		Human capital	Information provision, stakeholder influence	Financial and environmental performance
Fearne et al. [12]			Information provision, stakeholder influence	
Setthasakko [26]	Health and safety	Human capital	Information provision, stakeholder influence	
Blanc [4]		Community capital	Stakeholder influence	
Cross [8]	Health and safety, employment practices	Human capital, community capital		
Spence and Bourlakis [29]		Human capital	Information provision, stakeholder influence	
Oglethorpe and Heron [22]		Human capital, community capital		
Pulina and Timpanaro [24]	Health and safety	Human capital		
Wang et al. [32]	Health and safety	Human capital	Information provision, stakeholder influence	
Zhang et al. [35]		Human capital		
Urquhart and Acott [31]		Community capital	Stakeholder influence	Environmental performance
Manning [20]		Human capital	Information provision, stakeholder influence	

(continued)

Table 59.1 (continued)

Authors	Internal human resources	External population	Stakeholder participation	Macro-social performance
Wiese and Toporowski [33]	Health and safety	Human capital, community capital		
Davenport and Low [9]			Information provision, stakeholder influence	
Chen et al. [6]		Human capital	Information provision, stakeholder influence	
Bisogno [3]		Community capital	Stakeholder influence	
Shnayder et al. [27]	Health and safety, employment practices, capacity development	Human capital, productive capital	Information provision, stakeholder influence	Environmental performance
Jacob-John and Veerapa [15]		Human capital, community capital	Information provision, stakeholder influence	
Tidy et al. [30]			Stakeholder influence	
Wilhelm et al. [34]	Health and safety, employment practices	Human capital	Stakeholder influence	Environmental performance
Giovannucci and Potts [13]		Human capital productive capital		Financial and environmental performance
Beber et al. [2]	Job stability, health and safety, employment practices, capacity development	Human capital, community capital	Information provision, stakeholder influence	Environmental performance
Famiola and Adiwoso [11]		Human capital, community capital, capital productive		

approach to elements that are external to the target organization, since indicators related to internal human resources are present in only 11 articles.

Among the spheres of sustainability indicators, considering the external population, it is verified that human capital was the predominant indicator, being approached in 22 articles. The frequency of approaching this indicator in the analyzed articles demonstrates the importance given to human aspects such as health, education and local development of the communities, due to the impacts of agrifood enterprises. Elkington [10] emphasizes that aspects related to human capital should encompass broader aspects of society and the potential for wealth creation in order to contemplate health, education and skills in populations.

In the category related to stakeholder participation, most articles deal with the stakeholder influence (19) followed by the information provision (15). Thus, the authors highlight the empowerment of stakeholders and the importance of more effective positioning and relationship strategies, especially of the most fragile members in the agrifood supply chain. Another highlight in the indicators is related to the provision of information, in order to reduce the asymmetry in supply chains, as well as providing social and environmental information to different internal and external groups.

The indicators inherent in internal human resource organizations have shown to be practically aligned with issues of prevention of occupational diseases and labor safety actions, framed under the health and safety indicator.

The results related to macro-social issues obtained a lower number of approaches among the other indicators considered in this study, addressed in only six articles when considering aspects related to social and environmental performance. The socio-environmental performance of a macro-social analysis considers social and environmental transformations at regional and national level, being one of the reasons for the low approach in these studies, since the impacts on a larger scale are generated by enterprises with larger scale of agrifood production and extrapolate most of the articles, which are practically composed of case studies.

The articles that compose the sample presented indicators of social sustainability that presuppose that, for its effectiveness and transition to sustainability in agrifood supply chains, it is necessary to provide cooperative or collaborative arrangements among stakeholders. Silva and Lourenzani [28] stress that cooperative arrangements between agents of an agrifood supply chain favor alternatives for the insertion of more fragile entities into the distribution and commercialization channels, and also in the improvement of social welfare.

Based on the collective and integrative cooperation and collaboration relationships identified in the sample articles, as specified in Table 59.2, it is noteworthy that all articles displayed cooperative approaches. Among the cooperative actions identified, these were classified according to Britto [5] and are also presented in Table 59.2. In the classifications of cooperative approaches, interorganizational cooperation was predominant (25), followed by technological cooperation (21) and, finally, technical-productive cooperation (11). Therefore, there is a predominance of cooperation involving elements that influence decision-making between chain entities or the cooperative network, followed by cooperative actions related to information exchange

Table 59.2 Categories of cooperative and collaborative actions

Authors	Cooperative actions	Collaboration	Vert.	Horiz.	Collaboration relations
Manning et al. [21]	Interorganizational				
Rimmington et al. [25]	Interorganizational and technological				Consumer/supplier
Fearne et al. [12]	Interorganizational	Information sharing/technological and scientific dissemination	X		Retailer/supplier
Setthasakko [26]	Interorganizational				
Blanc [4]	Technical-productive, interorganizational and technological	Information sharing/infrastructure sharing/technological and scientific dissemination		x	Among suppliers
Cross [8]	Technical-productive, interorganizational and technological				
Spence and Bourlakis [29]	Interorganizational and technological	Information sharing/technological and scientific dissemination	X		Retailer/supplier
Oglethorpe and Heron [22]	Technical-productive, interorganizational and technological				
Pulina and Timpanaro [24]	Technical-productive	Technological and scientific dissemination	X		Supplier/industry /consumer
Wang and Sarkis [32]	Interorganizational and technological	Technological and scientific dissemination		x	Among restaurants
Zhang and Chen [35]	Interorganizational	Information sharing	X		Industry/retailer

(continued)

Table 59.2 (continued)

Authors	Cooperative actions	Collaboration	Vert.	Horiz.	Collaboration relations
Urquhart and Acott [31]	Technical-productive, interorganizational and technological	Information sharing/infrastructure sharing/technological and scientific dissemination		x	Among suppliers
Manning [20]	Interorganizational				
Wiese and Toporowski [33]	Technical-productive, interorganizational and technological				Retailer/supplier
Davenport and Low [9]	Technical-productive, interorganizational and technological				
Chen et al. [6]	Interorganizational and technological	Information sharing	X		Retailer/supplier
Bisogno [3]	Interorganizational and technological	Information sharing/infrastructure sharing/technological and scientific dissemination		x	Among suppliers
Shnayder et al. [27]	Technological	Information sharing		x	Among industries
Jacob-John and Veerapa [15]	Interorganizational and technological				
Tidy et al. [30]	Interorganizational				
Wilhelm et al. [34]	Interorganizational and technological				
Giovannucci and Potts [13]	Technological	Information sharing/infrastructure sharing	X		Industry/supplier
Beber et al. [2]	Technical-productive, interorganizational and technological				
Famiola and Adiwoso [11]	Technical-productive, interorganizational and technological	Technological and scientific dissemination	X		Industry/supplier

that optimize the innovation process and, to a lesser extent, cooperating to improve operational and production efficiency among chain or network agents.

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On the other hand, in collaborative actions, where an evolutionary relationship is expected and presupposes a joint implementation and shared management by common objectives within supply chains, 15 of the 29 articles collected in the sample displayed this type of integration among the members. Collaborative actions are classified according to Barrat [1], and it is shown that in the sample there was a predominance of collaborative interactions in information sharing (11) and technological and scientific dissemination (11). The results show that the collaborative arrangements are evidenced in researches that investigate agrifood supply chains of organizations where this interaction predominates to overcome information flow bottlenecks and promote technological cooperation between entities. The collaborative arrangements for infrastructure sharing and integration of the productive process were presented only in 6 and 1 articles of the sample, respectively.

Observing the analysis of these interactions, it can be seen that collaborative arrangements are scarce in articles when they refer to the infrastructure sharing and the production process, which shows very distinct characteristics of business among the members in the agrifood supply chain, since rural producers, retailers, wholesalers and branches of industry present a very distinct configuration of activity and economic and social development. However, because they are chains with a high degree of uncertainty and price volatility, overcoming bottlenecks related to information asymmetry and the incorporation of technological processes, especially for farmers, makes the research more compelling.

When verifying the types of collaborative interactions between vertical and horizontal, the latter was presented in seven articles and the former in nine. Considering the vertical collaborative interactions, the occurrences were: industry/supplier (3), retailer/supplier (3), supplier/industry/consumer (2) and industry/retailer (1). As for horizontal interactions, there was a predominance of interactions between suppliers (4) and, in the others, only 1 article.

The vertical collaborative relationships identified displayed a close relationship in the integrative relations with suppliers, which, in this case, are presented in most approaches with integrations between rural producers. The same happens in the horizontal interactions, with a higher frequency of rural producers, where the formalization of groups, associativism or cooperativism, shaped the collaborative arrangements. This information demonstrates that the authors' approaches to raise issues that involve relationships with farmers become necessary, since they are seen as the most sensitive and weakened link compared to other entities, hence the investigation of collaborative interactions next to partners and suppliers of the same level, with a view to forming collective arrangements to access markets.

The number of articles in the sample related to the state of the art of social sustainability in the agrifood supply chain in the last 10 years shows a growing tendency during the period considered that began in 2006, whose peak occurs in 2016, the year in which 7 studies were produced.

59.3 Concluding Remarks

This paper has identified, in the international literature, the state of the art of research on social sustainability in agrifood supply chains. Considering the general analysis of the selected studies, there is a large predominance of papers addressing social indicators related to actions with external populations that are affected, influenced or impacted in some way by members or processes. The most important aspects of the external population were those inherent to the human capital, in factors such as health, education and development of communities that supply raw materials. Another important sustainability indicator refers to stakeholder participation, where it addressed the empowerment of more fragile entities in the chain and overcoming market access bottlenecks with reduced information asymmetry to increase efficiency gains for the productive chains.

The studies analyzed predominantly expose interorganizational and technological cooperation. This predominance demonstrates that aspects related to the reestablishment of trust between the entities that participate in the agrifood chains in order to provide information exchange and improvement of production planning, especially for suppliers of raw materials, are a fundamental condition for the social sustainability of the chains. The analysis of the papers also shows that cooperative technological aspects are fundamental to reduce the uncertainties inherent in the agrifood supply chain.

As limitations, the research was restricted to bibliographic queries in some academic portals, and the results that demonstrate the state of the art are restricted to the sample analyzed. Because it is an exploratory and descriptive study, the results, as well as the sample analyzed, are not statistical; therefore, it is inappropriate to extrapolate for analyses at populational levels. In addition, the articles that are the object of this analysis are restricted to the social dimension in the agrifood supply chains, not extracting indicators related to the environmental or economic dimensions, although these are present in numerous articles of the sample.

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Chapter 60
Analysis of Potential Demand for Agriculture Products at Itaqui Port in Brazil

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Abstract This paper presents the potential demand at Itaqui Port for the three major groups of agriculture products exported by Brazil, in monetary values. A linear programming model was utilized, considering the shortest distance between origins, Brazilian State capitals, and destinies, the ten largest importing countries, passing through the port.

Keywords Brazilian ports · Itaqui Port · Mathematical model · Agribusiness · Transportation

60.1 Introduction

Agribusiness is very important for Brazil, contributing 23% of gross domestic product in 2017 [1]. The abundant natural resources and the area available to expand food production make Brazil a competitive country in the agricultural area [2]. However, the agricultural production gains can be limited by the lack of logistic planning and by the serious problems related to the poor infrastructure for the storage and transport of the agricultural production [3].

This paper aims to contribute with the logistics planning for the agribusiness and transportation sectors, by estimating the potential demand for exports of agricultural products in the Port of Itaqui, at the Maranhao State in Brazil, which is the sixth biggest port in Brazilian regarding economic transactions by sea in the year 2016, this according to data obtained from the Brazilian Ministry of Development, Industry and Foreign Trade—MDIC.

Exports that occur through the waterway sector reached about 80% of the total monetary value exported by Brazil in 2017. The modal is highlighted by the vast coastal extension that the country has, allowing greater availability for the movement of cargo through this alternative.

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The estimation of ports demand can help in the planning of: actions for improvement in the port sector; infrastructural capacity; in the destination of internally originated products to their best port of export.

The study was based on the three groups of agricultural products most exported by Brazil in monetary values, representing 27% of the FOB value, being: "grains," "meats," and "sugar." To estimate the demand, a linear programming model was developed and employed. It was used as data: the supply of selected products in the Brazilian capitals; the shortest distance between origins and destinations, measured in kilometers by the Brazilian road network; nautical miles converted into kilometers, between ports and importing countries; and the demand for such products from the ten largest importing countries of these Brazilian products. The model was solved in the software Lingo 17.0, academic version.

The optimum solution indicated by the model allocated a larger volume of products of the "meats" group and lower volume for the "grains" group, when compared to the volume exported by the Port of Itaqui in 2017.

60.2 Literature Review

In the literature review carried out in this research, no studies were found that were investigating the demand forecast for the Itaqui Port; however, different articles were found on the logistics related to the flow of agricultural products covering the Brazilian ports.

In the research carried out by Dos Santos Lopes et al. [4], the authors analyzed the export of soybeans originating in the State of Mato Grosso, concluding that the Port of Vitória and ports at the Northern region o Brazil would be the most efficient for this transportation. Oliveira et al. [5] were employed a mathematical model that considered the competitiveness between the Brazilian ports to calculate the attractiveness potential for the export of corn, with the same region of Mato Grosso as the origin of the grains to be exported. The results pointed mainly to exports through the Santos Port, which was responsible by the transportation approximately of 30% of total Brazilian exports in monetary value in 2017.

Lima [6] analyzed the logistics scenario of soybean exports, without the application of a mathematical model of transport. Do Amaral et al. [7] addressed the intermodality of soybean transport in Brazil. In this article, several models were analyzed to choose the ideal location for an intermodal terminal. The proposed model selected the intermediary points of soybean transactions, similar to the role of Brazilian ports exporting products to the destination countries studied in this work.

Branco et al. [8] used the multi-product minimum cost flow model for transport optimization of agricultural crops in the Midwest [8]. The authors used the multi-product minimum cost flow model. The results of the model delimit the best geographical locations for the movement of products in the Midwest, considering waterways and railways as points of intermodality. Branco et al. [8] highlighted the movement of domestic transport of cargoes for export, but without transport analysis for their export destinations.

Dos Reis [9] analyzed the sugar demand forecast for the Central-South rail network, considering the road network and the Brazilian ports of the main coastal regions, using the Bertsekas algorithm for flow allocation.

60.3 Port Logistics

Logistics is distributed in several branches, the component parts of a system, the scope of this work resumes the topic of transport in the logistics supply chain. Transport logistics is subdivided into five main modes: rail, road, waterway, pipeline, and air [10].

In the waterway sphere, it is possible to analyze modalities defined by Nogueira [11] as: maritime—characterized by coastal or oceanic navigation; cabotage—carried out between ports in the Brazilian territory; long course—responsible for the transaction of goods between Brazilian and foreign ports; river—navigation between rivers and canals; and lacustrine—performed via lakes. This study will focus on long-haul shipping for export.

From a water transportation perspective, Ballou [10] emphasizes that the predominant costs of this mean of transportation are related to the operations in the port terminals, since the loading and unloading in this process are very expensive, also dependent on the use of mechanized equipment linked to the infrastructure port. Another Brazilian problem in transport management is the lack of tools and computer systems that are accessible to the planning and execution of the work of the carriers [12].

From the point of view of Brazilian transport, it is possible to list some obstacles that are impediments for the logistics of cargoes in rail and road alternatives. According to Reis and Leal [3], rail transport is insufficient to meet the great demand, especially of grains in the country, while road transport has drawbacks in relation to the highly volatile cost and the low credibility of carriers in meeting deadlines and contracts. In relation to port infrastructure, the extremely high queuing time for loading and unloading of ships and land-based fleets is one of the major logistical bottlenecks [13].

Despite the importance of the port industry, Brazil still faces some problems. According to Wanke and Hijjar [14], the problem of cargo flow and the access to ports are among the main difficulties faced in the port transactions of goods.

This work analyzed different Brazilian ports, all of which are organized public ports which are responsible for the movement of passengers, handling and storage of goods and are under the jurisdiction of a Brazilian port authority. Through data collection of the export data available in the Alice Web System (controlled by the Brazilian federal government), twenty-seven administered public ports were selected that qualified to analyze the study.

Due to the scope of the research, a port was chosen in order to analyze the results of the model, taking that into account potential soybean exports from the promising MATOPIBA region (Maranhão, Tocantins, Piauí, and Bahia). The chosen Port was the Itaqui Port or Port of São Luís located in the State of Maranhão. It is in operation since 1972, consisting of six berths and an oil tanker. According to data from the MDIC, the Port of Itaqui already reached the sixth position in total monetary relevance in Brazilian exports in 2016, demonstrating its importance in this market.

60.4 Operational Research and Model

The model used to estimate the demand potential of the Itaqui Port was a mathematical model of linear programming, categorized by multiproduct flow problem for transport models [15].

The focus of the problem was on minimizing the distances traveled for the transport of multiple products, between origin (Brazilian capital) and destination (capital of the exporting country), passing through the Brazilian ports. The results make it possible to observe the demand potential of the Itaqui Port.

The minimization equation has the following indices: i (origin); j (port); k (destination); p (product) and follows these parameters: D_{ij} as distance between origin and port; D_{jk} as distance between port and destination; O_p as product supply; and D_p as product demand. Apart from that, it also has the following decision variables: F_{ijp} being the volume transported between origin and destination port by product and F_{jkp} as volume transported in the flow between port and destination by product, having as an objective function:

$$\text{Min} \sum_{ijp} D_{ij} F_{ijp} + \sum_{jkp} D_{jk} F_{jkp}. \tag{60.1}$$

The constraints of the model were also defined by the constraints of demand (60.2), supply (60.3), and flow (60.4).

$$\sum_{j} F_{jkp} = D_{kp} \forall (p \in P). \tag{60.2}$$

$$\sum_{j} F_{ijp} \leq O_{ip} \forall (p \in P). \tag{60.3}$$

$$\sum_{i} F_{ijp} = \sum_{k} F_{ikp} \forall (p \in P). \tag{60.4}$$

Through the data collected, it was possible to apply the proposed linear programming model for the multiproduct flow problem. The software chosen for the computational application of the model was Lingo software—version 17.0. The results were obtained in 0.45 s with an Intel Core i3 2.0 GHz computer with 4 GB of RAM.

60.4.1 Data Delimitation and Collection

In methodological terms, the study is included in the field of design science research by obtaining results from models and methods and not by action, as classified in Research-Action [16]. The approach used was quantitative with the application of the data determined and obtained through different electronic means and physical documents.

This research considered the supply of three groups of products most exported in monetary terms in agribusiness in 2017: 1—Grains Group, responsible for 7% of total FOB US$ (Code 12—oil seeds and fruits, grains, seeds and various fruits, plants' industrial or medicinal, straw and fodder); Group 2—meats—7% of total FOB US$ (Code 02—meat and offal); Group 3—sugar—6% of total FOB US$ (Code 17—sugar and confectionery) and the demand for these products in the ten main buyers countries.

The values of supply by state that produced/cultivated/extracted the three chosen products and the demand data of each product by country of destination for the study were withdrawn from the Alice Web System between January and February 2018, considering the net kilogram exported in the year 2017. This site provides regulated queries that are made available by the Brazilian Ministry of Development, Industry, and Foreign Trade (MDIC).

The capitals of the 26 Brazilian states and the Federal District were considered as the point of origin, the Brazilian ports as outlets for these three product groups, and the ten countries that most imported these products in 2017 as destination. The countries delimited were: Bangladesh; China; Egypt; Hong Kong; Iran; Japan; Saudi Arabia; Netherlands; Russia; and the United Arab Emirates.

The Brazilian ports chosen as the outlets were: Manaus; Salvador; Natal; Santana; Niterói; Santarém; Paranaguá; Santos; Rio de Janeiro; São Francisco do Sul; Porto Alegre; San Sebastian; Suape; Recife; Rio Grande; Vitoria; Itaqui; Fortaleza/Mucuripe; Itajaí; Ilheus; Aratu; Imbituba; Areia Branca; Itaguaí (Sepetiba); Belém; Cabedelo; Maceió.

The distances between the origins to the ports and ports to export to destination countries were collected in three different ways. Through the Google APIs' tool; through the distance table defined by Antaq between the Brazilian ports and through the use of the site distances.com. For the internal distances of Brazil was used the Brazilian road network, measured in kilometers. Between ports and importing countries, distance data were obtained in nautical miles and converted to kilometers.

60.5 Results

Table 60.1 shows the optimal allocation in the Brazilian ports obtained by the model for the three product groups analyzed. The potential distributions of exports between ports and destinations are shown in Table 60.2, and international acronyms were used to designate the countries that received the products through their ports: BAN—Bangladesh; CHN—China; EGY—Egypt; HK—Hong Kong; IRI—Iran; JPN—Japan; KSA—Saudi Arabia; NED—Netherlands (Holland); RUS—Russia; UAE—United Arab Emirates.

As a general analysis, it can be seen from Table 60.1 that some ports were not allocated as an optimal solution for any of the three groups of products analyzed. The proximity between some selected ports and the difficulty of internal and external movement are relevant causes for this result. For the sugar product, the distribution was concentrated in the Port of Santos with more than 50% of the volume of exports, corroborating with the study of Reis and Leal (2007).

The Ports of Santos and Rio Grande were the main ports chosen for exports of the group of grain products with, respectively, 36.7 and 25.7% of the total exported volume. These high values were achieved mainly by the primary demand for seeds from one country, China.

Table 60.1 Optimum allocation in the Brazilian ports by the analyzed products

Port	Origin		
	Meat	Grains	Sugar
Areia Branca, RN	DF/GO/MS		GO
Belém, PA	PA	PA	
Cabedelo, PB	PB	PB	PB
Fortaleza/Mucuripe, CE	CE	CE/PI	CE
Ilheus, BA		TO	
Imbituba, SC	SC	SC	
Itaguaí (Sepetiba), RJ		MG	
Itajaí, SC	PR	PR	PR
Itaqui, MA	MA/TO	MA/TO	
Natal, RN			RN
Porto Alegre, RS			RS
Refice, PE	BA/MG/PE	PE	AL/MG/PE
Rio de Janeiro, RJ	SP/RJ	DF/MG	SP
Rio Grande, RS	RS	MS/RS	
Salvador, BA		BA	
Santana, AP	AC/MT/MS/RO	AP/TO/RO/RR	GO/MS
Santos, SP	SP	GO/MT/SP	SP
Vitória, ES	ES	ES	

Table 60.2 Optimum allocation in the importing countries for the products analyzed

Port	Destination		
	Meat	Grains	Sugar
Areia Branca, RN	KSA		KSA
Belém, PA	NED	KSA/UAE/IRI/NED	NED
Cabedelo, PB	NED	NED	NED
Fortaleza/Mucuripe, CE	NED	IRI	NED
Ilheus, BA		CHN/HK	
Imbituba- SC	BAN/UAE/IRI/JPN	CHN/BAN	
Itaguaí (Sepetiba), RJ		CHN	
Itajaí, SC	CHN/HK	CHN	CHN/HK/IRI/JPN
Itaqui, MA	EGY	EGY/NED	
Natal, RN			EGY
Porto Alegre, RS	UAE		BAN
Refice, PE	KSA/EGY/NED	IRI	KSA/EGY/NED
Rio de Janeiro, RJ	EGY	JPN	EGY
Rio Grande, RS	CHN	CHN	
Salvador, BA		CHN	
Santana, AP	RUS	RUS	RUS
Santos, SP	CHN	CHN	BAN/UAE/IRI
Vitória, ES	EGY	CHN	

For the meats' group, the Port of Santana was able to absorb more than 10% of the volume exported by four different origin states and send it to a destination country, Russia.

The Port of Itaqui obtained flow of cargo originated from the state of Maranhão and Tocantins for two groups of products, meat and grains, and was not allocated to the sugar group. The importing countries that received cargo flow from Itaqui were Egypt, receiving meats and grains and the Netherlands, receiving grains, as shown in Table 60.2.

The recent agricultural developed region known as MATOPIBA, a soy production region, has the Itaqui port as the main logistical hub.

For the meats' group, the model allocated 0.7% of the Brazilian volume to the Port of Itaqui, 4.3 thousand net tonnes (0.1%) from Maranhão and 23.2 thousand net tonnes (0.6%) of Tocantins, both to the destination Egypt. Regarding the actual export data for 2017, the Port of Itaqui did not transport the meats group, but the port was already responsible for the transaction of this product in previous years.

Regarding the grains group, the model allocated 2.7% of the total Brazilian volume to the Port of Itaqui, 1.423 thousand net tons (2.4%) from Maranhão and 164 thousand net tons (0.3%) from Tocantins, of which 93% is for the Netherlands and 7% for Egypt. Regarding the real export data for 2017, the Port of Itaqui exported

4787 thousand tons of the grains group, 0.4% of which was for the Netherlands and Egypt, from the states of Maranhão, Mato Grosso, Pará, Piauí, São Paulo, and Tocantins.

This result may indicate that the grains' product has a lower cost of road transport if it is exported from another port, but since no port capacity restriction was considered in this model, it is possible that other indicated ports do not have adequate capacity and sufficient infrastructure to support the flow of such product.

As for the sugar product, the model allocated more than 50% of the total volume of sugar exported to the Port of Santos. The Port of Santos stands out mainly for the proximity of the states that offer the goods of the category "sugar" in Brazil, considering that more than half of the volume offered concentrates in the Southeast region. The Port of Itaqui did not obtain any volume moved to the product via mathematical model and did not move such product in 2017.

60.6 Conclusion and Further Research

The article proposed to analyze the potential demand of the three main products exported by Brazil through the Port of Itaqui, located in Maranhão, northeastern Brazil. In addition to contributing to studies in the state of Maranhão, the work resulted in a directly applicable model for the analysis of potential demand for products for other Brazilian ports.

Among the three products selected, two of them had an optimal allocation for export through the Port of Itaqui: "meats" (Code 02) and "grains" (Code 12). The sources selected by the model for the Itaqui Port flow were the states of Maranhão and Tocantins. In terms of destinations, the optimum points for disposal were Egypt (EGY) and the Netherlands (NED).

According to MDIC data, taken from the AliceWeb platform, the Port of Itaqui in 2017 was responsible for the transaction of 8% of total exports of "grains" (Code 12) for the ten countries considered in this study, for the optimal resolution of the model was the potential demand for this product would be lower than that already achieved, accounting for 3% of total exports. In relation to the product "meat," the port would be responsible for 0.7% of the total turnover, and for the "sugar" group, there was no allocation via mathematical model and there was no movement in 2017 by the Port of Itaqui.

A limitation of this work was that the lowest cost between origin and destination was directly proportional to the distance measured by the road modal, disregarding the real cost of freight, taxes, and the possibility of using other modes.

For future studies, it is suggested a more concise analysis on the main trade-offs to choose a port of export for a particular product and the improvement of the model with the inclusion of other parameters, such as freight and port costs, as well as capacity restrictions.

The modeling results can be used to assist public actors in future discussions on Brazilian port management in special regarding the Port of Maranhão or other specific ports. In addition, due to the model's result, it was possible to notice that the movement of the products analyzed in this study in the year of 2017 by the Port of Itaqui was not optimal when considering the shortest distances, which implies that, maximum with exports, or other factors being considered, such as capacity constraints, differentiated freights, port costs, transaction facility, and other qualitative aspects.

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Chapter 61
The Impacts of Non-address Balancing on the Productivity of a Picking Line

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Abstract The objective of this work is to analyze the effects of address balancing for the productivity of a *picking* line in a distributor. The development of the research was based on the study of the times involved in the process and identification of the product rotation through the ABC curve.

Keywords Picking · Study of times · Chronoanalysis · ABC curve

61.1 Introduction

Over the years, industries and service providers are looking to develop their processes continuously in order to become more competitive in the market and exceed the expectations of their customers. The logistics activity performed by the organizations, once seen as an isolated factor and considered as just one of several departments of companies, is now seen as a strategic factor for increasing organizational competitiveness. Due to the dynamism that involves the commercial operations, it perceived the necessity of evolution of the logistic systems in a form that adapted to the characteristics of each time.

Thus, the concepts of integrated management and supply chain became widely diffused and as highlighted by Ballou [1] logistics is part of the supply chain process, which means that it includes all the important activities for the provision of goods and services, when and where they wish to acquire them. Among the various branches of industries and services that require an efficient logistics activity, we have the logistics of pharmaceutical distribution as an example, due to the complexity of the product involved.

Among the activities carried out in the distribution centers, involving storage, separation, conference and shipment, picking is performed manually, as one of the

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activities of greater complexity and that demands a specific attention within the DC. The storage of products is related to the picking activity because it interferes directly in the arrangement of the items that will be separated, and for this reason, the stocking process must be well managed in order to guarantee a balance between stock and consumption [5].

The classification of items according to the ABC curve provides a better arrangement of the products according to the frequency of sale, allowing the picking line to be adjusted and increasing the separation productivity. According to Dias [4], in addition to contributing to inventory management, the use of the ABC curve also assists in the definition of sales policies and production scheduling.

According to the aforementioned facts, this study aims to analyze the impacts of non-balancing on the picking line of a pharmaceutical distributor and what its influence on the productivity of the operation. The theoretical contribution of the research is justified by the low number of studies relating address balancing to the picking line, and its practical cooperation is based on the possibility of identifying opportunities for improvement of the separation activity. The analysis of the results will propose measures that aim to increase productivity and service level of the operation through the use of tools that improve the identification of product turnover, impacting on the correct allocation of the items in the picking line.

61.2 Theoretical Base

The picking or sorting of request is the activity responsible for collecting the products, in the correct quantities from the storage area to meet the needs of the consumer. This activity is of paramount importance to the company, since it allows the increase of productivity, which makes this process directly linked to the optimization concept [6]. A survey conducted by storage professionals in the UK identified the picking process as the warehouse's top priority for productivity improvement [9].

When the organization intends to make better use of the available operational capacity and an adequate disposal of the products in stock, techniques should be applied to measure losses, gains and what opportunities for improvement can be verified. Thus, the analysis of the time involved in the picking process is of significant importance for best practices and new methods, both for the activity performed and for the parallel operations, and for the ability of the company management to be transmitted to the employees [2].

According to Peinado and Graeml [8], the study of times, movements and methods approaches techniques that submit to a detailed analysis of each operation of a given task, aiming to eliminate any unnecessary element to the operation and determine the best and most efficient method to execute it. In the picking operation, using chronoanalysis, it is possible to verify the inefficiency points of the process and according to Oliveira [7], the application of this technique is indicated when there is a need to improve productivity and to understand what happens in the production process and check the waste of time.

The adoption of a method of organization of the products according to quantity data requested is an ally to reduce time wastage with respect to the movement of the separator in the picking line. Thus, the use of the ABC curve in addition to classifying inventories according to their monetary representativeness can be seen as a key tool to assist in the disposition of the products in the picking according to the rotation of each item and according to Costa [3], the ABC curve, also called the Pareto curve, is an important tool that has been widely used lately by several areas of knowledge for decision making.

In the ABC classification, products classified as "A" are those that have a higher demand; "B" are products that have a considerable demand, but that is lower than the items of curve "A" and "C", which represents the products of lower handling. Maiellaro et al. [5] define the ABC classification as methodology, which aims to separate the items into groups of similar characteristics, according to their consumption and values, in order to proceed to an appropriate management process for each group.

61.3 Methodology

The study was conducted at a Distributor of Medicines and Pharmaceuticals located in Teresina, Piauí, and will analyze the impacts of non-balancing picking line addresses on operational productivity and seek strategies that should be used to improve the process by the use and classification of product turnover by the ABC curve. The analyses were carried out from May to August of 2018, in which the optics of the collaborators who carried out the activity in the sector were analyzed, the analysis of the authors *in loco* and the statistical data verified through the sales frequency of the distributor.

Regarding the design, this research is classified as a case study in which "it is an empirical investigation that investigates a contemporary phenomenon in depth and in its real-life context, especially when the boundaries between the phenomenon and the context are not clearly evident" [10]. The classification of the technical procedures is a field survey carried out by observing the tasks performed by all the people involved in the process that will be studied, as well as conversations with the employees to verify the complexity of the activity performed and the empirical perception about the medicines which have higher and lower turnover. In this classification, the research also fits as bibliography, since it will be developed with theoretical basis of books, journals and articles that approach the theme and the problematic research.

61.4 Results

The company's main activity is the distribution of medicines and hygiene and beauty products. Its main customers are drugstores, pharmacies and hospital networks throughout the state in which it operates. The sector of application of the study—

separation—is one of the five subsectors of internal logistics, divided into: receiving, stock replenishment, medicines separation, conference and request dispatch.

The separation operation consists of collecting products in the warehouse, being able to be of different categories and units, according to the request of the customer, in order to satisfy it. For this, the sector is divided into alphanumeric addresses, which are arranged sequentially along stations, characterizing the type of separation by zone, where each employee is associated with one of these zones.

This form of separation is the most appropriate to the company due to the nature of its operations and facilities. With a large storage area, the warehouse has approximately 4150 different items, requiring different methods of packaging and handling.

Shipping 2000 orders and moving 80,000 units on average daily, the separation activity has a high degree of complexity, requiring a lot of concentration and focus of the employees involved, and it can be done in two ways: separation in the "thick" stock and the "fine" stock.

The separation in the wholesale stock is made when the customer requests a standard box, with quantity pre-established in its manufacturer, having little representative in the sales of the company. The separation in the fine stock is made when the customer requests a lower quantity than the standard box, being the one of greater representativeness in the sales and object of study of that research.

As already mentioned, the addresses are alphanumeric, where the letter represents the station where the product is located and the numbers indicate the exact location of those items in the stock (following established sequence). Thus, the collaborator responsible for the separation waits for requests that are slipping under a conveyor belt to arrive at his station. Upon arrival, the employee must check if the request requests any medication from the station, to effect the separation, and at the end of pushing the request to the next station.

The products are arranged in plastic boxes, which are allocated on shelves and in the flow rack, a storage system with shelves slightly inclined in which allows the plastic boxes to slide on rollers as they are emptied and removed. It has two faces, one for replacement and the other for separation.

In these structures are stored different goods, all identified with their respective addresses. The flow rack, because it is coupled with the conveyor belt where the orders are sent and allows the packing of several boxes, is used to allocate the drugs of curve A. The shelves, in their two forms of spatial configuration and because they are relatively distant from the treadmill, are used to allocate the drugs of curve B and C. A simple illustration of the spatial arrangement of the goods in the stock in which the separation process occurs can be seen in Fig. 61.1.

The monitoring of the sale of products in stock must be carried out quarterly, so that the balance of products can be realized according to the sale of the quarter, that is, change the position products according to changes in their sales. This measure aims to reduce the loss of productivity by unnecessary movements in the separation process.

However, it was observed that the responsible parties, resulting in bottlenecks throughout the process, making it difficult to replace the goods and generating a disorganization in the separation area, were not carrying out this balancing.

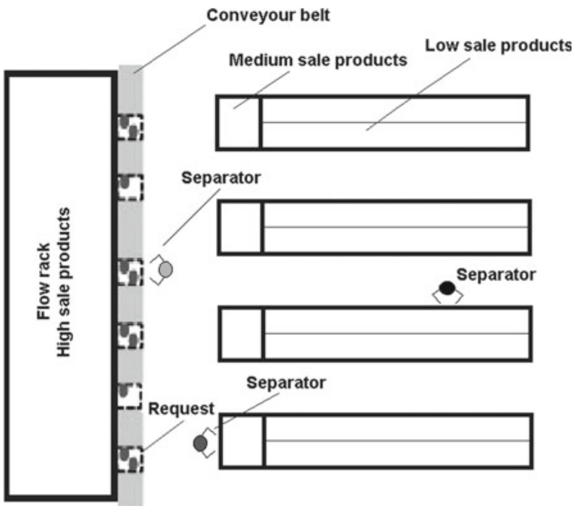

Fig. 61.1 Spatial arrangement of goods in stock

In order to know more about the effects of balancing products in stock and their relation with the operational productivity, the process of separation of goods, and to be able to present pertinent information about the need of the activity to the responsible ones, a study of times was made in the sector.

Three different profiles were selected for time analysis: high-performance separator, medium-performance separator and low-performance separator, based on the work rhythm observed in the development of the activities performed in the sector. In a complementary way, the study was carried out in all separation stations and in three different periods: beginning of shift, half of shift and end of shift, seeking to cover characteristics of the process in these periods throughout the day. Measurements with external interference were disregarded.

The number of cycles to be considered for the analysis was twenty measurements for each separator profile, per shift. From this, the standard time, measured in seconds, can be observed in Table 61.1.

Knowing the times, we tried to identify how many addresses were wrongly allocated. With the aid of the system, a report with sales information was generated, classifying the products according to the ABC curve. Crossing this classification with the existing addressing, it identified which products were allocated wrong, according to Table 61.2.

The same report informs the frequency that the addresses were requested during the quarter. So, can be calculated how much time was being lost by the lack of balancing on the separation line. The analysis was done in relation to only the addresses that needed balancing, according to Table 61.3.

Taking into account all the analyses performed on the picking process, the impact of non-balancing on productivity is evident. The result of the time study shows a loss of 206.2 h with unnecessary movements during the analyzed quarter, totaling more than the monthly workload of a collaborator. Thus, it is necessary to establish

Table 61.1 Standard time calculation

Performance	Curve	Average time/shift	Average time
High performance	A	12.92	13.80
Medium performance		13.57	
Low performance		14.92	
High performance	B	14.63	15.63
Medium performance		15.37	
Low performance		16.90	
High performance	C	23.93	25.56
Medium performance		25.12	
Low performance		27.64	

Table 61.2 Percentage of wrongly addressed products

Products curve	Correctly addressed	Wrongly addressed	% Wrongly addressed
A	384	336	46.7
B	395	973	71.1
C	1566	499	24.2

Table 61.3 Analysis of separation times before and after balancing

Current location	Requested frequency	Separation time before balancing (h)	Separation time after balancing (h)	Difference (h)
Curve A				
Curve B	31,968	138.8	122.5	**−16.3**
Curve C	28,517	202.5	109.3	**−93.2**
Curve B				
Curve A	9035	34.6	39.2	**4.6**
Curve C	40,402	286.9	175.4	**−111.4**
Curve C				
Curve A	405	2.9	1.6	**1.3**
Curve B	3200	22.7	13.9	**8.8**

a frequency so that the addresses are balanced in order to obtain gains in operational productivity and increase the competitive potential of the organization.

61.5 Conclusion

In the study indicated in this article that aimed to verify the impacts of the lack of balance in the productivity of the picking line, it verified the extreme importance of the process monitoring so that the organization can identify gaps in the executed operations. Based on the theories about chronoanalysis, time, productivity and ABC curve, the necessity of applying these tools and methods in the picking sector was evidenced, corroborating with the literature regarding the increase of productivity and improvement of verified processes after completion of this study.

From the development of the research, it was also possible to obtain a view of all the factors that can interfere in the increase of separation time and that impact on the loss of productivity. This monitoring of the performance of the operational routine through chronoanalysis enabled the verification of product disposition failures, since the sector studied does not have a periodicity to perform the picking line balancing.

By analyzing the times measured and comparing this information with the demand quantity data, it was verified that the non-balancing of the picking line has a great impact on the level of productivity, impacting on the logistics performance and that the organization of the items according to the ABC rating would be instrumental in reducing employee waste of time and increasing efficiency levels of the operation.

In order to seek the continuous improvement of the logistics activities performed at the distributor, it is imperative that the operation being studied continues to be monitored and that further research is carried out establishing the need for frequency of line balancing and that a standard operating procedure is being developed to carry out the new disposition of products considering the turnover of each item.

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Chapter 62
Transporting Soybean from Brazil to China Through Green Corridors

Thiago Guilherme Péra, Daniela Bacchi Bartholomeu, Connie Tenin Su and José Vicente Caixeta Filho

Abstract Brazil has been a leading supplier of soybeans to China, and in recent years, both production and export Brazilian levels have significantly expanded. On the other hand, society is demanding actions that promote the most integrated, efficient and environmentally friendly transportation involving long-distance routes. The objective of this article was to evaluate the potential of strategies to promote green corridors of soybean exports from Brazil to China. We can conclude that the scenario that consolidates the green corridor of low GHG emissions is one that expands the capacity of the rail terminals of Alto Araguaia and Araguari and increases the capacity of the ports of Santos, Paranaguá and Vitória, besides the use of ships of the type Capesize using the Cape of Good Hope route.

Keywords Mathematical model · Maritime transport · Soybean

62.1 Introduction

The global soybean production rose 14 times between 1950 and the 2009/2010 crop year, from 17 to 250 million tons. In the same period, the global grain production increased only four times [1]. Soybean production keeps increasing and reached 348 million tons in the 2016/2017 marketing year [2].

There are four major players in the global whole soybean export market: China, the main importer, and the USA, Brazil and Argentina, the main exporters. Brazil has two main advantages in this market. The major strategic advantage is a large capacity of expanding soybean planted areas, in opposition to the decrease in planted areas in the USA [1]. The second advantage is that Brazilian soybeans yield about 4.5% more oil and have 4.5% more protein than US soybeans [1]. On the other hand, Brazil's transportation system is inferior to the USA's, increasing transportation costs and lowering profits. The situation is more critical in the Centre-West of Brazil, which

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includes Mato Grosso, the highest soybean-producing state. Trucks transport most of produced soybeans from farms to ports and travel more than a thousand miles in low-quality highways. In the ports, trucks and ships may face long queues, which lead to high waiting times [1]. This inefficiency causes transportation from Mato Grosso to Brazilian ports to cost more than four times the transportation from American Midwestern states to American ports. Even the lower costs of labor and other inputs in Brazil do not compensate for the higher transportation costs [1].

The objective of this article was to evaluate the potential of strategies to promote green corridors of soybean exports from Brazil to China.

62.2 Literature Review

62.2.1 The Brazil–China Soybean Trade

Brazil and China began informal trade in 1949. In the 1990s and in the early 2000s, there was a formal agreement, which led to a boom in bilateral trade [1].

From 1998 to 2017, Brazil's whole soybean exports to China increased 53 times, from 0.9 to 49.9 million tons [3] becoming the main Brazilian exported product and the main destination with 9.8% of total Brazilian exports [4]. Since 2015, the value of Brazilian whole soybeans exported to China is greater than Brazilian second most exported product, iron ore, considering all its destinations [4].

Three main factors explain this rapid advance. Firstly, the Brazilian government offered subsidies and price supports to soybean farmers, increasing exports and generating currency to pay for imports, e.g., petroleum [1]. Secondly, Japan provided technical assistance to increase soybean production on marginal areas. Finally, the US soybean export embargo in 1973 artificially raised soybean world prices, turning it into a highly profitable crop [1].

62.2.2 Soybean Exportation Logistics: From Brazilian Centre-West Farms to China Ports

The Centre-West region of Brazil comprises the states of Mato Grosso, Goias, Mato Grosso do Sul and the federal district. It is the main soybean-producing region, with 46% of total Brazilian production for 2015/2016 crop year [5], and the second main region exporting to China, with 37% of total Brazilian soybeans exported to China in 2017 [3].

Mato Grosso is the biggest soybean-producing state, with 27% of total Brazilian production for 2015/2016 crop year [5], and the biggest state exporting soybeans to China, with 23% of total Brazilian soybeans exported to China in 2017 [3]. Mato Grosso's whole soybeans are exported to China mainly through the port of Santos, with 61% of volume in 2017 [4]. Until 2016, the ports of Vitoria and Paranagua alternated second and third places, with the port of Sao Francisco do Sul occasionally following close. However, from 2015 the ports of Barcarena and Sao Luis became more competitive, assuming second and third places in 2017 with, respectively, 15 and 8% of Mato Grosso soybean exports to China [4].

The soybean production travels at least 1100 km by truck from farms to the port of Miritituba, located on Tapajos River. This journey through highway BR-163 lasts three days. At the port of Miritituba, soybeans are loaded onto barges and transported along 1000 km for another three days, reaching the port of Barcarena, where they are loaded onto Panamax-size vessels [6–8]. This northern route allows a time reduction of 15% in shipments to China and a transportation cost reduction of approximately 34% [8], which compensates payment of fees to cross the Panama Canal [7].

Trucks transport 67% of Brazilian whole soybean production, traveling long distances from farms to ports, with an average of 900–1000 km [9]. In contrast, from 2002 through 2011, trucks transported only 13% of the US exported soybeans, with 50% being transported by barge and 37% by rail [10].

Figure 62.1 presents the logistic export corridors of grain in Brazil.

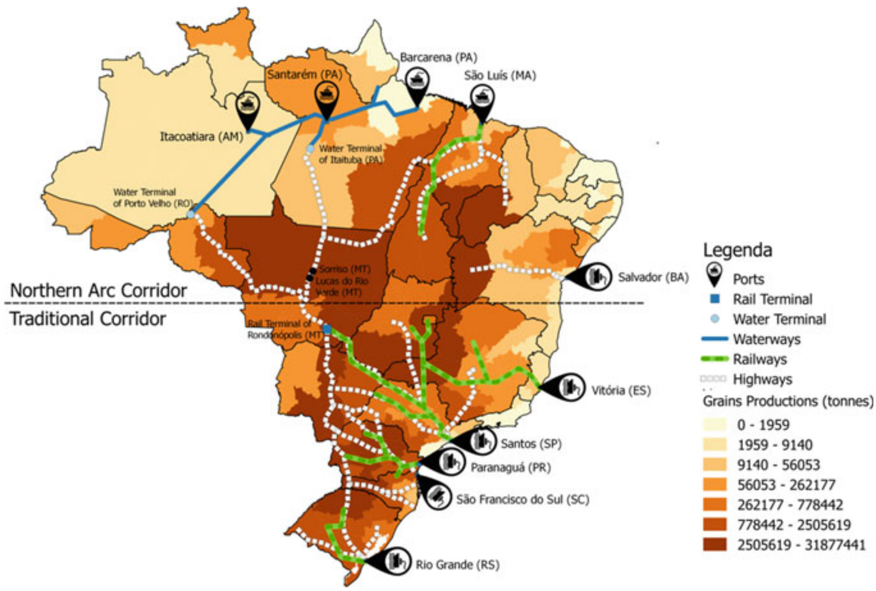

Fig. 62.1 Export logistic corridors of Brazil with emphasis on Mato Grosso. *Source* Prepared by the authors based on data from Brazilian Institute of Geography and Statistics—IBGE [11]

62.2.3 Green Transport Corridors

The concept of “green transport corridors for freight” was introduced in 2007 in the European Commission’s Freight Transport Logistics Action Plan. This document introduced a series of policy initiatives and a number of short- to medium-term actions to develop integrated, efficient and environmentally friendly transportation of freight between major hubs and over relatively long distances. It has a view to develop sustainable and competitive co-modal freight services in Europe [12–16].

Still, “industry will be encouraged along these corridors to rely on co-modality and on advanced technology in order to accommodate rising traffic values, while promoting environmental sustainability and energy efficiency. Green transport corridors will … be equipped with adequate transshipment facilities at strategic locations … and with supply points initially for biofuels and, later, for other forms of green propulsion. Green corridors could be used to experiment with environmentally-friendly, innovative transport units, and with advanced Intelligent Transport Systems (ITS) applications” [14, 15].

This concept was developed further within the SuperGreen. This project was launched in 2010 to support the Action Plan on green corridor issues [16]. It was also epitomized by the 2011 White Paper on Transport, which aims to shift road freight carried over 300 km to more environmentally sustainable modes, such as rail or waterborne transport (30% by 2030 and 50% by 2050), in order to achieve an overall 60% greenhouse gas (GHG) emission reduction [12, 17].

The set of key performance indicators (KPIs) proposed by the SuperGreen project resulted from a process that included the compilation of a list of performance indicators and their categorization into different groups. In the final set, indicators focus on economic (efficiency and service quality) and environmental aspects. The infrastructural and social aspects are absent [14, 16].

Table 62.1 details the KPIs chosen to evaluate green corridors in some of the studies found in international journals when searching for keywords “green transport/freight/logistics corridors” [12, 18, 19, 14, 15]. The green aspects that are mostly considered reflect economic (cost and service quality) and environmental (CO_2 and pollutant emission) issues. It is important to highlight that, in general, they: (a) have a qualitative approach; (b) are derived on or are related to the SuperGreen project; and (c) apply the KPIs to evaluate green corridors in Europe.

Table 62.1 KPIs chosen to evaluate green corridors

KPI		Study				
Group	Indicator	Aditjandra	Clausen	Fozza	Psaraftis	Panagakos
Efficiency	Absolute/relative transport costs	x	x	x	x	x
	Loading factor incl. return cargoes		x			
Service quality	Reliability (on time deliveries)	x	x	x	x	
	Frequency of service	x	x	x	x	
	Cargo security	x	x			
	Cargo safety	x				
	Transport time or speed		x	x	x	x
	ICT application		x			
Environmental sustainability	CO_2 emission	x	x	x	x	x
	Polluters (NO_x, SO_x, PM emission)		x	x	x	x
Infrastructural sufficiency	Congestion	x	x			
	Bottlenecks	x	x			
Social	Land use	x				
	Noise	x				
	Cargo security/safety	x				
	Congestion	x				
	Bottlenecks					
Quantified KPIs?		Yes	No	No	Yes	Yes

Source Organized by the authors

62.3 Materials and Methods

The methodology of the study aims at evaluating strategies for the consolidation of green corridors in the logistics of supplying soybeans from Brazil to China. The structure involves the movement of soybeans from the producing regions on farms in the Brazilian Midwest (Mato Grosso, Mato Grosso do Sul and Goiás) through the various logistical infrastructures available (highways, railways and waterways) to the main Brazilian export ports to China. In the sequence, the behavior of maritime transport flows from the Brazilian ports to China using different types of ships (Panamax, post-Panamax and Capesize) was modeled on two distinct maritime routes involving Cape of Good Hope (South Africa) and Panama Canal. Figure 62.2 shows the logical structure of network logistics modeling.

Figure 62.3 summarizes the logical structure of the methodology used in this article, involving the input data, description of the mathematical model and the main results generated.

We analyzed six scenarios identifying results such as mean transport cost, average greenhouse gas emissions (kg of CO_2 per ton transported by soybean) and quantity handled in each logistic activity. Table 62.2 presents the configuration of each analyzed scenario, changing parameters and adjustments in the mathematical model. The mathematical model was built into MS Excel spreadsheets and was processed using the simplex LP algorithm. Table 62.2 shows the description of scenarios evaluated.

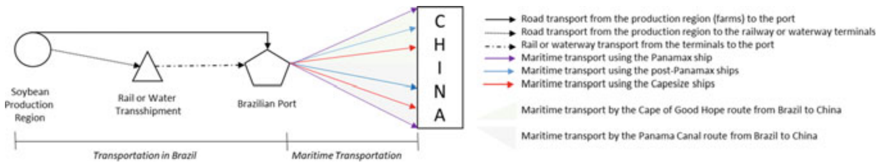

Fig. 62.2 Graph of the logical structure of modeling

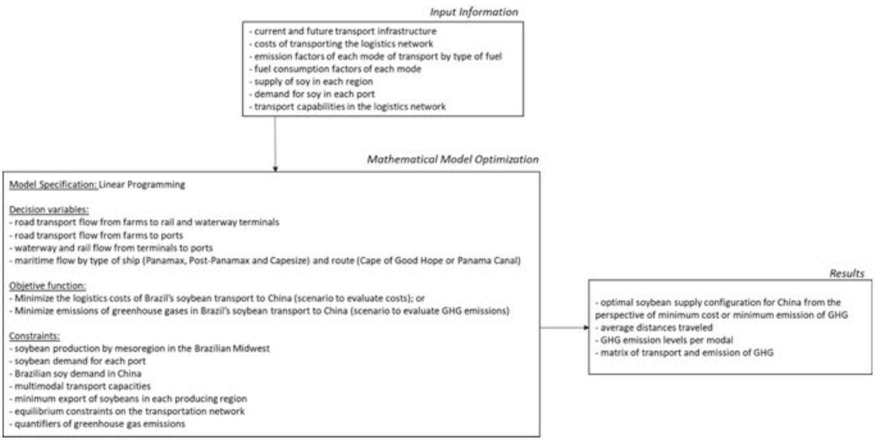

Fig. 62.3 Description of the modeling structure

Table 62.2 Description of scenarios-Configuration of each analyzed scenario

Settings in the model	S1	S2	S3	S4	S5	S6
Objective function (minimiz-ing)	Logistics costs	Logistics costs	Logistics costs	Logistics costs	Logistics costs	GHG emissions
Panama Canal toll fee	Yes	No	No	No	No	No
Restriction of railway capacity	Yes	Yes	Yes	Yes	No	No
Restriction of waterway capacity	Yes	Yes	Yes	Yes	No	No
Restriction of port capacity	Yes	Yes	Yes	Yes	No	No
Restriction of navigation with Panamax ship	No	No	No	No	No	No
Restriction of navigation with neo-Panamax ship	Yes	Yes	No	No	No	No
Restriction of navigation with Capesize ship	Yes	Yes	Yes	No	No	No

62.4 Results and Discussion

In scenario 1 that models reality for the year 2016, the relative transport matrix from the total ton-kilometer transported from each modal for export of Brazilian soybeans to China is 2.5% road, 4.4% rail, 0.1% waterway, 93.0% maritime. However, the GHG emission matrix by modal has the following configuration: 18.3% road, 18.4% rail, 0.1% waterway and 63.2% maritime. In this scenario, the participation of total logistics cost by modal is 38.1% road, 40.9% rail, 0.1% waterway and 20.9% maritime. It is important to highlight that the maritime modal is the one that presents the largest participation in the transportation matrix, as well as in the GHG emission matrix, but represents the lowest transportation cost, except for the waterway.

Table 62.3 presents the result of the six scenarios analyzed. The first scenario that modeled the reality using data from the year 2016 of Brazilian soy exports to China from the Brazilian Midwest shows that the average cost was US$68.67 per ton, with an issue in the order of 133.87 kg of CO_2 per ton of transported soybeans. It is important to note that the total volume exported for all scenarios was 14.8 million tons.

The table also highlights the quantities handled in each Brazilian port, as well as in each transshipment rail and waterway, in addition to the amount allocated to soy in each maritime route and type of ship. In this scenario, the soybean was only moved using the Panamax ship along the route of the Cape of Good Hope, which has been the Brazilian reality.

In scenario 2, the withdrawal of the Panama Canal toll fee was analyzed, since the soybean originated in the northern ports of Brazil presents a comparative advantage in terms of maritime transport costs using such a canal in relation to the traditional route of the Cape of Good Hope. However, the toll fee currently charged on the channel has taken this comparative advantage. Therefore, in this scenario, the average cost of transportation of soybean reduced to US$68.60 per ton and the emission to 133.30 kg of CO_2 per ton of soybean.

In scenario 3, neo-Panamax transport was included, and the majority volume allocation was verified using this type of ship along the Cape of Good Hope route and a parcel of almost 5% for the Panama Canal route. The cost was reduced to $66.91 per ton, as well as the GHG emission to 127.16 per ton of transported soybeans.

In scenario 4, the possibility of maritime transport was introduced using the Capesize-type ship with greater transport capacity and more efficient in terms of fuel consumption efficiency. In this scenario, the cost was reduced significantly to US$60.82 per ton and the GHG emission to 92.98 ton of CO_2 per ton of transported soybeans. The shipping of soybeans occurred exclusively by the Cape of Good Hope.

In scenario 5, the capacity restrictions of rail and waterway transports and ports were considered unlimited. In this context, it is observed that both the transport cost and the emission level of GHG are reduced drastically. In addition, in this scenario it is possible to assess the infrastructure required to promote a greener and cheaper transportation, involving the significant expansion of capacity of the Alto Araguaia rail terminal and the Porto Velho water terminal, as well as the expansion capacity of the ports of Santos, Paranaguá and Manaus.

In scenario 6, the objective function of minimum total logistic cost was replaced by the minimization of GHG emissions in logistics. In this context, there is a small reduction in the GHG emission level in relation to scenario 5 and a small marginal increase in logistic cost. This scenario assesses what the recommended infrastructure configuration for a green corridor should be: expanding the capacity of the Alto Araguaia and Araguari rail terminals, increasing the capacity of Santos, Paranaguá and Vitória ports, and investing in the accessibility of Capesize-type ships using the Cape of Good Hope route to export soybeans from Brazil to China.

Table 62.3 Evaluation of scenarios for the export of Brazilian soybeans to China

Indicators		S1—Base	S2—Panama Canal without toll fee	S3—Neo-Panamax inclusion	S4—Capesize inclusion	S5—Unrestricted infrastructure	S6—Minimizing GHG emissions
Average cost (US$/t)		68.67	68.60	66.91	60.82	56.65	57.61
GHG emission (kg CO_2/t of soybean)		133.87	133.30	127.16	92.68	88.11	87.13
	Brazilian ports						
Export from Brazilian Port to China (tons)	Manaus (AM)	162,581.00	162,581.00	162,581.00	162,581.00	518,060.00	–
	Barcarena (PA)	690,382.00	690,382.00	690,382.00	690,382.00	–	–
	São Luís (MA)	806,526.94	806,526.94	806,526.94	806,526.94	–	–
	Vitória (ES)	2,212,758.49	2,212,758.49	2,212,758.49	2,212,758.49	–	2,669,456.00
	Santos (SP)	7,573,339.88	7,573,339.88	7,573,339.88	7,573,339.88	12,246,611.80	10,095,215.80
	Paranaguá (PR)	1,800,361.96	1,800,361.96	1,800,361.96	1,800,361.96	2,119,516.50	2,119,516.49
	São Francisco do Sul (SC)	1,638,238.02	1,638,238.02	1,638,238.02	1,638,238.02	–	–
	Transshipments						
Soybean handling by railroad transshipment (tons)	Alto Araguaia (MT)	242,675.00	242,675.00	242,675.00	242,675.00	6,513,151.50	6,979,405.50
	Araguari (MG)	2,212,758.49	2,212,758.49	2,212,758.49	2,212,758.49	–	2,669,456.00

(continued)

Table 62.3 (continued)

Indicators		S1—Base	S2—Panama Canal without toll fee	S3—Neo-Panamax inclusion	S4—Capesize inclusion	S5—Unrestricted infrastructure	S6—Minimizing GHG emissions
	Itiquira (MT)	204,884.00	204,884.00	204,884.00	204,884.00	–	–
	Palmeirante (TO)	806,526.94	806,526.94	806,526.94	806,526.94	–	–
	Rondonópolis (MT)	3,918,884.00	3,918,884.00	3,918,884.00	3,918,884.00	2,194,816.50	2,246,622.50
Soybean handling by waterway transshipment (tons)	Itaituba (PA)	504,293.36	504,293.36	504,293.36	504,293.36	–	–
	Porto Velho (RO)	162,581.00	162,581.00	162,581.00	162,581.00	518,060.00	–
	Ships						
Maritime flow: Good Hope Cape (tons)	Panamax	14,884,188.30	14,031,225.30	–	–	–	–
	Pós-Panamax	–	–	14,031,225.30	–	–	–
	Capesize	–	–	–	14,884,188.30	14,884,188.30	14,884,188.30
Maritime flow: Panama Canal (tons)	Panamax	–	852,963.00	–	–	–	–
	Pós-Panamax	–	–	852,963.00	–	–	–
	Capesize	–	–	–	–	–	–

Source Results

62.5 Conclusion

The objective of this article was to evaluate the potential of strategies to promote green corridors of soybean exports from Brazil to China.

In this context, from the construction of a mathematical model of optimization of soybean supply from the multimodal logistics network, it was possible to quantify the economic costs and levels of GHG emissions for different simulated scenarios.

It is interesting to note that the promotion of strategies that reduce levels of GHG emissions for the export of Brazilian soybeans to China also promotes the reduction of logistics costs, as presented in the different scenarios.

We can conclude that the scenario that consolidates the green corridor of low GHG emissions is one that expands the capacity of the rail terminals of Alto Araguaia and Araguari and increases the capacity of the ports of Santos, Paranaguá and Vitória, besides the use of ships of the type Capesize using the Cape of Good Hope route. In this situation, logistical costs are reduced by 16.1% and GHG emission levels by 34.9% compared to the current (baseline) scenario. Therefore, it is recommended for future work, feasibility analyses for expansions of these infrastructures and evaluation of new multimodal projects in the Brazilian territory that can promote green corridors—which may be attractive projects for Chinese.

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Chapter 63
Performance Measurement System: A Case Study

Edson da Costa Pinto, Luiz Felipe Scavarda and Gabriel Simões de Oliveira

Abstract This paper analyzes the performance measurement system (PMS) from the perspective of the redesign phase. It presents the findings of a case study in the oil industry. It addresses a research–practice gap regarding the lack of studies in this phase when compared to the other ones, especially the design phase.

Keywords Supply chain · Business process · Logistics

63.1 Introduction

Corporate competitiveness has been one of the major issues faced by different industries from distinct markets. The need for survival in an inhospitable and aggressively competitive environment has led organizations to collaboratively group together leading to the formation of supply chains, where such a number of organizations assist each other to reduce costs, inventories and risk of labor liabilities, leading to higher revenue gains. From this experience of aggregation among organizations, the delegation of supply chain activities to suppliers and customers for the purpose of gaining business became widely used [25, 24]. The environment of greater competitiveness with the use of new management concepts and increased complexity in the management of companies brought to light the need to use the performance measurement system (PMS) tool capable of quantifying and classifying in values the particular performance of components of the supply chain, clearly measuring the distance between the actual performance and the strategy defined by the chain's own focal organization. Although PMS has become the subject of academic studies since the early 1980s [13], academic documents that address the redesign phase of the PMS life cycle are scarce, which has led to the development of this research. Given this reality, this article proposes to discuss a case study about the redesign of the PMS

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used in an oil and gas supply chain. This paper proposes as a final product a new list of indicators suggested based on the critiques obtained based on the analysis of academic documentation and on the observation of the actual performance of the evaluated organization.

63.2 Theoretical Reference

Currently, the implementation of PMS has become a critical factor for the successful management of supply chains [3]. PMS is an information system used by managers to track the implementation of a business strategy by comparing current results with strategic objectives and goals [28]. PMS uses indicators as tools for communicating performance information from the assessed organization to supply chain managers. Performance indicators are mechanisms that indicate whether the organization is being competitive with the demands of its customers [20]. Performance indicators are ways to numerically represent product characteristics and processes [29] and are trademarks or flags that seek to express and demonstrate the reality in a form that can observe and obtain more concrete data to improve the assessment [4]. Although management of the whole of the PMS life cycle is of paramount importance to the organization, the review phase is highlighted as problematic due to the need to perceive several peripheral aspects that may affect the success of the review of the indicators necessary to capture the performance of the evaluated one that acts within the scope of a supply chain.

Some authors also describe the revision phase as a vital process, with the objective of providing a real performance communication mechanism, aiming at the continuous improvement of the system itself [2, 13, 22].

According to Ghalayini and Noble [9], the PMS should include an effective systematic review, covering the analysis of the need to revise the goals, indicators and standards described in the system, in light of the objectives defined in the strategy. Another relevant item refers to the need to fix revisions in previously agreed periods [13, 30]; regardless of whether, at any time, the need for change is detected due to internal or external aspects. Relevant aspects that should be used as comparative factors, in order to verify the adequacy of the indicators, are some characteristics that they must possess. These characteristics identified in this work are consecrated by several scholars as relevant, although there is no clear consensus among them [10]. The main ones are described next.

(I) One relevant feature is the need for alignment between the strategic objectives and the PMS. Once PMS is a formal feedback system used to monitor and coordinate the implementation of plans with a view to reaching organizational objectives, it provides the role of feedback on operational performance [14], and it needs to be robust enough and include indicators that support the achievement of the proposed objectives [19, 26].

(II) According to academics, it is absolutely important that PMS adds value to the business, especially to customers and shareholders, without neglecting the other stakeholders involved, such as regulatory and supervisory bodies, other relevant government bodies, the financial market, etc. A PMS should have among the indicators those that stimulate positive corporate attitudes and measure, mainly, the value added to the shareholder and/or the customer by the organization [6]. According to Dornhofer and Gunthner [7], the PMS should be an instrument of value creation for the organization and also the generation of value, a key piece for the continuity of using the tool.

(III) The PMS needs to reflect the process in an integrated way [22], visualizing the entire chain as a single organism. For example, a cost reduction measure taken by a supplier or partner must bring a value aggregation to the chain as a whole. What goes against integration is a measure of cost reduction by one of the actors in the chain that can lead to an increase in logistics costs for the whole supply chain and especially for the main organization, completely subverting the concept presented. The analysis of the supply chain PMS indicators should provide data reflecting the performance of the supplier or partner, while taking into account the fact that it is embedded in a supply chain that has clearly defined objectives that need to be achieved, for the good of the business.

(IV) Currently, the PMS focus is related to financial and non-financial aspects. Several authors refer to the need to balance financial and non-financial indicators, such as Neely et al. [23], Gunasekeran et al. [12], Beamon [1] and Neely et al. [23].

(V) The PMS needs to be robust enough, including simple metrics that reflect the achievement of the proposed objectives [26]. Indicators with unintelligible formulas in the eyes of the collaborators do not constitute skillful tools to the management of the supply chain. It is important that employees perceive what is expected of their performance, guiding them in the path of objectives and adding value to stakeholders and product orientation and services.

(VI) The PMS should focus on a limited number of indicators [7]. Care must be taken in relation to the number of indicators used to compose the PMS [16]. The biggest challenge for many organizations is to develop a PMS with a limited number of indicators [15]. In organizations where there are a large number of processes to manage, priority should be given to monitoring via PMS; otherwise, a large number of indicators will be generated.

(VII) The indicator should reflect the actual performance of the organization; it must have the operational characteristic. An indicator is operational when it is possible to effectively measure the associated property [21]. In order to be operational, the indicator must reflect the performance, in the dimension (cost, value added, availability of equipment and facilities, profitability, productivity, inventory level, customer satisfaction, etc.) in which it was created to monitor. The elaboration of the identities and goals related to the indicator should demonstrate the effective performance [11].

(VIII) Knowing what to measure is a key factor. Because of this, the prioritization of indicators in PMS management is considered a critical success factor [11]. The design and review phases of the PMS must analyze, among the various processes carried out by the organization to be evaluated, which one or more of them are most relevant when the subject is performance measurement. A clear criterion of prioritization of the indicators to be used should be identified, in order not to miss the opportunity to effectively add value to the business.

(IX) According to the approach defended by Melnyk et al. [18, 17], indicators must have, among others, the following characteristic: to have references or goals associated with consequences attributed to those responsible for the poor performance in cases where the results present values above or below the references or stipulated goals. All indicators must have clear, achievable and measurable goals; they must have an associated performance standard that is translated by the goal [21, 27].

(X) The indicator should be of possible control by the manager [2]. There is no point in establishing a particular indicator in a given specific PMS if the manager is not given autonomy to influence the indicator [19].

(XI) The indicators of the PMS should have a cost-benefit relation favorable to their use [19]. It means that the cost to carry out the measurements has to be less than the possible benefits that the use of the indicator can bring to the management of the business.

(XII) PMS indicators should not have conflicting objectives [23]. More than this, PMS indicators cannot conflict with other internal indicators of the evaluated organization [8], in order to exist "forces" that, in a certain way, boost the organization to opposing sides that nullify any possible improvement envisaged.

63.3 Research Methods

The current case study follows the application of the 4 (four) steps of the framework described in Costa Pinto Jr. et al. [5]: (I) policy elaboration/review, (II) prioritization of processes to be measured, (III) analysis of preliminary list of characteristics and identity, (IV) definition of indicator goals, as discusses next.

The first step—policy elaboration or review—was executed through the identification and analysis of the objectives described in the strategic supply chain planning. These objectives were taken as a basis for revision of the current PMS. The main questions to be answered were: Are current PMS indicators aligned with strategic objectives? Is there any noticeable misalignment? Is there a need for some revision of the strategic objectives?

The second step—selection of the processes to be measured—consisted in the selection of the processes to be measured, followed by the choice of a selection criterion.

The third step—analysis of the current list of indicators—consisted in verifying the adherence of the indicators to some relevant characteristics by the academics, through the application of a questionnaire to ALFA employees—focal organization of the supply chain considered in the work. The questionnaire was built with the help of the respondents themselves, based on the identification of the characteristics present in the literature. When, perhaps, the answers given by the collaborators presented some doubt or contradiction, new interviews were carried out to clarify the obscure points. Next, the data answered by the collaborators were tabulated and triangulated to make possible the understanding of possible contradictions in the answers. We also collected and tabulated relevant information from researches in support systems for the logistics of the focal company, based on information related to three (3) terminals of the BETA organization, located in different regions of the country. The choice of these terminals occurred as a result of the volume (more than 50% of the total volume) of products moving to and from these terminals. Based on this mass of data, a list of critics of the indicators was elaborated. The end product of this phase was a new list of indicators.

The fourth step—definition of goals of the indicators—based on the new list of indicators, the criteria for goal setting, was discussed.

63.4 Case Study in the Oil and Gas Sector

Costa Pinto et al.'s [5] PMS revision framework is applied in the interface between the ALFA and the BETA organizations. The BETA organization is hired by the ALFA organization and occupies a relevant role in the supply chain under consideration. BETA operates mainly in the logistic operations of oil (refinery supply), by-products and natural gas (outflow), bringing together platforms (oil and natural gas fields), terminals (land and waterways), refineries and consumer centers. The BETA organization carries out its activities through an infrastructure of marine and terrestrial pipelines and terminals. In addition to supplying the domestic market, the BETA organization is also an important logistics player in the import and export operations of oil and oil products produced by ALFA in its platforms.

Step 1—Policy Elaboration/Review

In the application of the first step of the framework, we sought to compare the strategic planning drivers of the supply chain whose ALFA is the focal company, with the indicators that compose the current PMS, with the sole aim of verifying the alignment between them. The conclusion reached at the end of the application of the first step is that there is alignment between the drivers and the indicators. Existing drivers in Strategic Planning are Strengthening the SMS culture; Improvement of the decision-making process due to the confidence in the timing and veracity of the information exchanged between the two companies, reduction of logistics costs and the costs of the ships' stay. In addition, some of the drivers obtained from the service contracts signed between ALFA and BETA were identified. They are: preservation of the quality and quantity of the product delivered to the movement.

Step 2—Selection of the processes to be measured and definition of the preliminary list of indicators

All the processes performed by BETA were identified, and then the process to be measured was selected, considering 3 (three) criteria: (I) percentage of volume of product moved through the process, (II) prevailing mode used in most of the operations performed and (III) identification of critical problems identified through unwanted events perceived from research in ALFA's logistics support systems. The process chosen to serve as a priority measurement base was the process of operation with ships because, among the modalities used in the BETA movements, the modal ships move a greater percentage of volume in relation to the others, and besides the majority of operations use this modal. In addition, there is a feeling among professionals involved in the activities of ALFA that the major problems related to operations refer to the process considered.

Step 3—Analysis of the current list of indicators

The current list of indicators was analyzed in light of the characteristics described in the chapter to describe the theoretical framework. Secondly, critiques of the current PMS were raised from the application of a questionnaire to a team of experienced professionals who in the present or recent past have worked in at least one of the phases of the PMS life cycle. From the answers, these were tabulated and triangulated with the objective of measuring the level of adherence of the indicators to the characteristics described in the theoretical framework. In relation to the characteristic simplicity, the professionals did not consider the indicators of simple understanding due to the lack of clear definition of the objectives of the indicators, added to the complexity of the identities used, much according to the use of weighting (flow, volume moved, etc.) which is used in some indicators such as the efficiency of operation with ships, availability of tank and availability of pipelines. On the characteristic alignment to the strategic objectives, the respondents considered that the current PMS is perfectly aligned with the objectives of the supply chain. Regarding the integration characteristic, they understood that the PMS does not reflect the need of integration of the supply chain. An example that reflects this fact is the existence of different criteria in the classification of BETA assets as critical. Assets considered critical by BETA for monitoring performance are not considered critical by ALFA. Another feature analyzed was the aggregation of value that PMS stimulates in the supply chain business. Respondents mentioned that the indicators do not stimulate cost reduction and revenue growth, since indicators do not provide managers with the information needed for decision-making. The PMS does not really reflect the performance of BETA. They replied that a system of consequences was not applied, although there is provision for application in the PMS. Regarding the characteristic balance, they considered that there is no balance between financial and non-financial indicators because the PMS does not have any financial indicators. The question of the prioritization of the processes to be measured was also analyzed: Respondents were unanimous in saying that the PMS already prioritizes the process of operation with ships and that among the services provided by BETA, this process must continue to be prioritized because it is the predominant mode practiced by BETA in its logistics operations. About 50% of BETA's operations are with ships. Given the answers, some indicators should be discontinued, because there are some in duplicity that measure the same performance item, but with different identities. Another aspect is the number of indicators. The number of indicators was not considered high. Among the observations listed by the respondents, it was mentioned that the critical success factor is not a small number of indicators, but the existence of information system (s) that is able to adequately manage the relevant information. As for the targets, it was agreed that these are not challenging, since the indicators are not able to reflect the actual performance of the BETA organization. According to the respondents, the PMS indicators do not conflict with each other, but there are internal indicators that conflict with those of the PMS. For example, the overtime indicator was cited as an internal indicator that negatively impacts the efficiency indicator of vessel operations. Finally, the professionals who responded to the questionnaires considered that the cost of performance monitoring is less than the possible benefit obtained from the decision-making facilitated by the PMS information. Based on the compilation of these criticisms obtained from practitioners, a new list of indicators was considered, as presented in Table 63.1.

Table 63.1 New list of indicators suggested

Suggested indicator	New?	Razon	Comments
Assistance to preventive maintenance of terminal equipment	YES	Stimulate the improvement of maintenance management	Indicator that shows the percentage level of attendance to the execution of the preventive maintenance of pumps and arms that were planned in the period corresponding to one month
Availability of pumps	YES	Stimulate the reduction of the stay of the ships operated in the terminals and the associated logistic costs	Indicator to be created that shows a relation between the amount of delays and delays caused by the unavailability of pumps and the total amount of hours in the month. Availability = (Delays due to non-availability of pumps)/(Total number of hours in the month)

(continued)

Table 63.1 (continued)

Suggested indicator	New?	Razon	Comments
Availability of pipelines	NO		Indicator to be created must consider only some ducts judged critical from the perspective of the organization ALFA. Displays the relationship between the hours of duct unavailability and the total number of hours in the month. The concept of criticality should be eliminated only from the standpoint of BETA
Availability of tanks	NO		Indicator to be created that takes a periodic "photograph" of the volume of space available for storage, comparing it with the volume of planned space for the period. Measures the distance between the actual and planned space volume
Time spent for alignment at terminals for ship operations	YES		Indicator to be created that presents the time spent between the concession of the ready to sta rt by the ship until the actual start of the operation
Time spent in laboratory analysis by the terminal	YES		Indicator to be created, which presents the average time spent between the withdrawal of the sample and the actual disclosure of the product quality certificate, taking into account all the analyzes carried out by the terminal
Delays due to lack of staff	YES		Indicator to be created that shows the average time spent with delays and delays in ship operations due to lack of personnel at the terminals

(continued)

Table 63.1 (continued)

Suggested indicator	New?	Razon	Comments
Efficiency of ship operations (financial indicator)	NO		Indicator to be created that presents the inefficiency in U $ that represents the delays and interruptions, due to the responsibility of the BETA organization. The value in U $ will be calculated as a function of the average hire of the ships chartered by the organization ALFA
HES (Health, Environment and Safety) indicators	NO	Strengthening the HES (Health, Environment and Safety) culture	Indicators of Leakage (volume leaked), accidents and severity of accident rate

Step 4—Goal Setting

All suggested indicators should not keep any identity relationship with the indicators that are used in the current system. As there is no historical database that can guide the definition of challenging goals and that add value to the supply chain, it is suggested that after the implementation of the suggested PMS, the indicators are monitored for a period of at least six months, so that, based on these data, it is possible to set feasible targets that can be considered truly challenging.

63.5 Conclusions

The present work had the objective of suggesting to criticize the current indicators and listing a new list of indicators from the critical ones. New indicators can be created, avoiding the use of weightings that undermine the operation of the PMS, the understanding of objectives by managers and the entire workforce. New indicators should focus on obtaining local and non-global performance data. In order to balance the basket of indicators, it was suggested to create the indicator of the efficiency of operations with ships (cost—U$/m^3 moved). Considering that there are problems related to the maintenance management of the equipment operated by BETA, it was suggested to monitor the availability of equipment through the creation of availability indicator (pumps) and continuity of the indicators of availability of pipelines and tanks. It is necessary that these continued indicators have their identities modified so that they clearly reflect the actual performance of BETA. The discontinuity of indicators such as reliability of information and product quality was suggested, due to the inexistence of events that impact the processes. Future studies should be carried out aiming at the implementation of the suggested indicators, since the work did not set out to this task. Further studies can further analyze the conduct of the deployment, as well as the benefits brought by the new management. It is important that a system of consequences that has a system of bonuses and discounts be established to actually stimulate the elevation of the level of service delivered by the evaluated one.

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Chapter 64
Challenges and Barriers of Performance Measurement Systems: Lessons from Different Initiatives Within One Single Organization

Patricia Renata Carvalho de Mendonça, Marcelo Maciel Monteiro, Luiz Felipe Scavarda and Joana Rocha

Abstract Many organizations are unable to implement successfully performance measurement systems. There is still a lack in the literature of a better understanding of the challenges and barriers faced by these organizations and what needs to be done to overcome them. This paper develops an empirical study to enhance this understanding.

Keywords Performance measurement system · Performance measurement · Success factors

64.1 Introduction

In supply chain management, the performance measurement system (PMS) is seen as a fundamental tool that directly collaborates in the strategic objectives evaluation and in the achievement of business excellence [1, 9, 18, 20], and, given the constantly evolving nature of the business strategies, many companies are directing efforts in the development of new projects, adaptations, and improvements of their PMS [4, 10], as well as in the efficient use of this management tool [6, 7].

Despite the development of numerous studies in the performance measurement subject, many organizations are unable to fully implement its PMS and/or are not extracting the benefits that effective performance measurement offers, due to unexpected difficulties encountered during its application [7, 12, 22]. The research for a better understanding of the factors that affect the PMS success can contribute to more effective strategies, to improve resource allocation and to allow professionals to be

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better prepared and more responsive during the application of a PMS [11]. In addition, detailed case studies aimed at identifying the factors that affect the performance measurement of supply chain are still considered a gap in the current literature [1].

This paper presents a case study that examines performance measurement initiatives applied to the petroleum and derivates supply chain of a single company to identify the critical factors and barriers that affected the success of these PMS.

After this introductory chapter, the article is structured as follows: Sect. 2 presents the theoretical background of the study, bringing the current context about PMS, highlighting the critical success factors. Section 3 describes the research method. Section 4 presents the main findings and discussions of the case study. Finally, the last section offers the conclusions drawn by the authors and their recommendations for future research.

64.2 Theoretical Background

This section presents first the basis of PMS, then its life cycle, and at the end the critical success factors.

64.2.1 Performance Measurement System and Its Life Cycle

PMS can be defined as the set of metrics used to quantify the efficiency and effectiveness of actions [23], encompassing software, databases, and procedures to perform the metrics in a consistent and complete way [16], including a component that will continuously verify the validity of cause and effect relationships between measures [15] and their dissemination [21].

Franco-Santos et al. [8] emphasize the importance of explicit statement of characteristics (properties or elements), roles (purposes or functions performed by the system), and related processes (series of actions that combine to form the system), which define the PMS studied, in order to ensure a better understanding of the research carried out in this field and the possibility of adequately comparing the findings.

Therefore, in the context of supply chains, PMS can be defined as a set of metrics used to quantify the efficiency and effectiveness of supply chain processes and relationships, encompassing various organizational functions and companies, allowing the integration of the internal and external systems of the supply chain [18]. Internal PMS covers internal supply chain processes and relationships between different organizational functions, and the external PMS deals with supply chain processes and relationships involving external components [18]. The study addressed in this article focused on the internal supply chain PMS.

An important feature of PMS is the need to be dynamic [13]; they need to be modified as business strategies evolve as a result of changes in global, business, and technological trends [14], so that measures remain relevant and continue to reflect important issues to the business [17]. From the distinction of the PMS life cycle phases, the researchers were able to observe their different aspects and develop strategies adapted to the unique challenges presented by each phase [12], aiding in the PMS evolution dynamics.

According to Bourne et al. [2], the development of a PMS can be divided into three conceptual phases: (1) the design of performance measures, which has two requirements: the identification of the main objectives to be measured and the design of the measures themselves; (2) the implementation of performance measures when the systems and procedures that allow regular measurement are took in place; and (3) the use of performance measures, which include the challenge of the strategic assumptions, starting from which are made updates/revisions of performance measurement systems, that some authors highlight as another phase of the PMS life cycle [4, 10].

64.2.2 Critical Success Factors for Performance Measurement Systems

Although many studies have been directed to a single process of the life cycle, Franco-Santos and Bourne [7] argue that PMS cannot be fully understood using an analysis perspective that focuses only on the single process, being necessary to use a perspective wide to advance understanding of the factors affecting the PMS. Another difficulty found in the literature that addresses the critical factors of a PMS is the lack of consistency in terminology, build definition and scope of the identified factors [12, 25], characterized by a general lack of convergence, mainly due to the great diversity of interdisciplinary studies [25], with approaches ranging from general management systems to very specific measurement structures [8].

The categorization of critical factors based on the framework developed by Pettigrew et al. [24] brings a holistic or contextualized approach to understanding the life cycle processes of the performance measurement system, such as in the evaluation of organizational change processes, rather than a simplistic approach that focuses only on episodic or change project [7].

The literature generally uses the categories of Pettigrew et al. [24]—process factors, content factors, and context factors—to classify the critical factors identified. The process factors refer to the process of introducing a PMS into the organization [7] and can be related to the PMS design, implementation, and use phases [2]. The context factors are related to the issues that influence the PMS and can be divided into internal and external context factors. Content factors are related to the effects that PMS produces in different levels of the organization [7].

Table 64.1 offers the main critical factors identified in the literature. A critical content factor, six critical context factors, and fourteen critical process factors were categorized.

Table 64.1 Synthesis of the critical factors found in the basis literature

Categories of Pettigrew et al. [24]	Critical factors
Content factors	PMS results/benefits [3, 5]
External context factors	Environment [7]
	Industry characteristics [7]
Internal context factors	Organizational culture focused on performance management [3, 5, 7, 10, 13]
	Firm strategy [5, 7, 13]
	Resistance to measurement [3, 5, 10, 13, 22]
	Size/organizational structure [3, 7]
Process factors	Alignment and integration [7, 10, 13]
	Leadership support [3, 5, 7, 10, 13]
	Capacity [3, 5, 7, 10, 13]
	Performance measurement facilitator [3, 7, 13]
	Focus on performance measurement management [5, 10, 13, 22]
	Time and effort required [3, 5]
	Set of metrics [5, 13, 22]
	Metrics design [3, 5, 7, 13]
	Accountability and rewards [5, 7, 13]
	Success map [5, 7, 22]
	Information infrastructure [3, 5, 7, 10, 13, 22]
	Analysis of results and action plans [5, 7, 13, 22]
	Resources [5, 13]
	Structured process for reviewing PMS [7, 13]

64.3 Research Method

A case study approach was used to conduct an empirical investigation of critical success factors for PMS application from the analysis of operational performance measurement initiatives applied in an oil and gas company. The authors followed McCutcheon and Meredith [19] guideline to conduct the case study. The initiatives had the objective of assisting in the management of the integrated supply chain of oil and derivates, with the critical analysis process coordination by the logistics department of this company.

Following different studies on the topic (e.g., [3, 7, 25], this research uses the categories of Pettigrew et al. [24] of process factors, content factors, and context factors to classify the critical factors identified in both the baseline literature and the case study observations, and collaborate on the argument that a consistency and convergence gain is required in studies in this area [25] and that research on the PMS should utilize a broad perspective [7].

For the case study, a semi-structured interview protocol was developed and based on the revised literature [3, 4, 10, 13]. The pre-established questions were elaborated to obtain answers without creating a bias, besides seeking to identify both the factors that directed to the success of the PMS and the factors that were seen as barriers or obstacles to the application of the PMS. The literature review also provided a list of the main factors that aided the interviewer in order to prevent the respondent from concentrating on a single factor and ignoring other important factors [3]. Participants who held different roles (managers, consultants, and users) in the PMS initiative were invited to participate in the study interviews. The resulting interview protocol was as follows [3] and had a total of six respondents: (i) Each interview began with a leveling of the performance measurement system definition that was being studied; (ii) Then proceeded with the series of pre-established questions; (ii) Answers to these questions were probed to ensure that the interviewer understood the points being made and collected specific examples; (iv) The pre-established questions were followed by questions focused on a quick list of possible factors; (v) Responses to the factor list were probed to ensure understanding; and (vi) After the interview, the questionnaire was sent to each interviewee for validation.

The analysis of the evidence for the case study was made from the triangulation of the information collected during the interviews, from internal company documents, information systems, and direct observations of the researchers. Triangulation was important to avoid research bias that one could obtain when focusing on just one source. Indeed, crossing the responses among the different sources led sometimes to contradicting responses that were solved after going back to the respondents and checking the reasons. The findings of this research are presented in the subitems below.

64.4 Case Study

The company studied in this article operates in the oil exploration, production and refining segments, commercialization, transportation and distribution of oil products, natural gas, electric energy, biofuels, and petrochemicals. The two main areas of company operational activities, which are divided into directories, are Exploration and Production (E&P), which comprise preliminary investigations of oil and natural gas reserves, drilling, exploration, and production, and Refining and Natural Gas (RNG), which is responsible for activities ranging from platform offloading operations, to oil refining and natural gas processing, marketing and delivery of oil, natural gas, and oil products. Within the RNG board, there is also the subdivision between the activities related to operations involving oil and derivates and the operations involving natural gas. This case study focuses on RNG activities involving oil and derivates operations.

64.4.1 SMDO Initiatives—Operational Performance Measurement System

SMDO initiatives began to be developed in mid-2009 as a project for a new management model for RGN's logistics activities. The SMDO included initiatives to create a new process of critical analysis of the oil and derivates supply chain, creation of an indicators panel with measurements in all processes in the logistics area, and implementation of a new layout of the collaborative work environment. The use of the SMDO began in 2011 when the monthly operational performance reports and periodic critical analysis meetings were started. The SMDO failed to have the metrics set fully implemented, and this PMS was discontinued in 2014, with the start of using another PMS initiative.

The semi-structured interviews were taken with six participants from different positions in the initiative (one manager, one project team leader, one performance measurement coordinator, and three users), who identified the critical factors displayed in Table 64.2.

64.5 Results and Conclusions

The case study identified twelve factors that were considered critical by participants of different roles in the applied PMS. Categorization from the perspective of Pettigrew et al. [24] can provide a holistic assessment of factors, improving the perception of how one factor may influence another. Many of the respondents initially identified a critical factor as being fatal to the discontinuation of PMS, and, in the case of SMDO, many pointed to excess metrics as the main motivator. However, analyzing more deeply from the perspective of context, content, and process factors, other important critical factors could be identified. The use of the perspective of Pettigrew et al. [24] proved to be quite efficient for understanding the critical factors that affect the success of PMS.

Based on the need for convergence of the research related to the critical success factors of PMS [12, 25], it is recommended the development of an adaptation of the framework of Pettigrew et al. [24] for direct application in these surveys, as well as the identification of other critical factors from the application of more empirical research.

Table 64.2 Synthesis of the critical factors identified in the case study

Categories of Pettigrew et al. [24]	Critical factors
Content factors	**PMS results/benefits**: Some interviewees reported this factor as the main motivator for the initiative in the company. Bourne et al. [3] found this factor as the most cited reason to continue using PMS among companies that successfully implemented it. However, companies that failed to implement their PMS reported the lack of results and benefits of the tool as a reason for not going ahead [3, 5]
Internal context factors	**Firm strategy**: Some interviewees reported that the motivation for the PMS initiative sought to fit into a new company strategy and the importance of everyone involved understanding it. The definition of firm strategies with clear objectives contributes to the success of the PMS [5, 7, 13]
	Organizational culture focused on performance management: The need to develop an organizational culture focused on measuring the performance of the integrated supply chain was also seen as a motivational factor to start the initiative. However, as cultural change does not occur overnight, the success of PMS is often affected by this factor [5]. Given the time and strategies required, this is a difficulty that can be overcome [3, 10]
	Resistance to measurement: The interviewees perceived the resistance to the performance measurement process. People may be apprehensive of the personal consequences that the application of PMS may bring [3]. It is important to align the PMS objectives and implement the system in a way that eliminates the opportunity to be used as punishment [22]
Process factors	**Alignment and integration**: Difficulties were encountered in relation to lack of alignment and integration during all phases of the initiative. The lack of integration with the IT team from the beginning of the project [10, 13] generated delays and the creation of a difficult tool. The low involvement of the operating areas in the discussion of the design of metrics [10, 13] led to rework, reduced reliability of the result, and resistance to measurement. A positive feature of the initiative, which helped the integration, was the new layout in the work environment where all involved (performance managers and operational activity teams) were physically close and with few visual barriers to each other
	Capacity: It was perceived difficulties in relation to the lack of the experience related to the team assigned to carry out the performance evaluation [5, 7, 10, 13]. It was tried to overcome this barrier with the application of training [10, 13] and redistribution of the work within the team. The high turnover of IT staff [13] also led to delays and difficulties with the support tool

(continued)

Table 64.2 (continued)

Categories of Pettigrew et al. [24]	Critical factors
	Information infrastructure: There are many problems reported during the interviews, and also found in the literature, related to the information infrastructure, such as system with little flexibility, fragmented and unreliable sources of information, delay in the implementation of the tool, among others [3, 5, 7, 10, 13, 22]. Some interviewees reported that there was an integration delay of the IT team in the SMDO project, making it difficult to deliver the system on time. Neely and Bourne [22] reported that even when organizations plan for information infrastructure reengineering, they often do not realize the scale of the task at hand
	Leadership support and performance measurement facilitator: In an integrated supply chain initiative, it is necessary to have support from the leadership of all the areas involved [3, 5, 7, 10, 13]. However, the participation of so many decision makers may lead to lack of consensus in the decision. The figure of a leader for the performance measurement process was reported with importance both in the case studies and in the literature [5, 13]. In addition, top management needs to be interested and present in performance measurement activities to increase energy levels regularly to ensure that the process continues [22]. After managerial change, the initiative lost priority and was replaced by another, as was observed in the research by de Waal and Counet [5]
	Accountability and rewards: There is a perception of a lack of accountability over the actions generated from the SMDO analysis, without anyone caring about it. As previously mentioned, should be careful that PMS does not become a means of punishment [22]. On the other hand, de Waal and Counet [5] argue that there must be a link between the PMS and the rewards system. If organizational members will not be evaluated and rewarded for working with the metrics, this leads them to work on other issues, considering that PMS is not relevant
	Set of metrics: The excessive number of metrics selected for the SMDO was a barrier mentioned by all interviewees. The contracted consultancy contributed with a benchmarking package. The operating areas were very attached to the old metrics, which were largely maintained. It was difficult to implement the full set of metrics, and in the use phase, the prioritization of deviations for analysis was impaired. Many authors emphasize the importance of defining the most relevant metrics and obtaining a minimum set that makes sense for the organization's strategy [5, 13, 22]

(continued)

Table 64.2 (continued)

Categories of Pettigrew et al. [24]	Critical factors
	Structured process for reviewing PMS: When asked what could have been done to ensure continuity of the SMDO, many responded to the need to review the performance measurement process and metric set. Instead, the company chose to start a new performance measurement initiative, new hire consulting and other teams involved, it was a much larger work. This collaborates with studies focusing on the PMS review, which have been gaining ground in the literature [10, 13]
	Time and effort required: The implementation of a PMS initiative and the perception of the benefits that were expected from the design of the project may take longer than expected [3, 5]. It is necessary to take into account all the difficulties previously reported, to ensure the maintenance of the breath to complete and maintain the use and reliability of the PMS. In the case of SMDO, many barriers were not overcome; the delays in the results generated a loss of reliability in the system and perception that this process was not more important, resulting in the discontinuity of the initiative

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Chapter 65
A MCDM Approach for Evaluating Smart Cities Projects

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Abstract In order to reduce evaluation subjectivity of projects in start-ups selection centers for smart cities, this article presents MCDM method application that is capable to explicit and rate the aspects considered in these evaluations, with a quantitative approach that minimizes evaluator's uncertainty and bias.

Keywords DEMATEL · Smart cities · MCDM

65.1 Introduction

Increasing urbanization has a number of negative consequences for urban centers, especially related to health, safety, education, and urban mobility. In order to solve these problems, efficient planning is necessary, balancing the population needs with the policies with the aiming at promoting urban center sustainable development [7].

Nowadays, there is an imbalance between population needs and public management capacity to provide organized and sustainable development for cities. So one of this imbalance solutions is information exchange between population service systems that happens from data integration between systems such as health, public safety, education, and transport, arising in this context the smart cities concept [2, 6]

Smart cities incorporate information and communication technologies in urban management, favoring the urban space development with an innovation, competitiveness, attractiveness, and resilience focus [1].

In this new concept's promotion to cities improvement, start-ups emerge, which are companies with an embryonic business model that present business strategies under uncertainty conditions and have an exponential growth capacity [8].

In this sense, there is a growth of events that promote actions focused on the selection of start-ups that present business models focused on smart cities strategies.

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In that sense, the present paper aims to characterize the evaluation criteria behavior for a selection process of smart cities concepts application focused projects in a midsize city using DEMATEL multicriteria decision-making method.

65.2 Methodology

In this section, the study object, the data collection, and the used processing script will be detailed.

The city of Maringá, in the Paraná state, has a private, nonprofit institution that supports regional development processes. This support is given by the innovation promotion through approximating entrepreneurs and universities with an economic development focus. One of the support institution urban strategies is to promote the smart cities concepts through the capture of entrepreneurial and innovative projects that simultaneously seek to contribute to the city urban maturity, so it can become a smart city and integrate local researchers and entrepreneurs.

In order to capture such projects, the support institution periodically conducts a selection process to adequately allocate money contribution to the most relevant projects in this type of program. Then, the candidate projects are evaluated by a correlated specialist group whose judge these projects performance considering certain criteria, assigning to each one a score from zero to ten. Thus, the project with the highest performance will be the one that presents the highest simple average of the scores obtained in the evaluation criteria.

Although evaluations are conducted with specialists in the knowledge field, evaluation criterion different preponderance is not considered, distorting the process final result. In order to identify this characteristic, the Decision-Making Trial and Evaluation Laboratory (DEMATEL) [3–5, 9] was applied with specialists that compose the support institution evaluators group. As a result, a diagnosis around the influence relations between evaluation criteria and consequently the structure of preponderances was defined.

65.2.1 Data Collection and Compiling

The evaluation criteria for the selection process were submitted to the DEMATEL method in order to identify the influence relationships between them. For this, a questionnaire of pairwise comparisons using the method proprietary scale—four-point scale, from zero to four, in which zero represents the relation “no influence” and four represents “very strong influence”—was applied to the experts.

After collecting the answers, the data were compiled using DEMATEL’s mathematical modeling to identify all the parameters of interest: more and less preponderant criteria, more active criteria in the system, cause criterion and effect criterion.

The method was developed between 1972 and 1976 and has been used as a support tool for research and solution of complex and interconnected problems [5]. Some of its contributions in decision models are the explicitation of interactions between factors under evaluation, the relational intensity discovery of the factors involved in the decision-making process, the cause and effect relationships visualization and which factors are most influential in the systems in which the method was applied [4]. Its calculations are detailed in Sect. 3.

The data collecting phase is applied with the use of pairwise comparisons in a way that domain specialists are able to judge the influence relation between the evaluated elements. Then, with all answers in hand, the DEMATEL mathematical algorithm is executed, as can be seen next:

1. Calculate the Mean Answer Matrix (mean of all pairwise comparison);
2. Normalize the Mean Answer Matrix;
3. Calculate the Total Influence Rate Matrix;
4. Detail the elements' given and received influente rate;
5. Calculate the analysis threshold;
6. Develop the Influence Map.

65.3 Results and Discussions

In order to evaluate the projects, it was necessary to establish what criteria the specialist group would analyze. So, these elements were collected through informal interviews with six specialists who composed the group that conducted the selection process for the presented projects. The criteria collected are:

- Originality: Aims to analyze the differentiation degree the presented solution has compared to other products aiming to solve the same problem;
- Innovation: The degree of the solution can solve the problem in a simpler, cheaper, and easy-to-apply manner, that is, the ability to simplify the development process;
- Feasibility: In this criterion, the solution financial and technical capacity to be developed was analyzed in the program construction chronogram;
- Mock-up: It is analyzed in this criterion the presented solution evolution degree, considering if it is in the idea stage, if it has a technical design, or if it is already physically developed even if it does not use the construction final materials;
- Pitch: The team responsible capability is evaluated through a presentation on clearly, orderly, and coherent project-related information, introducing the problem, solution, market, financial analysis, and team.

The study first stage consisted in the application of the pairwise comparisons questionnaire of criteria evidenced with the specialists. With the results, the mean response matrix presented in Table 65.1 was originated.

Table 65.1 Pairwise comparisons of mean response matrix

Mean response matrix	Originality	Innovation	Feasibility	Mock-up	Pitch
Originality	0.000	3.333	1.833	2.667	3.333
Innovation	3.000	0.000	2.667	3.167	3.000
Feasibility	0.500	2.667	0.000	3.000	2.833
Mock-up	0.750	1.833	2.333	0.000	3.833
Pitch	1.250	1.333	1.333	2.500	0.000

From the mean response matrix, the DEMATEL method mathematical steps were performed in order to obtain the total influence relations matrix, which can be observed by means of Table 65.2.

The DEMATEL method recommends that strong influence relationships should be considered those that have measured intensity above the mean of all shown intensities in the total influence relation matrix. This cutoff parameter is called the threshold, represented by the variable α, and is calculated according to Eq. 65.1.

$$\alpha = \frac{1}{N} * \sum_{i=1}^{n} \sum_{j=1}^{n} [t_{ij}] \tag{65.1}$$

In this way, the α threshold is equal to 0.478. Therefore, all influence relation intensity below this threshold will be hidden from the analysis because they are classified as weak relations. Thus, the total influence relation matrix can be rewritten, as shown in Table 65.3.

From Table 65.2, it was possible to construct Table 65.4 computing the total and net effects for the analyzed criteria. The total effects caused by a given criterion are quantified by the sum of all the effects caused by it, calculated by the sum of the effect intensity indicated on its respective line in T Matrix, represented by the variable R_i.

Table 65.2 Total influence relations matrix

Total influence relation matrix (T matrix)	Originality	Innovation	Feasibility	Mock-up	Pitch	Row sum (R_i)
Originality	0.272	0.604	0.503	0.673	0.773	2.825
Innovation	0.466	0.418	0.567	0.722	0.783	2.956
Feasibility	0.258	0.484	0.308	0.595	0.638	2.283
Mock-up	0.258	0.420	0.440	0.385	0.667	2.170
Pitch	0.246	0.334	0.325	0.466	0.348	1.720
Column sum (C_i)	1.499	2.259	2.142	2.841	3.211	–

Table 65.3 Total influence relation matrix after α threshold application

Total influence relation matrix (T-α matrix)	Originality	Innovation	Feasibility	Mock-up	Pitch
Originality	–	0.604	0.503	0.673	0.773
Innovation	–	–	0.567	0.722	0.783
Feasibility	–	0.484	–	0.595	0.638
Mock-up	–	–	–	–	0.667
Pitch	–	–	–	–	–

Table 65.4 Net influence effects

Effect analysis	R_i	C_i	$R_i + C_i$	$R_i - C_i$
Originality	2.825	1.499	4.324	1.326
Innovation	2.956	2.259	5.215	0.697
Feasibility	2.283	2.142	4.425	0.141
Mock-up	2.170	2.842	5.012	−0.672
Pitch	1.720	3.211	4.931	−1.491

The effects received by a certain criterion are quantified by the sum of all the effects received by it, evidenced by the sum of the effect intensity indicated in its respective column, also in T Matrix, represented by the variable C_i.

Therefore, the system total promoted effect by a certain criterion is the sum of its provoked and received effects. Its net effect, however, is the difference between its provoked effects and received effects. This analysis is shown in Table 65.4.

It is observed in Table 65.4 that the $R_i + C_i$ column represents the total effects—provoked and received—by each analyzed criterion. With the data, it is verified that the most active criterion in the set is Innovation. Innovation has a high influence rate ($R_i = 2.956$) in the same way that its received influence rate ($C_i = 2.259$) is the third highest in the set.

When analyzing the $R_i - C_i$ column—criteria net effect—it is observed that the net effect for Originality, Innovation, and Feasibility criteria is positive, whereas the net effect from the Mock-up and Pitch criteria is negative. The criteria that present positive $R_i - C_i$ parameter have greater intensity in the caused effects than in the received ones, thus characterizing them as cause criteria for the analyzed data set. Those that present negative $R_i - C_i$ parameter are characterized as effect criteria since they receive more influences from the set instead of provoking them.

The fact that a criterion is qualified as cause or effect is decisive in driving efforts when seeking greater performance. This implies that greater performance on the cause criteria will result in performance gains on the effect criteria.

To illustrate the relationships between Originality, Innovation, Feasibility, Mock-up, and Pitch, Fig. 65.1 constructs based on the data contained in Tables 65.3 and 65.4. The data in Table 65.4 represent the plotted points' x and y coordinates, in

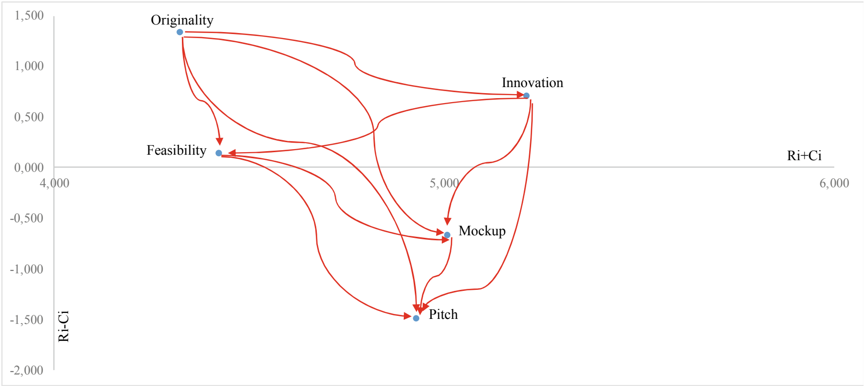

Fig. 65.1 Influence map

which x will receive the $R_i + C_i$ value, while y will receive the $R_i - C_i$ value. The data in Table 65.3 represent the relational loops that were plotted because they are characterized as strong loops (because they have measured intensity above the threshold α).

From the influence map, it is noticed the originality criterion provokes influence in all the other criteria, and in contrast, it does not receive any backway influences. On the other hand, the Innovation criterion influences the Feasibility, Mock-up, and Pitch criteria. The Feasibility criterion influences the Mock-up and Pitch criteria. The Mock-up criterion influences the Pitch criterion, and finally, the Pitch criterion does not cause influences in any criterion, but as already mentioned it is influenced by all the others.

In this way, the most influential criterion for this type of selection process is the one that refers to the degree of differentiation of the solution, that is, the project Originality.

65.4 Conclusion

The project's selection in large majority occurs in a simple way, where the judging specialist group does not consider each criterion particularities evaluating them in an equal manner.

In this study, the DEMATEL multicriteria decision method was used as a tool for supporting parameters of interest determination in a process of projects selection focused on smart cities concepts application. It was possible to identify which of the criteria have the strongest relations and preponderances for the specialist group evaluation.

The used method made it possible to identify that the most active criteria are Originality, Innovation, and Feasibility, and the less active are Mock-up and Pitch.

In this way, when evaluating the projects, the specialist group can consider its notes based on the criteria classification, making the evaluation a more robust process.

Therefore, identifying the influence relationship between used criteria to evaluate smart cities focused projects can help to develop a more effective selection methodology and consider the different relevance of these criteria.

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Chapter 66
Identification of Attributes Linked to Urban Freight Transports that Affect the Performance of Urban Traffic, Through a Systematic Review

Carlos Henrique Rodrigues Alves, Fernanda Ramalho, Pedro Gomes, Marcia Marcondes Altimari Samed and Franciely Velozo Aragão

Abstract This study aims to identify the principal attributes related to the urban cargo transport (UCT), which directly and indirectly affect or carry out urban traffic, through a systematic literature review using the method Ordinatio addressing issues related to city logistics and UCT.

Keywords Urban logistics · Systematic review · Freight transport

66.1 Introduction

The study of urban logistics or city logistics involves the process of optimization of logistics activities and freight transport in urban areas. In this way, urban freight transport performs functions which are linked to the activities of production, distribution and consumption of product or service [4, 8, 10].

For Taniguchi et al. [9], urban logistics is a process that involves planning the distribution of goods, focusing on the optimization of cargo movement in the urban perimeter. Benjelloun and Crainc [1] emphasize that the concept of city logistics is focused on minimizing the problems that are generated from the movement of cargoes in urban areas, minimizing the environmental and social impacts caused by freight vehicles.

Thus, the main impacts of freight transport in urban areas are: traffic jam, road damage, traffic accidents, pedestrian traffic damages, cyclists and public transport vehicles, environmental, sound and visual pollution [5].

The system of freight transport in cities has numerous restrictions, such as type of vehicle, type of road network, local traffic characteristics, type of concentration of undertakings, windows of loading/unloading schedules, among others. Therefore, problem solving involving the transport of goods should be based on the application of efficient methods and techniques [3].

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Browne et al. [2] and Taniguchi et al. [8] report that studies are carried out regarding the flow of traffic and its impacts on the urban environment; however, these are focused on the evaluation of public transport and private vehicles, urban freight transport.

Therefore, in this article is presented a study that has as its theme the main items related to urban cargo transportation, which directly and indirectly affect urban transport performance, through a systematic review using the Ordinatio method.

66.2 Methodology

Perisse et al. [7] report that the systematic review is a scientific research that addresses the most relevant studies of the area studied, and it is emphasized that it is based on a research question that bases the study to be carried out.

In this way, the systematic review proposed in this study has as a research question: Which attributes related to urban freight transport can affect the performance of urban traffic. Therefore, it evaluated the articles published in the last ten years on the topic proposed using the methodology Methodi Ordinatio. Figure 66.1 shows the methodological sequence performed.

In the first stage, the research intention was established, which was to identify the taxes related to urban freight transportation that can affect the traffic performance.

Afterward, the databases for the study were identified: ISI Web of Knowledge (Web of Science), Scopus, Google Scholar and ScienceDirect.

The search string was defined.

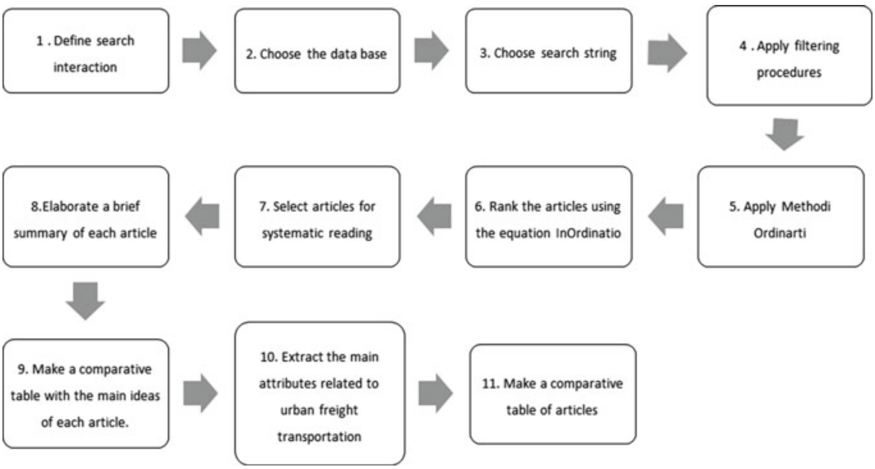

Fig. 66.1 Step-by-step methodology of the study in question. *Source* Adapted from Pagani et al. [6]

In the filtering of articles, it restricted the research from the following questions: year of publication, texts only of the typification of the article, delimitation of researches only on the subject in question.

After the filtering of the articles, the application of the InOrdinatio method was suggested by Pagani et al. [6]. After the classification of the articles, it applied the formula InOrdinatio, in which the numerical result will bring the level of relevance of the article in question; the greater the value, the greater its importance for reading.

After the execution of the method, the nine articles that presented an InOrdinatio value greater than 100 were used for the systematic reading, from which it was possible to extract the main attributes related to urban freight transportation.

66.3 Results and Data Analysis

The results and the analysis of the data can be described along the application of the methodology described in Fig. 66.1.

The line of thought of this article is developed from scientific articles on the theme: urban freight transport and its impact that affect the performance of urban traffic.

In this study, four databases were used: Web of Science, ScienceDirect, Scopus and Google Scholar. Being that, the base ScienceDirect was the most used for presenting texts with greater relation to the subject in question. In the search string, the choice was based on the idea of searching texts related to the line of thought of the study in question. Thus, two search strings were selected: “urban freight transport” and “city logistics.”

For the application of filtering procedures, each search that was performed with the search string, at first, presented a high result value. However, when the filter was placed between the periods from 2007 to 2018, a reduction in the result value occurred. Then, only text-type publications were restricted: articles; thus, there was a further reduction of the result value. With this, it was possible to read the titles of each article presented and select the 35 articles that were in fact relevant to the selected subject of this article.

The selected articles were arranged in a worksheet with impact factor (F_i) of the journal, number of citations (C_i) and its year of publication; in each article, it collected the information of its year of publication, the number of citations and its factor of impact, in which such values compose the equation of Methodi Ordinatio:

$$\text{InOrdinatio} = (F_i/1000) + \alpha^*[10 - (\text{AnoPesq} - \text{AnoPub})] + \left(\sum C_i\right) \quad (66.1)$$

α is the value that the researcher attributes to the year (usually is assigned by the value 10, which will be used in this study); AnoPesq is the year the research is being carried out; AnoPub is the year that was published.

With the information collected, it reached the number of 35 selected articles, which are presented in Table 66.1.

Table 66.1 35 Selected articles with respective data from Methodi Ordinatio

Article	IF	Year	C_i	InOrdinatio	Data base
Control y simulación de tráfico urbano en Colombia: Estado del arte/Urban Traffic Control and Simulation in Colombia: Literature Review	0.00	2009	23	53	Web of Science
A video-based real-time adaptive vehicle-counting system for urban roads	2.81	2017	0	110	Scopus
Traffic flow prediction with rainfall impact using a deep learning method	1.81	2017	1	111	Scopus
Modeling the effect of traffic regimes on safety of urban arterials: the case study of Athens	0.00	2017	2	112	Scopus
Comparative analysis of quantitative efficiency evaluation methods for transportation networks	2.81	2017	1	111	Scopus
The traffic congestion charging fee management model based on the system dynamics approach	0.80	2016	0	100	Scopus
Optimization of ITS construction scheme for road network under the restriction of different transports' passenger person-kilometers	0.80	2017	0	110	Scopus
Competitive traffic assignment in road networks	0.00	2016	3	103	Scopus
ECDS: Efficient collaborative downloading scheme for popular content distribution in urban vehicular networks	2.52	2016	6	106	Scopus
Weighted complex network analysis of Shanghai rail transit system	0.00	2016	3	103	Scopus
Estimating urban traffic patterns through probabilistic interconnectivity of road network junctions	2.81	2015	3	93	Scopus
A classification of city logistics measures and connected impacts	0.00	2010	113	153	ScienceDirect
Recent advances and future trends in city logistics	0.00	2012	5	65	ScienceDirect (Elsevier B.V.)
Critical factors for viable business models for urban consolidation centers	0.78	2017	1	111	ScienceDirect (Elsevier B.V.)

(continued)

Table 66.1 (continued)

Article	IF	Year	C_i	InOrdinatio	Data base
An ontology-based CBR approach for personalized itinerary search systems for sustainable urban freight transport	4	2015	21	111	ScienceDirect (Elsevier B.V.)
Identifying solutions for car vehicle deliveries in urban areas: a case study in Belo Horizonte (Brazil)	0.00	2016	2	102	ScienceDirect (Elsevier B.V.)
Traffic risk generated by large urban commercial centers	0.00	2016	0	100	ScienceDirect (Elsevier B.V.)
Designing multimodal freight transport networks: a heuristic approach and applications	3	2009	116	146	ScienceDirect (Elsevier B.V.)
Multi-criteria approaches for urban passenger transport systems: a literature review	2	2015	47	137	ScienceDirect (Elsevier B.V.)
Multi-period location of flow intercepting portable facilities of an intelligent transportation system	1	2016	2	102	ScienceDirect (Elsevier B.V.)
A simulation framework for modeling urban freight operation impacts on traffic networks	0	2018	0	120	ScienceDirect (Elsevier B.V.)
Impacts of planning and policy strategies on freight flows in urban areas	0	2016	1	101	ScienceDirect (Elsevier B.V.)
Freight group behavior under freight traffic restriction policy	2	2017	0	110	ScienceDirect (Elsevier B.V.)
Receivers' willingness-to-adopt novel urban goods distribution practices	0	2017	4	114	ScienceDirect (Elsevier B.V.)
Guiding cities to pursue a smart mobility paradigm: an example from vehicle routing guidance and its traffic and operational effects	0	2017	0	110	ScienceDirect (Elsevier B.V.)
Factors affecting modal choice in urban mobility	0	2012	29	89	ScienceDirect (Elsevier B.V.)
Urban mobility in Presidente Prudente city	0	2014	0	80	Google Scholar
Urban geographic space: a landscape modified by the transit of the Port of Porto Velho	0	2017	0	110	Google Scholar
Traffic modeling from counts to assess the level of mobility efficiency	0	2017	3	113	Google Scholar

(continued)

Table 66.1 (continued)

Article	IF	Year	C_i	InOrdinatio	Data base
Integration of an urban environmental monitoring system into a smart city	0	2016	3	103	Google Scholar
Modeling of the road network of the city of Guimarães: a case study associated with the impact of the construction of a new road	0	2017	3	113	Google Scholar
Diagnosis of loading and unloading positions for the urban distribution of goods: a case study in Belo Horizonte	0	2017	11	121	Scopus
Point of support as a solution for distribution of loads in urban centers	0	2015	1	91	Google Scholar
Attributes of cargo distribution and logistics performance indicators: research with companies operating in the metropolitan region of São Paulo	0	2016	2	102	Google Scholar
Study of urban logistics in the municipality of Campos dos Goytacazes/RJ	0	2017	0	110	Google Scholar

Source Author

Subsequently, articles with a value above 100, the nine largest, were selected for systematic reading, which are presented in Table 66.2.

After the systematic reading of the nine articles selected, it was possible to identify the various attributes that affect the performance of urban traffic, such as: large congestion caused mainly at peak times in which domestic cars and trucks often split streets and narrow avenues, causing accidents, delays in deliveries and stress among drivers, pedestrians and passengers. Another attribute mentioned in some of the articles was the impact on the environment generated by the different traffic pollution, such as noise and air pollution.

All these consequences have a common root cause: the lack or bad planning of the transit network in relation to the transport of people and goods present in these places; it noticed the difficult task of connecting the large volume of automobiles with all the services that they need to run in a short time, in addition, serve different types of people to be transported from one location to another at an affordable and efficient cost. Another difficulty is to make the transit work in a harmonious way, with sustainable and low-cost resources amid a continuous growth of the fleet of cars and consumption of goods to be delivered at home.

Therefore, most of these articles were concerned with this planning, using various resources: such as traffic simulation systems, analysis of solutions to deliver cargo,

Table 66.2 Nine selected articles

Ranking	Article	InOrdinatio
1	A classification of city logistics measures and connected impacts	153
2	Designing multimodal freight transport networks: a heuristic approach and applications	146
3	Multi-criteria approaches for urban passenger transport systems: a literature review	137
4	Diagnosis of loading and unloading positions for the urban distribution of goods: a case study in Belo Horizonte	121
5	A simulation framework for modeling urban freight operation impacts on traffic networks	120
6	Receivers' willingness-to-adopt novel urban goods distribution practices	114
7	Traffic modeling from counts to assess the level of mobility efficiency	113
8	Modeling of the road network of the city of Guimarães: a case study associated with the impact of the construction of a new road	113
9	Modeling the effect of traffic regimes on safety of urban arterials: the case study of Athens	112

Source Author

observing good examples in some cities to be applied in the country, among other solutions.

The objectives and the proposals of the nine articles selected are summarized in Table 66.3.

66.4 Conclusion

It may be noted that systematic review through the application of Methodi Ordinatio is an efficient and rapid way of obtaining information on a given subject. Thus, it is possible to apply a quantitative method as a tool for applying the systematic review.

With regard to the study here, most of the articles have as main focus solutions for cargo transportation, which usually involve the implementation of programs or simulators that present exits to problems present in road networks. However, it was not proposed to expand railways, subways, means of transport in rivers and other forms of transportation. In addition, an economic viability analysis under such changes was not even presented.

Another point not discussed throughout the articles was the change of habits among the residents of each region through more frequent consumption of locally produced products, thus reducing significantly the volume of vehicles in circulation.

Table 66.3 Objectives of the articles and their respective proposals

Article number according to ranking	Objectives	Proposals
1	Freight policy implemented in urban scale	Apply an urban distribution center
	General classification of measures adopted within urban areas	
	Regulate the transport network in relation to: schedules, routes and delivery times	
2	Multimodal freight transport	Model for strategic transport planning aiming to develop inter-regional cargo and freight terminals through different actions
3	Systematic study of articles on multi-criteria decision-making (MCDM) technique for the design and operation of urban passenger transport system. Decision-making criteria for each person to be transported	Understand what is being addressed in these articles in relation to urban transport decision trends
4	Approach on the rotation of the loading and unloading and counting of vehicles in the Belo Horizonte area. The structure of variables that must compose the structure of the diagnosis of the urban distribution of goods	Diagnose the operation of distribution of goods in urban centers, in order to demonstrate the importance of loading and unloading spaces to generate the efficiency of the urban distribution of goods
5	Simulation of traffic to reproduce urban freight movements, where the simulation is macroscopic and allowing the tracking of delivery vehicles along the routes	Present a hybrid framework that simulate traffic phenomena macroscopically and enable the tracking of vehicles
6	Practices of distribution of goods. On the behavior of the receiver in different scenarios and alternatives of traffic reduction	Analyze the behavior of the recipients of goods in two Spanish cities (Santander and Barcelona) when they are faced with the possibility of adopting new practices of merchandise distribution
7	The automobile circulation of an urban area based on stratified road traffic counting data also addressed the need to restructure urban centers, making them sustainable. He presented about six streets identifying the peak times and executing some predictions based on the count, so you can study the impact of changing the network operation	Characterize the circulation of the automobile of an urban area through the data of counted of stratified road traffic and to present its difficulties

(continued)

Table 66.3 (continued)

Article number according to ranking	Objectives	Proposals
8	It presents the impact of several changes in Guimarães city A modeling and traffic allocation procedure were presented to the city's road network through the use of PTV Visum software	Develop a calculation procedure for the application of PTV Visum in the city of Guimarães, to demonstrate the applicability of this type of tool in urban planning, with the creation of the origin—destination matrix
9	To analyze the probability of accidents and the severity of the accident, using the database of accidents registered in the period from 2001 to 2011 under two major arterial roads in Athens. A combination of vehicle flow information and speed time measurement was used. It also used the Bayesian logistic regression models to correlate the transit regime with traffic safety	It aims to divide traffic into significant clusters (schemes) and investigate their impact on the probability of accidents and severity of the accident

Source Author

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Chapter 67
Inverse Logistics Model for Recycling Multilayer Containers in Mexico: Designing Efficient Recovery Route

Ximena Vega Hermosillo

Abstract This project proposes routes that minimize recovery costs for multilayer containers, which connects high waste generation points with facilitated methods of waste separation to increase its recycling rate. The objective is to reduce the accumulation of 100-year-degrading-time material by facilitating its separation and supplying recycling companies with their raw material.

Keywords Recycling · Inverse logistics · Recovery route

67.1 Introduction: The Problem of Multilayer Containers

Nowadays, Mexico City is one of the top 5 cities globally that generates the most amount of garbage, producing 13,000 tons daily [1]. Considering various sources, the solid waste is one of the activities damaging the environment the most. In addition, only one-third of the waste produced is recycled, leaving the rest in dumping sites, being a serious incremental problem from the ecological, sanitary, social, and economic perspective. From the generated amount of waste, 32% is paper and cardboard, 25% PET and plastic, 14% glass, 17% various types of metals, and 16% of other types of garbage. Within this last 16%, there is a type of material called multilayer liquid containers, better known as Tetra Pak [1].

Tetra Paks are made from a six layers of materials. The biggest layer is the paper layer, which makes up 75% of the container, 20% is polyethylene, and 5% is aluminum.

Because of the known combination of materials forming it and the lack of a universal recycling alternative, the amount of Tetra Pak's garbage has never been officially separated. It is a daily present one-use material, provoking large amounts of waste generated from private sectors and citizens themselves and with its greatest problem being the lack of information and involvement on recycling efforts [2].

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As a result of its composition, the multilayer container has an estimated degradation time of 100 years, releasing different gases to the atmosphere in the meantime. According to Sundqvist et al. (1999), 12 g of methane is formed per kilogram of polyethylene landfilled; plus, the amount of methane released to the atmosphere is thus 102 g per kg of cardboard. Measuring the environmental impact considering the quantity of substances released per kg of waste landfilled is how it is identified as the direct contribution to the greenhouse effect.

Global warming is one of the biggest concerns of today, and one of its causes is the amount of waste being generated and not handled correctly. To have a perfectly balanced consumption cycle would be to recycle and reuse what is produced. In this specific type of material, present in everyday products such as milk, juices, and liquid beverages and used daily by the restaurant and coffee shops' industries, there must be introduced a solution to take care of the garbage generated and not recycled. With the combination of public policies and private initiatives, a better product cycle can be created and the environmental impact can be reduced.

From the estimated 16% of other types of garbage stated previously, if we assume 25% of it is multilayer packaging, we would be talking of 18.5 tons generated daily just in Mexico City. Today, there are only four companies working to recycle and recover multilayer containers in Mexico: SCA, Fab Papel San Jose, Kimberly Clark, and Ziklum. Because of the lack of legislation supporting its proper garbage separation, the variation in the price paid for a kg of the material in landfills as there is no standardization and the special treatment predisposal needed to avoid the material to rot, these companies face a critical problem: their raw material is garbage, but there is no universal process to separate and collect it, making it very difficult and pricy to obtain. The waste collection system process starts with the consumer generating the garbage all the way to the garbage being disposed in a dumpsite. Through all the process, waste scavengers separate and sell cardboard, PET, copper, and aluminum.

As explained previously, the lack of a legislation or general knowledge of the possibility of recycling this material prevents the consumer of separating it. Next, the absence of a standard price for the collected waste rules out that the scavengers separate it themselves. Therefore, today these companies get their raw materials by an extra effort of pacting with people working in dumpsites or with alliance with companies that use this type of material.

Waste management is not a priority to consider in most developing countries, even if the waste generation is increasing. Therefore, the approach to attack the problem must include an integrated effort from the public and private sectors to develop local solutions [3].

An important issue to consider is, apart from the lack of price standardization, the material itself has no immediate value in the market and for the characteristics of the material, and the amount of containers needed to have a worthy weight is high. The solution many companies have given to this is to establish recovery points [4].

For this project, we based the model proposed on the operations of Ziklum, for being the only company that recycles and recovers 100% of each container. Ziklum is a Mexican company dedicated to the recycling and recovery of multilayer containers since 2011. They recycle more than 220 tons of Tetra Pak a year, obtaining the material directly from dumpsites and from industrial disposal. The result products obtained are ZiklumCel, ZiklumPlak, and ZiklumComp. The ZiklumCel is long fiber cellulose used as a substitute fiber virgin for making various tissue products (napkins, tissues, paper towels) and sold to companies such as Kimberly Clark and Scribe. The ZiklumPlak is a poly aluminum bioclimatic sheet used as insulation panel, vertical gardens structure, furniture composition, and as a substitute timber formwork. And the ZiklumComp are polyaluminum bonded chips, used as raw material application for the plastic industry.

Their plant is located in Tepexpan, Mexico State, and has a capacity of recycling 400 tons of multilayer containers a month. But, their main problem is they work only at 60% of their capacity for lack of raw material. As previously mentioned, the complexity of obtaining the disposed material is the lack of price standardization (which makes it difficult to work directly with scavengers or dumpsites), the absence of knowledge of the possibility of recycling it and the predisposal steps to take to facilitate the material to last longer and not to rot for the liquid it was containing. Also, the transportation costs can increase considerably if the material is not unfolded and compressed, because the material would occupy a lot of space but not be a lot of weight.

As mentioned previously, for the lack of legislation, an integrated approach between sectors is needed to generate the planned impact. Multilayer containers are present on everyday products and have no apparent and more ecological substitute; and, unfortunately, Mexico City's waste recovery system works under a certain degree of corruption, difficulting recycling companies to obtain their raw material (any type of waste). This work suggests a systematic solution involving public and private sectors to address a specific material waste accumulation in Mexico City, avoiding the traditional recovery system.

67.2 Model Proposal: A Solution Using an Inverse Logistics Approach

The objective of the project is to create an inverse logistics model for multilayer containers recycling, to solve the problem of recycling companies of not having enough raw materials or not receiving it in adequate conditions to work with it.

The source of the disposed material can be divided into two: industrial or company generation or individual/residential generation. For the latter, there would be several extra complications to consider:

- Small amount of material in many points to collect
- Awareness and cultural education for the proper disposal (rinse the container)
- Many iterative routes needed to obtain a significant volume to make it feasible.

Reason why the company or industrial generation was selected to the initial part of the project, the creation of the inverse logistics model. The assumptions made for this sector of waste disposal were the volume would be bigger in more concentrated points of collection, the predisposal steps could be introduced as company's policy, and the total system cost could be financed between the private sector and the public sector to make it feasible.

To create the basic model, a specific company was selected, known for using products contained in this type of material daily in big quantities: Starbucks.

Starbucks has 303 stores around Mexico City and Metropolitan Area, with an average daily demand in the total area of more than 90,000 beverages with milk; and every type of milk they use is contained in a Tetra Pak. Based on an estimation of 1 L of milk being used for every 2.5 beverages with milk (medium sized), an estimated daily consumption was established. In the area, the daily consumption is around 38,000 L of milk, which would mean a ton of waste generated daily in the area by the 303 stores. With the amount of stores in the area and the estimated daily demand, the volume of material to be recovered is significant enough to be considered.

After analyzing the stores, the volume and the location of the plant, the basic model was defined as this:

1. Adapted trash can and a predisposal process per store
2. 12 routes, one per cluster, of multilayer containers recovery
3. Material disposed warehouse in the area of Industrial Tlaxcolpan, Tlalnepantla
4. Transport of an important amount of multilayer containers to the Ziklum Plant.

A key aspect of the model is the waste generation part. The multilayer containers have perishable liquids and if they are not rinsed properly, when the liquid rot, so does the container. On the other side, to leverage the transport, each container must be unfolded and compressed to diminish the amount of space it occupies.

Establishing the previous requirements as a process, the result is an extra process to realize in this sequence: Empty the container, rinse it with water, shake it to drain it as much as possible, unfold and compress the container, and finally throw it away in its specific trash can. The estimated time per container is 1.5 min.

If the containers are properly rinsed, they can remain in the trash can without smelling. Otherwise, each container could start to smell in a day of disposal. The adapted trash can is designed to compress again the containers together, to leverage the space inside and when it is transported. As part of the model, a basic design is presented to show its functionality. One of the next steps of the project is a formalization of the design as well as a cost evaluation.

The trash can is meant to include a compressing function, decrease the space each container takes, and facilitate the transport. The drawer will allow to introduce a previously unfolded and compressed manually a container. Then, when closed, the compressing function will push together the waste inside.

With an opening in the back part, the trash can allow to remove the disposed material in its compressed form, to optimize the space in the routes and facilitate moving the waste from the route vehicle to the warehouse and from the platform truck to the plant.

12 routes: The 303 stores were clusterized, grouping close locations and defining routes which minimize distance between them and facilitate its execution. The

amount of stores per cluster varies from 12 to 41 stores to consider on a recovery route.

Next, the waste generated was analyzed to determine frequency of collection. As each store generates an estimated of 3.5 kg of multilayer containers waste a day, three scenarios were considered. A daily recovery would mean 3.5 kg from each store, resulting in average 90 kg per route. Recovery every three days equals 10.7 kg per store with an average of 275 kg per route. A weekly recovery equals 25 kg per store and 640 kg per route. For the pilot of the project, recovery every three days was used based on the van capacity, on the route distribution and the warehouse space. When the project moves forward and includes more than one company on its routes, the collection may be done daily, taking advantage of the entire space available.

For each cluster, the following model was established to determine the optimal route, following the models proposed by Toth [5].

$$\min z = \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{m} d_{ij}x_{ijk}g$$

$$\text{S.t.} \quad \sum_{k=1}^{m}\sum_{i=1}^{n} x_{ijk} = 1 \quad \forall j$$

$$\sum_{k=1}^{m}\sum_{j=1}^{n} x_{ijk} = 1 \quad \forall i$$

$$Q_k \geq \sum_{i=1}^{n}\sum_{j=1}^{n} x_{ijk}bf \quad \forall k$$

$$u_i - u_j + \sum_{i=1}^{n} x_{ijk}n \leq n - 1 \quad \forall i > 1, \quad j > 1, \quad i \neq j$$

$$\sum_{i=1}^{n} x_{ilk} - \sum_{j=1}^{n} x_{ljk} = 0 \quad \forall k, l$$

$$x_{ijk} \epsilon \{0, 1\}$$

$$u_i \geq 0$$

x_{ijk} binary variable, equal to 1 if arc *ij* is included in the *k* tour
d_{ij} distance between store *i* and store *j*
Q_k capacity of the vehicle *k* (kg)
g gasoline price and its performance factor (result from dividing the performance value (an average of 7.3 km/L) over the gasoline price (magna, \$17.81 MXN per L)
b amount of garbage generated per store a day (kg)
f frequency of recovery routes.

The capacities of the vehicles depend on its type, the best option being the small van, with capacity to transport 450 kg and a space of 2.3 m^3 approximately.

Material Disposed Warehouse and Ziklum Plant: For the model proposed, the costs are meant to be divided within the involved actors, with a more specific methodology of costs to be determined. But, in the final transportation of the multilayer containers collected from every route, the company is responsible for taking it to the plant in Tepexpan. For this, the transportation cost is \$4500 MXN per platform truck, with a minimum amount to be carried of 20 tons.

The reason behind having an intermediate warehouse is to accumulate enough material to transport to the plant for it to be feasible for the company. On each route, the final stop is considered the selected warehouse, and with the compressed materials collected, also in the warehouse the space and its cost are meant to be optimized.

With the data recovered previously, the amount of multilayer containers disposed daily equals around a ton. To leverage the most the transport to the plant, the warehouse would reunite the collection of waste for a month and there will be a route to the plant a month, in the beginnings of the Tetra Pak collection system. As well as the frequency of the routes to the stores, this is meant to increase when more companies and alliances are formalized, to increase the volume collected and lower the time between routes to the plant. For the selected warehouse, the cost is 75 per m^2 a day.

Summarizing, the proposed model gives as a result of 12 routes of recovery to cover the 303 Starbucks stores in Mexico City and Metropolitan Area. On every store, it is proposed to have a special trash can for multilayer containers, to facilitate its separation and later transportation. Every route has an average of 26 stores, and they are created focusing on minimizing distance between them; also, each route finishes on the selected warehouse, to accumulate enough waste to make feasible the transportation to the plant every month. This way, the model plans to create a system of multilayer containers separation, recovery and recycling directly from the high waste generation places.

67.3 Cost Analysis

As previously mentioned, the proposed system is planned to be financed between the private sector involved and the participation of the public sector.

The variable costs per route are a result of the distance traveled, and the fix costs for all routes are the warehouse, transportation to the plant, and the vans rental. In this project, the vans rental and its added considerations (maintenance and driver) are set aside, looking to reach an agreement with public offices for a subsidization. The initial investment would be the special trash cans and the vans (to be determined the scheme of payment between participants involved). The fixed costs considered are the warehouse (\$6293.72 MXN) and the transport to the plant (\$4500 MXN). Each route has a variable cost based on the total distance it goes through.

In total, the routing system has a cost of \$24,204.60 a month. This cost includes 12 routes and the possibility of recycling more than 25 tons a month of garbage. Plus, Ziklum pays $2.50 per kg of material, so for 25 tons it will represent an income of $62,500. If the project is subsidized, the costs of operation of the vans are covered (except the gasoline which is the variable cost considered) and the entire system represents feasible.

67.4 Scenario Analysis

The system is flexible regarding the amount of routes or the locations to recover the garbage. Its feasibility, established previously, is based on volume. By working together with other companies with similar waste generation patterns as Starbucks (such as Cielito Querido, Punta del Cielo, to mention other coffee places), the entire system can expand its reach by adding new routes, and by using the van to its full capacity, the frequency of recovery could be daily and there may be no need for a warehouse in the city as each route may recover enough material to take it directly to the plant. Therefore, the elements of the system are able to change, increasing the material recovered and maintaining its original purpose, while improving its overall efficiency and feasibility.

67.5 Conclusion

The objective of this project is to offer a sustainable solution of recycling for multilayer containers, a daily used material but rarely recycled, through an inverse logistics model. The proposed idea involves the participation of companies through store adaptation and process introduction for adequate disposal, routing system through the company's store, and the final transportation to the plant to be recycled. The feasibility explained previously emphasizes the return the system could provide when fully implemented, considering aside the initial investment to start it.

We conclude this initial model proposal with the confirmation of its feasibility, and several next steps to confirm the initial investment maintains it this way. As said before, if implemented, this system could collect and recycle more than 25 tons a month, just with one company allied. The potential of the operation was identified, and the following steps will focus efforts on solving details and assuring it.

67.6 Future Research

The next steps for the project are defining an action plan for the implementation and improving the optimization model for each recovery route. The action plan is focused on implementing a pilot store for the process proposed, to validate the amount of waste generation, the functionality of the trash can and the feasibility of including the predisposal process in the everyday work of the store. On the other side, the optimization route can be improved by considering minimizing carbon dioxide emissions alongside the distance.

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Chapter 68
Vegetable Oil Boxes Palletizing Process Improvements

Ana Carla Fernandes Gasques, Marcia Marcondes Altimari Samed, Tamires Soares Ferreira, Bruno Alexandre Nascimento de Carvalho and Amanda Lais Tanji Umemoto

Abstract This paper presents a study on vegetable oil boxes palletizing process, demonstrating its improvements. Product packaging adequacy preliminary stages are described to maximize the palletizing and transporting capacity. Finally, a proposal for the palletizing process automation and its economic feasibility is presented.

Keywords Logistics · Supply chain management · Oil boxes palletizing

68.1 Introduction

Logistics develops the role to improve product quality focusing on transportation and making products meet its demand, being on the right place at the right time [1]. In Brazil, the road transportation according to the National Confederation of Transport [3] represents more than 60% of all used modals. Despite of this, road transportation promotes a negative impact on products, due to damages occurrence, breakdowns, delays and others issues [5].

One way to minimize this type of problem is the unitization through palletizing, which reduces the quantity of needed trips to deliver the same products amount and the number of volumes handled, offering fewer risks that could damage the cargo [1, 5]. An efficient and optimized palletization enables the loaded boxes total volume maximization, which in turn reduces products transportation costs by using the maximum vehicle volumetric occupation used to cargo transport [4].

Palletizing process allows standardized material handling equipment to be used across a wide range of products, as well as increasing the storage capacity through more stable stacking and higher stock stacks, and significantly assist in weight and volume magnification of materials handled per person-hour of work [1].

The main pallet model used in Brazil according to Costa [2] is the PBR, created by the Brazilian Supermarkets Association and adopted in 1990 by the Permanent Pal-

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letizing Committee, which defines pallet requirements as 1.20 m × 1.00 m, 135 mm height, double face and four entrances, as well as those of mass and humidity.

One way to optimize processes within a manufacturing environment is to use automation with technology employment so an activity or even the whole process is executed without human intervention. As benefits, when process automation is performed in an effective way, quality and efficiency increase can be seen, consequently providing productivity increase with constant results, besides allowing work environment safer conditions, considering that worker physical participation in the process is removed [6].

The palletizing process automation in a production line, besides increasing its efficiency, reduces needed labor to execute the products disposal in pallets, which in turn increases the standardization in the process final result. Based on this, this paper aims to develop the study on vegetable oil boxes palletizing process, demonstrating its improvements.

68.2 Methodology

This study was conducted in an Agroindustrial Cooperative and it was divided into two parts. The first one consisted on oil bottle packaging suitability analysis to maximize palletizing and transport capacity. Due to the company's privacy, the financial information as cost, revenue and profit could not be revealed. So, to this stage, a simple representative payback was calculated, showing that the bottles lost amount due to damages is approximately 1 million BRL.

Umemoto and Samed [7] developed a model considering all relevant information to the packaging. The packaging study verified which are the optimal dimensions for this product. Basically, different palletizing layouts were proposed using CAD software, trying to fit the largest boxes amount for each layer on the pallet, originating five new scenarios, as shown in Table 68.1.

According to the pallet size, it is known that its area is equal to 1.2 m^2. So, considering the five scenarios, it is possible to calculate the boxes optimal number

Table 68.1 Possible layouts

	Diameter (m)	Status	Reason
1	0.06600	Discarded	Smaller dimensions than the minimum radius to fit one liter
2	0.06925	Discarded	
3	0.07250	One arrange	–
4	0.07575	Discarded	The arranges had dimensions out of the pallet or fit the same quantity of boxes of the actual layout
5	0.07900	Discarded	Actual bottle dimensions
6	0.07360	Two arranges	–

that one palletizing layer could handle, that is, the biggest boxes quantity that can be arranged in a layer, considering the occupied area by each scenario.

The second stage consisted on palletization stage characterization and automation project and its economic feasibility presentation, describing all the process execution changes to be made. For this study, data were collected regarding the current palletizing process, such as: number of involved employees, used the equipment and their processing capacities, the process layout and the activity involved costs. These data were used to perform the process characterization and are related to the period from February 2016 to February 2017.

After the palletization stage characterization, the automation project was presented, describing all the changes to be made in the process with its execution. In order to verify the project impacts and possible benefits, the positive aspects in terms of labor and input reduction were identified and quantified, with data obtained through the enterprise resource planning (ERP) system used by the cooperative during the visitation period. Finally, the net present value (NPV) and rate of return (IRR) methods were applied to evaluate the economic return related to the investment for the palletizing process automation in the cooperative, seeking to reveal the project potential.

68.3 Results

The company's current layout scenario was based on old packaging requirements that is 249 mm in height, 79 mm in diameter and 900 mm in volume. The palletizing layout is shown in Fig. 68.1, according to the Brazilian standard pallet dimensions.

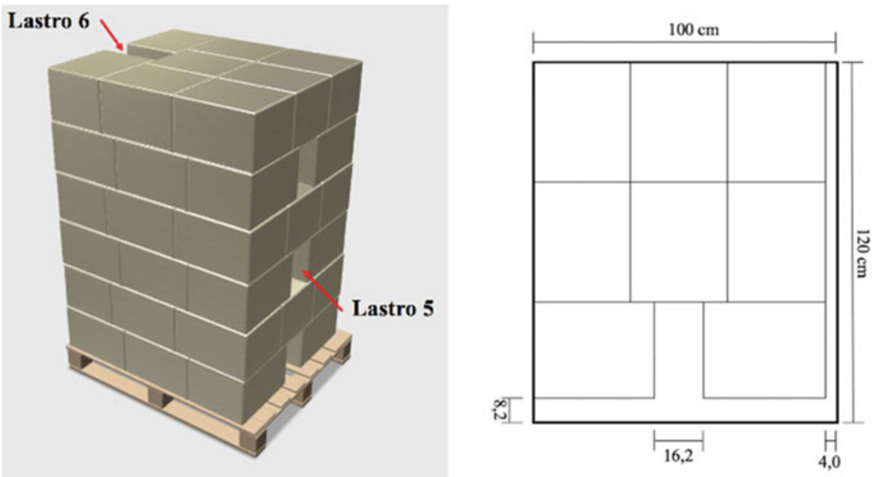

Fig. 68.1 Actual palletizing layout

Umemoto and Samed [7] analyzed the necessary aspects that involve the transportation to the distribution centers, which is made by three types of trucks: two, three or four axles.

The authors found that the market racks height is 26.2 cm, as determined by the trade marketing department, as well as the market requirement, and the full package contains 20 bottles, organized in 5 × 4 units. The oil package was studied to found the most satisfactory model, which consisted of a 0.0736 m in diameter bottle, occupying an 1.11 m^2 area with 8.33% of idleness (Table 68.2), resulting in a palletizing layout composed by 60 stacked boxes by pallet, in a total of six layers, called mosaics, each one with ten boxes (Fig. 68.2).

The new model resulted in a 25% increase in pallet capacity, in which the company's current arrangement was capable of carrying 48 boxes or 960 bottles, and with the implementation of the proposal, the new palletization layout would support 60 boxes or 1200 vials (Table 68.3).

Table 68.2 Chosen arrange

Scenario	Arrange	Diameter (m)	Occupied area (m^2)	Idleness (%)
6	1	0.0736	1.11	8.33

Fig. 68.2 Proposal palletizing layout

Table 68.3 Transportation capacities comparative

	2 axles		3 axles		4 axles	
	Actual	Proposal	Actual	Proposal	Actual	Proposal
Boxes transported	672	780	1152	1440	1344	1620
Gain (%)	–	16.07	–	25	–	20.53
Loads	1485	1280	1806	1445	65	54
Reduction (%)	–	13.80	–	19.99	–	16.92

In addition, logistical idleness, using the company's current palletizing, represents 13.39% of the total cargo for the two axles truck, approximately 20% for the three axles truck and 16.92% for four axles truck. Thus, from the proposal, the values would decay to 0.29, 0.87 and 3.35%, respectively.

After establishing the packaging model and analyzing the proposed new model benefits, it was found that the cooperative palletizing process used both labor and an old Cartesian palletizing system (Fig. 68.3) to assemble the product arrangements. Besides being inflexible in relation to the arrangements alteration, several employees are involved in the process activities, requiring a great amount of repetitive movements during the process execution. In this context, the cooperative high cost with the required labor to carry out the palletizing process stages, as well as the inflexibility to change the mounted boxes arrangement by the palletizing system due to the great difficulty of reprograming it and the necessity to reduce the freight cost practiced by the logistics sector.

It can be seen as the need to make it possible to change the boxes arrangement on the pallets when necessary, resulting in the cooperative freight cost reduction, as well as the reduction of the need for labor in the process. Thus, the palletizing process automation was proposed, which initially, despite the existence of a mechanical system that performs the palletizing, the application of the angles and the stretchable film take place manually after the pallet leaves this line.

The proposed model aims to carry out the products palletizing in both packaging lines from a system that has two layers that separate the stations, a robotic arm and a plastic stretch film wrapping machine. This set allows all products from the oil plant to be automatically palletized, without the need of human intervention (Fig. 68.4).

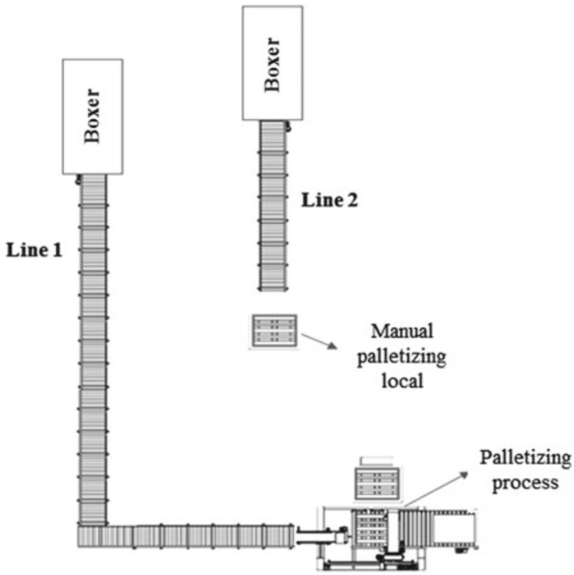

Fig. 68.3 Actual palletizing process

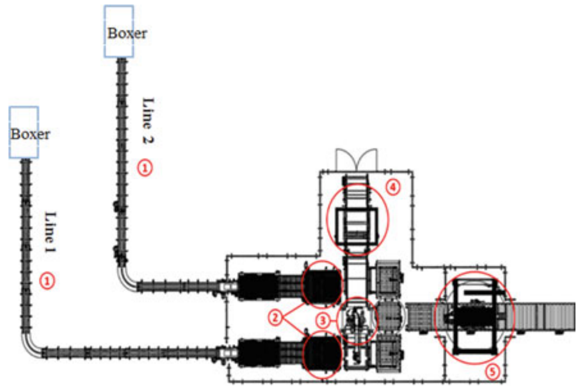

Fig. 68.4 Palletizing process proposal

From Fig. 68.4, it is observed that in the proposed model, both the container lines are directed by means of conveyors to separation stations, in which, through mechanisms located on the conveyor belt next to the station, the boxes are positioned in a place to assemble the layer according to the mosaic used. Because it is an automated set with programmable logic controls, the system enables the configuration and storage of different models of box arrays to be palletized, thus increasing the process flexibility.

The automation proposal, besides discarding the use of angle brackets, foresees an increase in the palletizing capacity of the packaging lines to 50 cartons per minute, equivalent to 72,000 cartons per day, exceeding in 92% the productive capacity of 26 cartons per minute. The execution of this project requires an investment of R $1,260,000.00 by the cooperative, representing the acquisition, transportation, adaptation of the site and installation of all palletizing system equipment, and the training of employees to operate it. Another important data to the project feasibility analysis is the capital cost or the minimum attractiveness rate (MAR). The value of the Selic rate, consulted in September 2017, was adopted and, according to the Central Bank of Brazil (CBB), is 9.15% per year, corresponding to the minimum desired return by the market for an investment.

The period chosen to carry out the feasibility analysis comprises a scenario of five-year horizon, considering the project initial investment and all the gains during this period. Such time interval was defined according to the cooperative strategic planning cycle, which also lasts for five years. As an aid to this analysis, we constructed a diagram representing the discounted cash flow forecast for the selected time horizon (Fig. 68.5).

In this cash flow representation, the periods are equivalent to one year, and the downward-facing vertical arrows depict the project outputs during the analysis period, while the upward-facing vertical arrows symbolize all the expected gains. Thus, the cash flow presented in the period 0 shows the total initial investment required by the automation project, while the values shown in other periods depict the sum of the labor reduction and purchase of cornering gains, totaling R $48,313,696 but adjusted by the chosen interest rate, in this case the Selic rate.

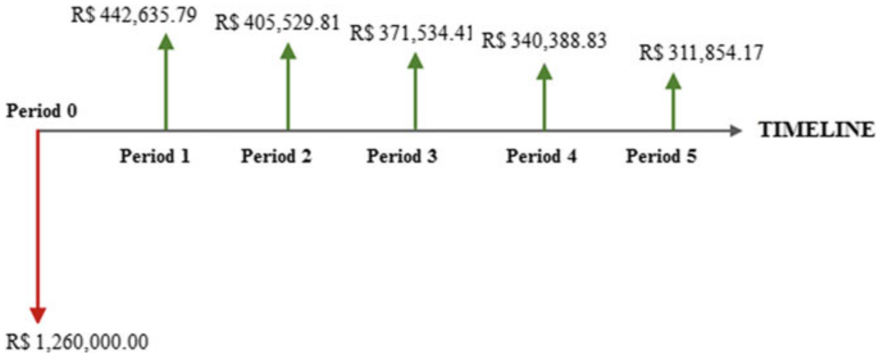

Fig. 68.5 Discounted cash flow

From the discounted cash flow, it is possible to calculate the NPV, since the terms of the sum of the NPV equation correspond respectively to the values of the discounted cash flow periods of the project. The project cash flow together with NPV and internal rate of return (IRR) analysis showed that the economy with the project implementation exceeds the initial investment value in a less than five years period, resulting in an IRR of 26.51%, almost three times higher than the value of the minimum attractiveness rate considered for the analysis, 9.15% (Selic interest rate).

In this sense, the proposed automation project would change the cooperative entire palletizing process by replacing the existing machinery with an automated system capable of palletizing two lines of vegetable oil packaging, thus reducing labor costs and inputs.

Thus, considering the results obtained, the suggestions of this research are economically positive for the cooperative, since both analyses were positive and concordant with the expectations of return required for an investment, since they exceed the Selic rate.

68.4 Conclusion

From the proposed study, as well as the analysis, the results found were satisfactory. In the packaging case, there was a 25% increase in palletizing capacity, resulting in less storage area and less problems with packaging damage in transportation and storage. Regarding the automation process, it could be verified that its implementation reduces the need of palletizing labor, besides extinguishing the use of carton angles in the finished pallet, resulting in the elimination of expenses with inputs purchase. Another benefit is the flexibility in the boxes unitization, reducing transport costs due to transported boxes total volume maximization.

The results show that the automation project analyzed meets the needs for reducing the cooperative logistic costs without reducing the palletizing process quality or productivity, being economically advantageous its execution despite the high initial required investment. Finally, it is important to consider that the results are not strictly useful for the oil bottles, but also for similar-shape packages, being useful for any kind of product, since all the information to a package study were been presented.

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Chapter 69
The just in Time Application in the Surgical Box Supply Chain Management

Annibal Scavarda, Gláucya Daú and Rachna Shah

Abstract The surgical box supply chain management can be problematic through the surgical scheduling without an effective management control of the forecast, the stock, and the pulled demand. This research study analyzes just in time application with the use of the Kanban in the surgical box supply chain management. The researchers realized this study between December 2016 and July 2018. The main objective of the study is to apply the just in time as a management tool for the surgical boxes. The research has two periods: the observational and the tool management adoptions analysis periods. The results section presents three subsections: "the inventory," "the integration among software, systems, and people," and the "participative management." The discussion brings two stages named: "the first stage-structuring the just in time delivery" and "the second stage-the just in time delivery." The authors conclude that the supply chain can be dynamic and customized. The mass customization can be inserted and the industry can bring contributions with new opportunities like the Kanban to implement the just in time application.

Keywords Just in time · Supply chain management · Surgical box

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69.1 Introduction

The supply chain, discussed in many studies [1, 5, 6, 16], can be more complex as its specificity raises to attend the demand of the productive areas in the healthcare institution. Regarding the healthcare institution specifically, the dynamics for attention to the medical specialities and the customization in order to attend to a surgical procedure are common to the practice. These challenges lead the managers and the healthcare professionals to seek for strategies to reduce the negative impact on the lives of patients.

The production management industrial model has been analyzed as a path to make adjustments on the health supply chain [15]. Among these many supply chains, the one that establishes a connection between the surgical boxes reprocessing (the Central Sterilization Service Department—CSSD) with the consuming sector (the Surgical Center—SC) stands out for the present study. This supply chain will be called by the CSSD–SC from now on. Figure 69.1 shows a cyclic and simplified model of this supply chain. The "cyclic model" name is adopted due to the continuous implementation of the logistics and the reverse logistics between the CSSD and the SC of the healthcare institution.

The dynamics of this supply chain with two equally complex sectors (the CSSD–SC) may suffer variations, according to the healthcare institution speciality, the number of beds and the surgical rooms offered. The SC is the biggest client of the CSSD, demand the just in time deliver, and it is presented as one of the most profitable sources of the healthcare institution. The income movement presented by the SC becomes the aim of the management attention for the supply chain planning, assessment, and dynamics analysis. The CSSD has, therefore, the foreknowledge responsibility and the supply materials for the surgical routines. It is expected that the intercurrence be minimized. Besides the inventory aspects, in order to the surgeries happen, materials should be safely reprocessed. The daily surgery map, composed by the elective, by the urgent, and by the emergency procedures, is a daily challenge for managers.

The connection between production and meeting the demands is a target concern, considering that, if the productive area capacity decreases, the demands are not going to be met [18]. The risks not only increase the financial autonomy of the healthcare institution, but also increase the risks for the patients. Then, many strategies are created in order to minimize these risks and to keep the continuous improvement

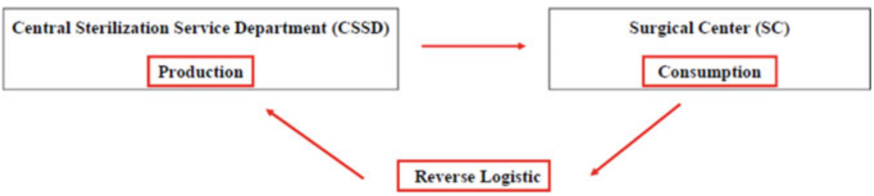

Fig. 69.1 The cyclic and simplified model of the CSSD–SC supply chain

on quality [10]. The contribution of these strategies already implemented by the industrial area brings to the healthcare sector the possibility to use strategies that aim to organize the offer, to control the demand, and to understand the priority.

The balance between the planned and the real inventories should be considered by the manager of the CSSD unit periodically. The low inventory generates conflicts, delays in surgeries, and unnecessary wait by patients and surgery staff. Even when appropriately managed, the passing and prioritizing flow of the surgical boxes can be carefully controlled, in order to avoid bottleneck production and inadequate reprocesses. Likewise, the public roads, where the vehicles flow has to be carefully taken care of by the traffic engineering sector, the CSSD should also have the "priorities traffic light" on the surgical boxes. The healthcare professional should deliver the proper surgical material with the appropriate timing implies respect for the patients in their physical and emotional conditions, as well as the family, the hospital, and the staff routine. The delay on surgery schedule is one of the stress promoters. The patient should be the main focus of attention of the healthcare staff and the healthcare institution.

The use of the management tools like the Kanban [11], the Lean [8], the Kaizen [12], and the just in time [11] is stimulated, therefore, for the continuous improvement of the actions developed in the supply chain. This way, the authors of the study, motivated by the routine lived along their professional trajectories on managing the supply chain, establish the following questions for research: Which managing tools may help the organization of the surgical boxes flow? How to involve all the CSSD and the SC staff on the control of this flow to make a quick and proper decision? The "priorities traffic light" can be implemented on the CSSD? Since the Kanban allows quick, visual, and color standardized access, according to a scale of priorities, the authors chose it among the tools previously mentioned. The characteristics enable that the just in time delivery for the SC to be done.

The next section, "materials and methods," presents the design of the study and the information regarding the data collection. The results section is divided into three subsections: "the inventory," "the integration among software, systems, and people," and "the participative management." Following, the discussion brings two subsections: "The first stage, structuring the just in time delivery" and "the second stage, the just in time delivery." In the "conclusions," the authors present the contributions of the study, as well as its limitations and stimulus to the future studies.

69.2 Materials and Methods

The researchers realized this study from December 2016 to July 2018 and it aims to apply the just in time routine as a management tool for the surgical boxes. The research has two periods. The first, named as observational, involved the observation and to assessment the CSSD–SC supply chain. This phase was made in a large private healthcare institution in downtown Rio de Janeiro from December 2016 to July 2017. A total period of 140 h was taken to observe 437 surgical boxes. The estimated rate of the reprocessed critical items monthly of the CSSD in a large institution is around 9000. The critical items are considered those which are put into body cavities. In this 140-h period, the surgical boxes flow and the assembly of kits according to surgical booking were closely observed.

The second phase analyzes the choice of the management tool to be adopted. This phase involved the search of the literature available with special attention to the supply chain, in order to enable the connection between the industrial supply chain and the CSSD–SC supply chain. Despite this observation, the Kanban routine was chosen for the just in time delivery as the best option. The use of the Kanban to aim a just in time delivery was chosen by the authors of the present study. The color standard visualization helps the quick identification of the priorities and the decision making. The model proposed for the Kanban implementation on the present study is named the "priorities traffic light." On the next section, the authors show the three aspects proposed for the study. They are: "the inventory," "the integration among software, systems, and people," and "the participative management."

69.3 Results

In order to establish the synchronicity and the surgical boxes flow, it is acknowledged that the challenge for the just in time delivery starts while planning the surgical instrument inventory. This instrument inventory is, in some cases, not assembled with enough pieces. The high expenses on purchase of the surgical instrument can lead to insufficient inventory. The loss of the pieces along the supply chain (either on the CSSD and the SC) and the damage for inappropriate usage of the material are also issues that may interfere on the reduction of the amount of surgical instrument.

The inventory reduction compromises the surgical booking, as the flow of the CSSD–SC supply chain. Therefore, the foreknowledge and the material supply for the surgical procedures not to be interrupted and canceled should be the attention target for managers. The pressure of the client [7, 14] for the just in time delivery comes up and it brings tension that can be minimized by the participative and synchronized flow management. Bruce and Daly [3] present the experience to establish just in time in the textiles and clothing industry.

The CSSD–SC supply chain requires that this system of goods and services production is assertive and safe on the delivery. Some healthcare institutions create strategies like the previous alignment of the surgical map. This strategy aims to check all the information among the sectors involved, in order to minimize lapses and to provide security for the patient. The sectors can be exemplified through the CSSD–SC, the intensive care unit, and the blood bank. But this previous alignment may still fail, since the surgical map alignment does not interfere on the decision making of the production area.

Some healthcare institutions are creating strategies, like "the alignment of the surgical map." This is a kind of checklist that aims to check information among all the sectors involved in order to minimize problems and to provide the patient safety.

Still, the dynamics of this procedure might have problems, since it cannot be used during surgery. By relating it with the traffic in a public road, this checklist for the surgical map alignment would be the plan before there are any vehicles circulating. The continuous evaluation while the cars move around is different. This action means to evaluate during the surgical boxes reprocessing, which is, to control, to adequate, and to reorganize the priorities. The study proposes the implementation of the Kanban for the surgical boxes management for the just in time delivery, based on the three aspects: “the inventory,” “the integration among software, system, and people,” and “the participative management.”

69.3.1 The Inventory

One of the weakest points of the healthcare institution is to have the proper surgical instrument inventory, regarding quality and amounts. Two different realities can be presented. The first is represented by those hospitals that have the planning, the replacement, and the maintenance control for the surgical instrument. The other reality is composed by those hospitals that, because of the lack of planning and due to the financial problems, cannot replace items of their stock. The financial investment for the purchase and maintenance of the inventory is high and also considered one of the biggest investments made by the CSSD manager.

The control and the balance between planned and real stock are challenges to be overcome. The excessive stock is not financially healthy for the institution [12]. By the time the supplies are about to be reprocessed by the CSSD, it is estimated that for each surgical procedure, there may have four equal surgical boxes with the same materials. This planning allows that the first surgical box is being used by the SC, the second is waiting by to be used for the next surgery, the third is being cleaned, and the fourth is being sterilized. The sterilizing process aims to destroy the microorganisms, delivering a safe product to get in touch with the cavities of the patient body. Therefore, it is expected to guarantee the synchronic flow to attend the surgical map.

69.3.2 The Integration Among Software, Systems, and People

In the fourth industrial revolution era, the use of the Internet of things comes to help the health supply chain [17]. The implementation of the integrated communication systems between the surgical map on the CSSD and the SC brings quickness and safe information for the decision making. The phone connections are left aside and a visual communication is provided by an integrated map, codified by colors. The cards previously established by the Kanban take the digital shape [11], bringing dynamism to the flow of the equipment, as well as a sustainable approach for the CSSD–SC supply chain.

The integration between industry 4.0 and triple bottom line (environmental, social, and economic) provides opportunities for the health supply chain [13]. Alternatives with the use of the cards might be analyzed. But the raise awareness and a wider look to understand that the use of the systems and the sustainable practices is expected. The systems and the sustainable practices can reduce costs in the supply chain.

69.3.3 The Participative Management

The engagement and the participation of the staff while structuring the new model to be implemented for the CSSD–SC supply chain is one of the main points of attention for the just in time surgical boxes delivery. The opinion of the professional who faces the problems on the edge and along any step of the chain brings the constructive information on the search for the better supply chain structure. The decision making should be as much assertive as possible [9], since it is going to happen on critical moments for the dynamic and continue flow. The participative management leads not only to the awareness of the practical situations and the problems faced on the supply chain. The engagement for responsibility and worshiping those professionals are the main actors of the reprocessing health products is the other point that can be considered.

The training in order to bring uniformity for the reprocessing is a part of the supply chain that can be reinforced. The pull production demanded by the SC is expected when the priorities of every surgical boxes are constantly assessed.

69.4 Discussion

On this section, the three strategies are unified an applied in two distinct stages: “the first stage-structuring a just in time delivery” and “the second stage-the just in time delivery.” These two stages are aimed to attempt the dynamic flow of the CSSD–SC supply chain.

69.4.1 The First Stage—Structuring the just in Time Delivery

The first stage is formed by the inventory organization, by the interaction among systems, software, and people, and by the staff involvement to promote the participative management. During the meeting, the problems are discussed, as well the bottleneck events and the impacts of the supply chain. After organizing the ideas, the aim is to present the “priorities traffic lights” for the CSSD and the SC teams. The opportunities and the challenges to be overcome are reinforced inattention the supply chain dynamic flow.

The integration and the communication among teams are elements that will enable to feed the project. The review of the current surgical material inventory with the appropriate surgical instrument number of the surgical boxes, the maintenance, and the acquisition of the new surgical instrument is the starting point after the meeting. A new stage is started by the integration among sector communication systems. A liquid crystal display (LCD) panel should be placed on the SC containing the surgical map information and the other LCD panel on the CSSD. The SC panel indicates in and out movement of the patients, as well as the return of the surgical boxes to the CSSD (the reverse logistics). The information should be transmitted to the stock area and the surgical kit assembly sector is responsible for this information on the "priorities traffic lights."

The third and the fourth LCD panels should be placed on the cleaning and the packing areas. On these panels, only the names of the surgical boxes indicate with the respective priority color (red–high priority, yellow–medium priority, and green–low priority), so that the stock professional will be able to indicate the priorities by checking the sequence on the surgical map and the stock. The decision making is continuous, with the pull production being conducted and the sequence of the boxes to be reprocessed. In any of these stages, the continuous training of the teams is implemented for a rapid and safe decision making. The participative management should happen throughout the CSSD–SC supply chain, providing autonomy and worshiping.

69.4.2 The Second Stage—the just in Time Delivery

For the second stage, the aim is the implementation on real cases, in which the surgical schedule is done, based on the number of the surgical boxes available. The kits for the first surgeries of the day are sent on the previous night. Once the surgical map is started, the professional in charge for stock defines priorities of the day by the current stock evaluation and the surgeries booked for the rest of the day.

Only on the shelves, the red, the yellow, and the green plastic cards will take place. By the time of the fourth industrial revolution in the hospitals, the radio-frequency identification (RFID) systems might be integrated. The insertion of the sensors on the shelves is an example that will alert the low stock of any item. On the other hand, the authors of the study suggest the plastic cards used (the plastic in the card aims to assure the cleanness of the card without damaged). These plastic cards might be disposed on each shelf for the surgical boxes, worshiping the signals and the control. It is a common sense that the industry 4.0 inserted in the hospital 4.0 and the CSSD 4.0 brings the cost reduction and the precision by the automation and the digital resources implementation.

In the manual or the systems, it is expected that the green cards show full stock, the yellow cards show 50% stock, and the red cards show stock below 50% and without stand by the material. The visual information helps the professional to put the proper

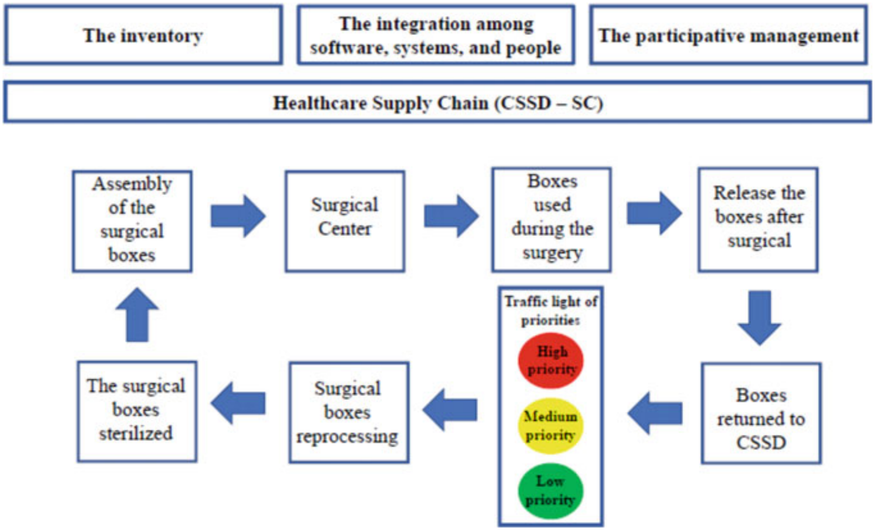

Fig. 69.2 The CSSD–SC supply chain applying the first stage and the "priorities traffic lights"

information on the information systems. Figure 69.2 presents the dynamics of the CSSD–SC supply chain.

69.5 Conclusions

The health supply chain is dynamic, sometimes standardized, and sometimes customized. The insertion of the mass customization on this supply chain can be made [2, 4]. The surgical boxes to attend a certain medical speciality with the different color pattern can be an example of this procedure. The mass customization insertion in this supply chain can be realized. The contributions brought by the industry may create new opportunities for the improvement of this supply chain. This study showed to discuss the just in time implementation through the Kanban on the CSSD–SC supply chain. The insertion of the industry 4.0 and of the triple bottom line allows the incorporation of new technologies that are enabled to the quality improvement and the cost reduction.

The outcomes point to three aspects with straight impact on this supply chain flow: "the inventory," "the integration among systems, software, and people," and "the participative management." The value created of the CSSD–SC supply chain, keeping a dynamic flow, is a challenge to be overcome. The section "discussion" established two stages: "the first stage-structuring the just in time delivery" and "the second stage-the just in time delivery."

The first stage is composed by the inventory planning and controlling, the insertion of technologies brought by the Fourth Industrial Revolution, and the continuous education. For the second stage, to keep up with the continuous education and the participative management, with the quick and assertive decision making. The activity development in each stage allows the worshiping of the CSSD and the professionals. The CSSD–SC supply chain is cyclic, using the logistics and the reverse logistics to achieve the goals. This supply chain is not standardized and it can vary in accordance with the kind of surgery to be performed and the surgical movement. The Kanban, a management tool, provides a better stock control and risk minimization on managing the supply chain for a just in time delivery of the surgical boxes.

Studies involving the supply chain should be stimulated, mainly, those that may contribute with opportunities for the management tool integration. These contributions enable reflections and adequacy to practices previously developed by the healthcare institutions. One of the limitations found by the authors for the study was the reduced numbers of the researches with the integration, the healthcare supply chain, and the management tools.

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Chapter 70
Prospects of Digital Transformation Technologies (DTT) for Sustainable Logistics and Supply Chain Processes in Manufacturing

Anna Lisa Junge

Abstract The work presents a literature review for clustering prospects of DTT for sustainable logistics and supply chain processes in manufacturing. Results indicate that DTT such as additive manufacturing, cloud, and auto-identification lead to possible improvements with regard to transparency in energy consumption, reducing distribution distances and optimizing logistics resources.

Keywords Digital transformation technologies · Logistics and supply chain management · Sustainability

70.1 Purpose

Digital transformation is a topic that is much discussed in practice and also paths its way as a scientific discipline. It encompasses people, organizations, and implemented technologies. Digital transformation describes the changes in value creation by the use of already known and evolving digital transformation technologies (DTT), adaptation of strategies based on new business models, and the acquisition of new skills and capabilities. Increased flexibility and productivity while focusing on customer needs are pursued objectives, whereas potential for logistics and supply chain management lies in decentralization, self-regulation, and efficiency [12, 15, 23].

DTT have become an important building block of value creation in manufacturing companies. Very often the term "digital transformation technologies" or "digital technologies" is used as a buzzword without indicating what technologies are or are not digital [19]. Publications with regard to efficiency improvement by DTT in logistics and supply chain management are already available. When applying the search string "digital transformation OR Industr* 4.0 AND logistics OR supply chain AND sustainability" to the database Business Source Complete in September 2018, it yields only one relevant result [10]. This highlights the need for more research at

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this intersection of smart technologies for achieving more sustainable logistics and supply chain management processes in manufacturing.

Hence, this paper intends to give an overview of DTT relevant to logistics and supply chain management and then clustering the resulting prospects for more sustainable processes for manufacturing firms. The resulting research question is as follows: "What are prospects and future research avenues of DTT for sustainable logistics and supply chain processes in manufacturing?"

70.2 Approach

To answer the research question, a systematic literature analysis was conducted in May 2018. The Boolean phrase

> (digital* OR Industry 4.0 OR smart) AND (logistic* OR SCM OR Supply Chain Management OR Supply Chain* OR SC) AND technolog* AND (manufacturing OR manufacturing industr* OR operation*)

was used to search through two databases (Business Source Complete and Web of Science) and was applied to title, abstract, and keywords. The two databases cover a range of journals relevant to manufacturing, logistics, and supply chain management and are thus considered to be apt for answering the research question. Despite the care taken in the systematic literature review, the language (English), the selected keywords, and selected databases represent a natural limitation. Inclusion criteria for the papers are as stated:

- Relevance of the manufacturing industry with multi-variant production. This excludes publications covering process industries such as oil, gas, and electricity.
- Focus on logistics and supply chain management.
- Discussion of the implementation or use of a concept or technology with regard to logistics and supply chain management and/or description of a classification/meta-analysis of digital transformation with relevance of logistics and supply chain management.

The results of the systematic literature analysis are displayed in Fig. 70.1, showing that 62 papers represent the basis for further consideration.

The remaining papers are published more often in production and manufacturing journals (e.g., International Journal of Production Research) than in logistics and supply chain management ones. They have different emphases representing the wide range of this interdisciplinary research topic.

The papers were subsequently analyzed and investigated with regard to the technologies covered (applicable to all 62 papers) and then with a focus on sustainability. Six out of the 62 papers address sustainability aspects representing 9.7%.

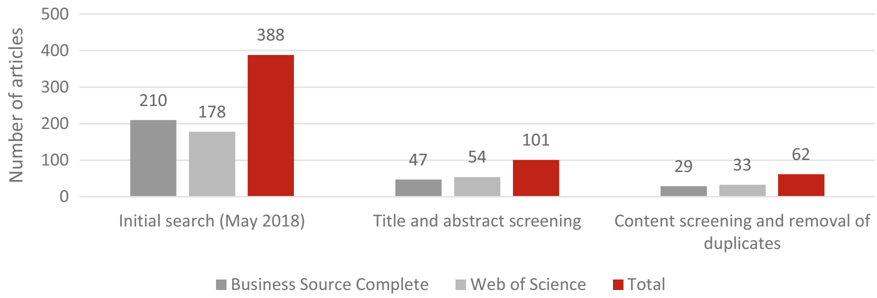

Fig. 70.1 Results of systematic literature analysis

70.3 Findings

Based on the analysis of the literature, the following technologies are found to be relevant to digital transformation in logistics and supply chain management in manufacturing: information and communication technologies (e.g., enterprise resource planning or manufacturing execution systems), auto-identification technologies (e.g. radio-frequency identification), cloud computing, cyber-physical systems, data analytics, blockchain, automation technologies (e.g., robotics), virtual and augmented reality, and additive manufacturing. This result shows that digital transformation is more than the digital representation of objects and information to create visibility. It enables new capabilities such as decentralization and autonomy.

The analysis of the literature reveals that there are several success factors as well as barriers for the implementation of DTT. Success factors are that technology must be learned in the real world and managerial skills tend to play the strongest role in value creation caused by information technology [6, 8]. The formation of flexible supply chain services that can be composed and decomposed according to requirements leads to more agile supply chains [14]. This requires service-oriented architectures run on an information technology infrastructure that fits organizational needs. The change process triggered by digital transformation is comparable to the paradigm shift in software development from structured to object-oriented development. This will lead to new and adapted ontologies used for specific problems in logistics and supply chain management [1, 16–18, 24].

Barriers for the mindful use of DTT are lacking standards for communication [7] hampering integration [13], limited flexibility of internal business processes [20], and the status of many companies not yet meeting the basic preconditions for digital transformation [4].

An open question remains whether the flexibility that is mostly pursued with the use of DTT (along with cost reduction) leads to increasing or decreasing complexity of supply chain networks. Baumers et al. [2] and Durão et al. [9] discuss whether the use of additive manufacturing will lead to more or less supply chain stages. This also impacts the sustainability of processes and products in supply chain networks.

In the following, the papers addressing sustainability aspects are presented and then clustered into the categorization of DTT as shown in Fig. 70.2 (Table 70.1).

A clear focus lies on additive manufacturing technology as an enabler for more decentralized production, which is covered in three out of the seven papers. Baumers et al. [2] suspect that additive manufacturing leads to the reduction of supply chain stages and stress the importance of further research for the environmental consequences. They differentiate between centralized and decentralized additive manufacturing supply chains. The first enables more efficient manufacturing processes, reduced inventory, and reduced requirements for distribution, while the latter is associated with environmental savings in terms of transportation and logistics of intermediate and end products. They conclude that additive manufacturing can offer new configurations for distribution, which may produce sustainability impacts [2]. Cerdas et al. [5] follow a similar construct and investigate the environmental impacts of additive manufactured products in a distributed manufacturing system with a focus on the product lifecycle of eye frames in comparison to a traditional centralized manufacturing system. From their achieved results, it cannot be stated clearly whether the distributed manufacturing system presents environmental advantage against a centralized manufacturing system or not. Results are impacted by the energy efficiency of the respective production process, the regional electricity mix, the material used, the experience of the user, and the quality of the printed product as well as the avoidance of rebound effects [5]. The combination of additive manufacturing with cloud computing and analytics can enable co-produced mass customization.

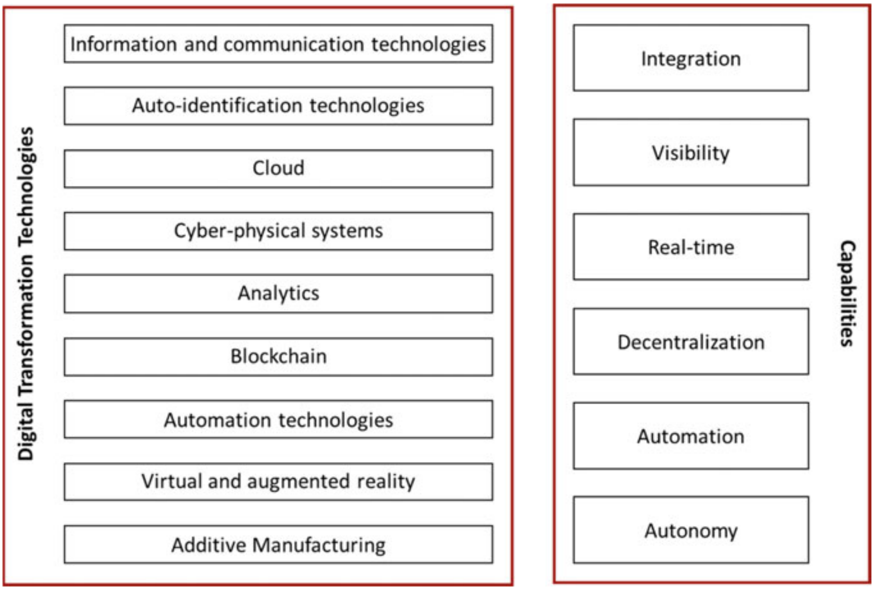

Fig. 70.2 Digital transformation technologies and their capabilities in logistics and supply chain management

Table 70.1 Overview of papers covering sustainability aspects

No.	Author	Journal	Technologies	Capabilities
1	Baumers et al. [2]	Journal of Industrial Ecology	Additive manufacturing	Decentralization
2	Bechtsis et al. [3]	Journal of Cleaner Production	Automation technologies	Autonomy
3	Cerdas et al. [5]	Journal of Industrial Ecology	Additive manufacturing	Decentralization
4	Guo et al. [11]	Applied Sciences	Automation technologies, cloud computing	Real time, autonomy
5	Tien [22]	Journal of Systems Science and Systems Engineering	Analytics, additive manufacturing	Real time, autonomy
6	Zhang et al. [25]	International Journal of Production Research	Cloud computing, auto-identification technologies	Real time

This can reduce the need for offshoring, because products are co-produced locally allowing a more effective and efficient production. This will shift the focus from supply of raw material to customer demand as the triggering event for production [22]. Guo et al. [11] simulate the use of automation technologies combined with a cloud service platform to actively publish or request logistics tasks. Their computational experiments (colored Petri nets) show that their method outperforms the event-driven method among others with regard to energy consumption [11]. Automation technologies, more precisely automated guided vehicles, are the research subject of Bechtstis et al. [3]. They account for the need to integrate sustainability requirements as a support for corporations in adopting automated and autonomous systems by proposing a framework for considering automated guided vehicles in a systematic manner. They propose a decision-making framework for analyzing literature based on economic, environmental, and social sustainability. Each of the three sustainability dimensions was then subdivided by decision making at the strategic, tactical, and operational echelon. The classification of literature grounded findings according to the sustainability framework reveals the factors important for supply chain decisions [3]. Zhang et al. [25] describe the use of smart auto-identification-enabled boxes as shared resources in distribution systems. A cloud service platform is used for collaboration. A third-party logistics provider owns the smart boxes and is responsible for their management including maintenance, status monitoring, information management, and recycling. By applying an optimization method, they conclude that the proposed setting shows advantages for increasing loading rate, reducing distribution distance, and optimizing logistics resources. The smart boxes as a product service system can help creating a green/low carbon logistics distribution pattern maximiz-

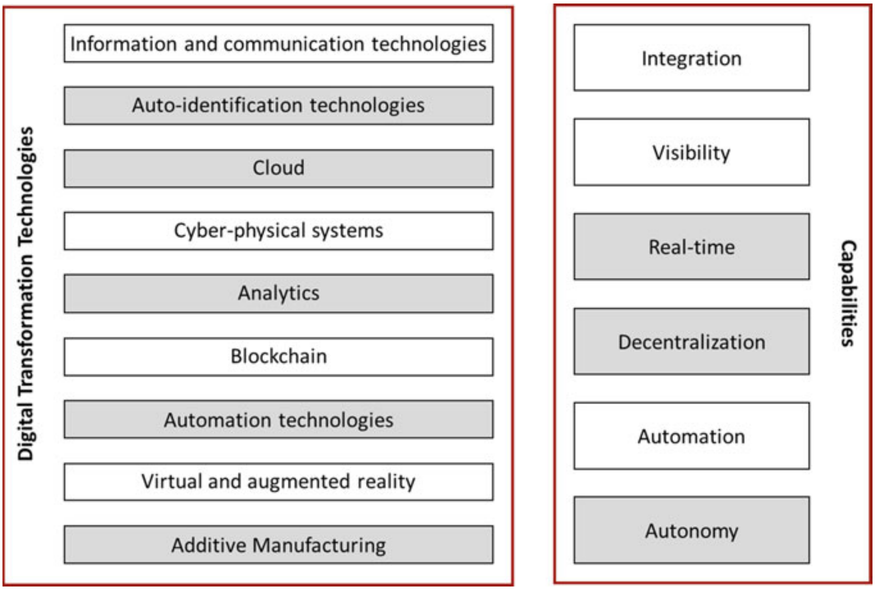

Fig. 70.3 Technologies and capabilities covered by papers with a focus on sustainability

ing revenue for all stakeholders, reducing the use of natural resources, and increasing logistics efficiency [25].

Figure 70.3 shows the areas covered by the discussed papers. They cover capability areas relating to putting data to value. This enables real-time, decentralized, and autonomous manufacturing and distribution processes.

70.4 Conclusion, Limitations, and Further Research

The presented literature analysis intends to give insights into a research area that is currently evolving. It offers a snapshot of subjects discussed in the scientific literature linking DTT with achieving more sustainable processes in logistics and supply chain management for manufacturing companies. Results indicate that prospects of DTT lie in the optimization of transportation distances in distribution within decentralized production networks (additive manufacturing), reduction of energy consumption (cloud computing and automation technologies), and optimizing logistics resources and minimizing distribution distances (auto-identification technologies, cloud computing). All these prospects account for environmental sustainability. In addition, Bechstis et al. [3] propose a decision framework for automated guided vehicles covering economic, environmental, and social sustainability.

The approach and findings of this paper show several limitations. Firstly, the design of the search string for the systematic literature analysis was deliberately broad to cover all digital transformation or Industry 4.0-related technologies. This might have excluded relevant papers that are not labeled accordingly. Secondly, the clustering of the findings only relates to the implemented technologies, their capabilities, and a description of sustainability impacts. For further research, it is worthwhile to cluster and describe the sustainability impacts in relation to logistics and supply chain management processes in manufacturing in a more systematic manner, e.g., based on the SCOR model. Strandhagen et al. [21] recognize the need for combining sustainability and digital transformation as well by proposing a framework for Logistics 4.0 and sustainable business models.

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Chapter 71
Decision-Making Method for Facility Location for Offshore Logistic Operation Based on AHP

Guilherme Silva Nunes and José Eugênio Leal

Abstract In Brazilian Oil exploiting Industry, offshore fields demands logistical bases to support the maritime operations. This work uses a simplified version of AHP to decide the location of a base to support operations in the Carcará Field.

Keywords Logistics · Oil industry · Facility location · AHP

71.1 Introduction

Since the majority of Brazil's hydrocarbon reserves are located in offshore fields, a crucial question arises: What are the best ways to render services for the offshore operations? All the demand for logistics to serve the offshore exploration and production rigs, including port facilities, transport services (including by air for personnel and small cargoes), and offshore and onshore storage necessarily involve a critical agent, the offshore logistics support base [3].

According to Donato [2], given their complexity of demand and need to render high service levels, offshore logistics support bases (or just shore bases) are considered by exploration and production companies as a central link in the operational support activities.

Central and strategic points in the upstream chain of the petroleums industry, these shore bases are specific port undertakings, with distinct operations and equipment in relation to regular commercial ports.

According to Ares [1], the logistics of offshore support can be divided into three types of operations: cargo logistics, personnel logistics, and service logistics.

Due to the significant operational risks, high cost, and central position in the supply chain, shore bases must be located strategically so as to provide all the resources necessary for offshore rigs. Hence, the decision on this location is crucial for the success of offshore campaigns.

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Based on these observations, the main objective of this work is to help an international oil company (IOC), through application of the traditional AHP developed by Saaty [7] and its simplified version developed by Leal [5], to choose a location for establishment of a shore base to support an exploration and production campaign that will occur in the Carcará Field. With the market opening in Brazil, investments in the sector have grown substantially [8].

The data to apply the processes were obtained by a field study, including visits to port terminals in the states of Espírito Santo, Rio de Janeiro, and São Paulo.

71.2 Literature Review

Human beings have a natural ability to establish relations between objects or ideas so that they are coherent, meaning that the interrelationships present consistency [6]. Therefore, one of the steps of the analytic hierarchical process (AHP) is to calculate the consistency ratio of the judgments of experts, denoted by CR = CI/RI, where RI is the random consistency index obtained for a reciprocal matrix with order n, with randomly generated non-negative elements; and CI is the consistency index, given by $\mathrm{CI} = (\lambda_{\max} - n)/(n - 1)$, where $\lambda_{\max}$ is the largest eigenvalue of the judgment matrix and n is the number of compared elements. According to Saaty [6], the condition for consistency of judgments is $\mathrm{CR} \leq 0.10$.

According to Gomes [4], multi-criteria decision methods were developed to better structure problems that involve making a decision based on a series of factors, either quantitative or qualitative, even when some are mutually conflicting.

The AHP method developed by Saaty is a powerful instrument for making multi-criteria decisions. It has been used in many applications in various areas of economics, politics, and engineering. At present, it is the most commonly used multi-criteria method, used in particular to support negotiation of conflicting points of views.

According to Leal [5], despite its wide applicability, the AHP is highly complex and time-consuming due to the huge number of pairwise comparisons that must be made to address problems with many criteria, such as important business problems faced by top executives.

Because of this difficulty, Leal [5] developed a method that by assuming consistency of judgment by decision makers reduces the number of comparisons for each criterion, or between criteria, to the comparison of only one element against all the others.

Leal [5] suggests that the element chosen as the base should have apparent greater importance, for which the expectation is that inconsistency of judgment will be minimized. Since consistency is assumed, one can calculate the vector of priorities, associated with the largest eigenvalue, based on a judgment between an alternative and all the others. The elements of the vector can be calculated by the following formula:

$$pr_j = \frac{1}{a_{ij}} * \frac{1}{\sum_k 1/a_{ik}} \tag{71.1}$$

where j is the element for which the priority is calculated, i is the element chosen as the base for comparison, and pr_j is the priority of alternative j.

The use of this method in the decision process is presented next.

71.3 Application: Selection of the Location of a Shore Base in the Petroleum Industry

Demand exists for a shore base to serve the needs of exploration and production from the Carcará Field in the offshore Santos Basin, location of potentially huge subsalt reserves, to be concatenated with a port terminal in the region.

To reach an optimal decision regarding the location of the shore base, the following steps were taken:

Visits were paid to the port terminals in the Southeast region of Brazil, and according to the demands of the IOC, all locations considered must already have a berth with minimum length of 100 m dedicated to offshore support operations. Six ports met this requirement, designated here $P1$, $P2$, $P3$, $P4$, $P5$, and $P6$ (one port terminal in the state of São Paulo, four in Rio de Janeiro and one in Espírito Santo).

A multidisciplinary working group was formed, composed of staff members of a firm specialized in offshore support logistics, where the first author works. This group defined the criteria and subcriteria used to evaluate the terminals, detailed shortly.

To enable obtaining the large amount of data necessary, extensive fieldwork was conducted at the six preselected ports. Then, the data were analyzed by applying modeling based on the simplified AHP method, for pairwise comparison of the criteria, subcriteria, and alternatives within each criterion.

The result of this comparison was a priority matrix of the port terminals, to help the IOC make a well-informed decision for location of a shore base to support the offshore exploratory campaigns in the Carcará Field.

71.3.1 The Criteria to Structure the Model

To structure the model, the consensus of the multidisciplinary working group was that to assure optimal performance of the shore base, it was essential to pay close attention to the criteria related to structure, location, and level of provision of logistics service (PLS).

In line with the method proposed by Saaty [6], Fig. 71.1 presents the ranking structure of the multi-criteria model.

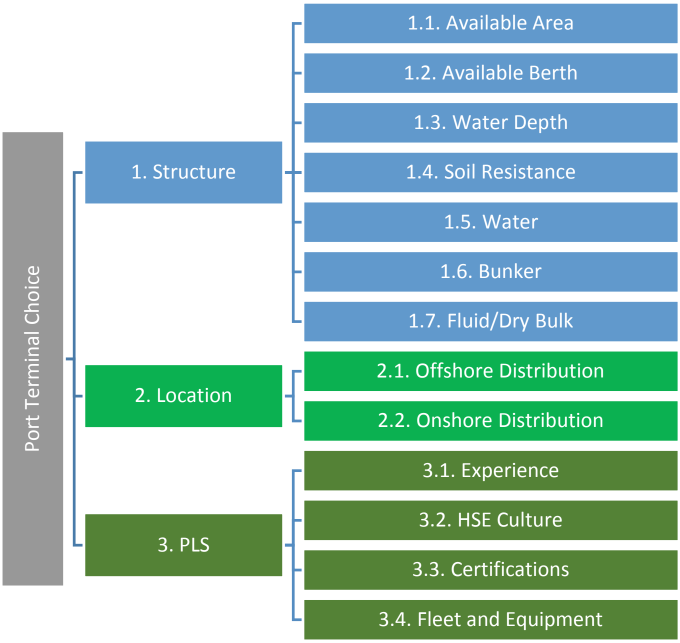

Fig. 71.1 Proposed ranking model—prepared by the authors

71.3.2 Application of the AHP

71.3.2.1 Summary of the Simplified AHP

Like in the traditional AHP, using the fundamental scale of Saaty, the application of the simplified AHP developed by Leal [5] proposes a method that, by assuming consistency of judgment by experts, reduces the number of comparisons for each criterion, or between criteria, to a comparison of one element with all the others.

The main objective is at the first level, the criteria that satisfy this objective are at the second level, while the subcriteria are at the third level and the alternatives to be compared in each subcriterion form the fourth level.

Each comparison of alternatives regarding a subcriterion results in a vector of priorities. These vectors in each subcriterion can be grouped in a priority matrix denoted by A_{sc}. The subcriteria are compared regarding their importance for each criterion, resulting in a subcriteria priority vector, VPS_C. The priorities of the alternatives regarding each criterion P_{ac} are calculated by the matrix formula:

$$P_{ac} = VPS_C^T * A_{sc} \tag{71.2}$$

Again, each vector of priorities (eigenvector) of the alternatives regarding each criterion can be grouped in a matrix $\boldsymbol{A_c}$. In turn, the priorities of the criteria with respect to the objective are calculated, resulting in the vector ***VPC***. The final priority of the alternatives is obtained by matrix multiplication:

$$P_{\text{final}} = VPC^T * A_c \tag{71.3}$$

71.3.2.2 Application of the Method

To attenuate the complexity by reducing the number of alternatives considered, we chose the alternative for each matrix that apparently is most important in relation to the others to perform the comparison. Table 71.1 presents the results of comparing between the criteria of the first level.

Tables 71.2, 71.3 and 71.4 present the comparisons of the subcriteria.

Based on the comparison of the criteria chosen, we applied the general Eq. (71.1) proposed by Leal [5] for normalization and calculation of the priority vector of the elements. Tables 71.5, 71.6, 71.7 and 71.8 present the priorities of the criteria and subcriteria.

Next, using the fundamental scale of Saaty and the information obtained from evaluating the terminals, the group of decision makers compared each of the six port terminals investigated with respect to each subcriterion. The result of comparing

Table 71.1 Comparison between criteria

	Structure	Location	PLS
Location	3	1	6

Table 71.2 Comparisons between subcriteria of the structure criterion

Structure	Avail. area	Avail. berth	Water depth	Soil resis.	Water	Bunker	Fluid/dry bulk
Water depth	4	3	1	6	5	6	4

Table 71.3 Comparisons between subcriteria of the location criterion

Location	Offshore dist.	Onshore dist.
Offshore dist.	1	3

Table 71.4 Comparisons between subcriteria of the PLS criterion

PLS	Experience	HSE culture	Certifications	Fleet/equip.
HSE culture	2	1	4	7

Table 71.5 Priorities of the criteria. Vector VPC

Objective	Structure	Location	PLS
Location	0.222	0.667	0.111

Table 71.6 Priorities of the subcriteria of the structure criterion. Vector $VPS_{structure}$

Structure	Avail. area	Avail. berth	Water depth	Soil resis.	Water	Bunker	Fluid/dry bulk
Water depth	0.106	0.141	0.423	0.07	0.085	0.07	0.106

Table 71.7 Priorities of the subcriteria of the location criterion. Vector $VPS_{location}$

Location	Offshore dist.	Onshore dist.
Offshore dist.	0.75	0.25

Table 71.8 Priorities of the subcriteria of the PLS criterion. Vector VPS_{PLS}

PLS	Experience	HSE culture	Certifications	Fleet/equip.
HSE culture	0.264	0.528	0.132	0.075

each alternative with respect to each subcriterion is a row in the comparison matrix. Tables 71.9, 71.10 and 71.11 present the results.

The values indicate the importance, or weight, of each of the six port terminals studied in relation to each subcriterion. The next step is to use Formula 71.1 to cal-

Table 71.9 Comparison matrix of the port terminals with respect to structure

Structure	$P1$	$P2$	$P3$	$P4$	$P5$	$P6$
Avail. area	9	9	5	7	1	3
Avail. berth	9	7	5	3	1	9
Water depth	3	3	9	5	1	7
Soil resis.	1	5	3	5	3	5
Water	1	5	1	1	5	5
Bunker	5	5	5	5	1	5
Fluid/dry bulk	5	5	1	1	1	1

Table 71.10 Comparison matrix of the port terminals with respect to location

Location	$P1$	$P2$	$P3$	$P4$	$P5$	$P6$
Offshore dist.	1	1	1	3	5	7
Onshore dist.	9	7	5	1	3	5

Table 71.11 Comparison matrix of the port terminals with respect to PLS

PLS	$P1$	$P2$	$P3$	$P4$	$P5$	$P6$
Experience	5	9	1	1	3	5
HSE culture	5	5	1	1	1	1
Certifications	3	5	1	1	7	3
Fleet/equip.	3	5	7	9	1	3

culate the priority of each terminal with respect to each subcriterion of the structure, location, and PLS matrices, presented in Tables 71.12, 71.13 and 71.14.

Multiplication of the priority vector of each subcriterion by the priority matrix of the alternatives produces the priority vector of each alternative with respect to each criterion. Taking each vector and grouping it in a matrix ordered according to each criterion yields matrix A_c (in boldface) presented in Table 71.15 with the priority vector of the criterion VPC, in the first column. The transposition of this vector multiplied by the matrix A_c produces the vector P_{final} of final priorities in the penultimate row of the table with the ranking of the terminals in the last row.

Table 71.12 Matrix $A_{\text{structure}}$ of priorities of the terminals for the structure criterion

Structure	$P1$	$P2$	$P3$	$P4$	$P5$	$P6$
Avail. area	0.059	0.059	0.105	0.075	0.527	0.059
Avail. berth	0.059	0.075	0.105	0.176	0.527	0.059
Water depth	0.157	0.157	0.052	0.094	0.472	0.157
Soil resis.	0.441	0.088	0.147	0.088	0.147	0.441
Water	0.278	0.056	0.278	0.278	0.056	0.278
Bunker	0.100	0.100	0.100	0.100	0.500	0.100
Fluid/dry bulk	0.045	0.045	0.227	0.227	0.227	0.045

Table 71.13 Matrix $\mathrm{A}_{\text{location}}$ of priorities of the terminals for the location criterion

Localization	$P1$	$P2$	$P3$	$P4$	$P5$	$P6$
Offshore dist.	0.272	0.272	0.272	0.091	0.054	0.272
Onshore dist.	0.056	0.072	0.101	0.503	0.168	0.056

Table 71.14 Matrix A_{PLS} of priorities of the terminals for the PLS criterion

PLS	$P1$	$P2$	$P3$	$P4$	$P5$	$P6$
Experience	0.070	0.039	0.352	0.352	0.117	0.070
HSE culture	0.045	0.045	0.227	0.227	0.227	0.227
Certifications	0.111	0.066	0.332	0.332	0.047	0.111
Fleet/equip.	0.157	0.094	0.067	0.052	0.472	0.157

Table 71.15 Matrix with final calculations

	VPC	*P*1	*P*2	*P*3	*P*4	*P*5	*P*6
Structure	0.222	**0.147**	**0.106**	**0.113**	**0.133**	**0.403**	**0.097**
Location	0.667	**0.218**	**0.222**	**0.229**	**0.194**	**0.083**	**0.054**
PLS	0.111	**0.069**	**0.05**	**0.262**	**0.261**	**0.193**	**0.165**
Priority		**0.186**	**0.177**	**0.207**	**0.188**	**0.166**	**0.186**
Ranking		3	4	1	2	5	6

Table 71.15 summarizes the result of the decision made by the IOC for best location of the shore base to support the offshore exploratory campaigns in the Carcará Field. *P*3 was considered the best location for establishment of the shore base, with 20.7% dominance, followed by *P*4 (18.8%), *P*1 (18.6%), *P*2 (17.7%), *P*5 (16.6%), and *P*6 (7.6%).

71.4 Conclusion

The predominance of offshore fields in Brazil's oil production means that logistics support terminals are important in upstream companies' productive chains, and the location of these terminals is a strategic key for the success of exploratory campaigns. Errors or suboptimal decisions regarding logistics raise costs and make operations more complex and laborious.

Besides location, the success of the offshore logistics support operation depends on various other factors, which must be observed, compared, and ranked for the decision process.

This study describes an application of the AHP to help a determined IOC to choose a port terminal for construction of a shore base.

The main gain observed from using the method to rank the ports in light of many variables was the capacity to generate collaborative decisions and help people make complex decisions.

More than determining the best decision, the AHP helped decision makers to choose and justify their choice, meaning it is a powerful tool to address complex problems in a structured way.

The negative side of the complete AHP tool is the volume of work required of high-level managers in making the pairwise comparisons. This problem was overcome by applying the simplified AHP, by reducing the need to analyze inconsistent combinations and the chance of making judgment errors. This can help organizations to make fast and accurate decisions.

The application of the technique allowed defining the main criteria and subcriteria and their dominances, for analysis of a set of port terminals mapped and selected in advance for visits and data collection. The result was a ranking of the terminals to serve as the basis for the final decision on where to build a shore base.

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Part VI
Marketing and Operations Management

Chapter 72
Endogenous and Exogenous Factors Influence the Competitiveness in the Brazilian Textile Sector

Paulo Cesar Da Silva, Milton Vieira Júnior and Rosângela Maria Vanalle

Abstract Endogenous and exogenous factors influence the competitiveness in the Brazilian textile sector. A questionnaire containing 26 assertions were applied through a survey of the largest Brazilian textile companies and their respective experts. The objective of this research was to identify which factors influence the industrial competitiveness in the Brazilian textile.

Keywords Firm competitiveness · Endogenous and exogenous factors · Textile

72.1 Introduction

The textile industry is one of the leading processing industries in the world; it is present in all countries. It is a human need for clothing and various applications, and according to Fujita and Jorente [4], the historical and cultural trajectory of the textile sector in Brazil has undergone a process of systematic change. Since the opening of trade in the 1980s and globalization of the world economy, the Brazilian textile industry has had a major impact on its production processes to adapt to the new market demands.

In recent years, the major players, exporters of the world textile industry, such as China, India, and Turkey, have expanded their productions exponentially, claiming equivalent world market expansion. Countries such as Brazil, with great potential for consumption, suffer more from such strategic actions of expansion of world market implemented by the main exporters. In order to remain competitive in the domestic market as well as seek opportunities in the foreign market, the Brazilian textile industry has undergone a process of modernization, innovation, and intense technological transference.

There are several attributes necessary to evaluate competitiveness. They involve competencies and actions, of the public sector and the companies, making necessary

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an evaluation of the main questions. Competitiveness has a clear meaning when applied to companies.

An important aspect related to the textile industry, according to Lall [11], is the identification of endogenous and exogenous factors that may be improving the competitive performance of industries. This practice has a positive impact on economic performance. Textile companies according to the same author can reduce raw material costs and minimize water and energy consumption, besides selecting suitable equipment for production.

Due to the significant representation of the textile of Brazil industry to national and regional economies of Mercosur, emerging as one of the largest manufacturing industry in the country with a high hand occupancy rate of work, but with a long way to go industrial competitiveness issues, this study sought to identify the main endogenous and exogenous factors of the determinants of industrial competitiveness in order to identify which of these factors influence the textile industrial competitiveness in Brazil.

72.2 Literature Review

Hutzschenreuter and Israel [8] state that competitiveness can be defined as a dynamic situation that occurs when several companies in a given market compete for scarce resources, and produce or market very similar products or services that meet the same customer need. Thus, according to the interests of each company, competitiveness emphasizes the interdependence between them, both vertically and horizontally.

Haguenauer et al. [6] define competitiveness as the ability of a company to formulate and implement competitive strategies that allow it to expand or permanently maintain a sustainable position in the market.

For Schumpeter [20], competition is related to internal industrial efficiency and the development of new technologies, new sources of supply and new types of organization. In addition to this position, Nakagawa [16] states that the company's competitiveness is characterized by the ability to develop and sustain competitive advantages, enabling it to face and overcome competition.

In addition to the need to remain competitive in the market, Maramaldo [14] defined competitiveness as the best possible combination between satisfying the market in which the company operates and profit. From this definition, Maramaldo [14] also pointed out that in order to understand the level of competitiveness of a company, a comparison with its main competitors is essential. And for this, comparative two indicators are needed: (a) market satisfaction, which defines the company's expansion in relation to its competitors and (b) growth in sales over the last five years.

Going beyond market satisfaction indicators and revenue growth, studies of Meneghetti [15] emphasize that the company obtain and remain competitive against the competition must be attentive to the market and the options to be practiced in the future, and (c) investments; (d) costs; (e) new technologies; and (f) pioneering processes, procedures, and products.

In studies by Hitt et al. [7], it was emphasized that in order to achieve competitiveness and achieve above-average returns, a firm should: (g) analyze its external environment; (h) identify existing opportunities; (i) determine which internal capabilities and capabilities are core competencies; and (j) select the most appropriate strategy to implement.

Other relevant authors in the study of industrial competitiveness, such as Porter [17], resumed his studies, reinforced the concepts by which a company can stand out in the market, and be more competitive, confirming (l) cost reduction and (m) differentiation, highlighted earlier in studies [15]. For Prahalad and Hamel [18], (n) empowerment; ie., the redesign of processes and portfolio rationalization; (o) downsizing, the reduction of administrative expenses; and (p) process reengineering and continuous improvement, are factor that influence customer satisfaction, optimizing the time of the production cycle, availability, and overall quality, with Maramaldo [14] aiming to satisfy the need of the market.

For Lall [10] in a broader definition of competitiveness, it is necessary to express its meaning, how to be measured, what are the main factors with their interactions and their influence on the competitiveness in question. According to Camagni [2], competitiveness is composed of factors that involve accessible physical externalities or environmental quality, capital, and also the learning capacity contained in a given territory.

As the source of competitiveness, factors can be divided into endogenous factors related to internal activities of an enterprise and exogenous factors related to external demands of a company. In an environment of industrial competitiveness, employees can act directly on endogenous factors to improve productivity, operational performance, and costs. While the exogenous factors are related to the forces pre-arranged by the market where a company must act to be competitive. For Lu et al. [13], in practice the division in two groups of exo and endo factors, allows an analysis of a reduced set of vital factors, essential for assessing competitiveness improvement.

In his research and literature review, Saboniene et al. [19] identified a list of exogenous factors that influence competitiveness in low-tech industries. The list of exogenous factors proposed by Saboniene et al. [19] allows an analysis of the qualitative elements and identifies the sources of competitiveness, its extremes, and improvements to be implemented.

Regulatory and legal restrictions at national and international levels; economic policies competition policy; industry policy; innovation policy and other; number and scope of local and international competitors; globalization and its economic, political, social, cultural, and other impacts; financial impacts: real exchange rate, interest rates, and inflation; public investment; level of national infrastructure; national economy growth; national education and training level; national political situation; country geographic location; ecological factors: (natural hazards Force Majeure), political measures to mitigate climate change, global spread of infectious diseases.

The impact of influences of the endogenous and exogenous factors in the industry was examined, thus allowing a separation between the internal and external factors policy constructs.

In our resource, we identified main endogenous factors that influence at competitiveness firm, at textile industry, and apparel as following: product differentiation; innovation research and development; reliable access to other utilities; sales and distribution networking; domestic marketing; organization culture; quality management; employees training and education; intellectual right protection; working agreement international standard; production according international standard; international market policy; exports license requirements; environmental restrictions [12].

72.3 Method

This article is based on a survey of the 40 most influential sectoral and verticalized companies in the Brazilian textile companies, according to ABIT [1] and IEMI [9] Institute, involving 52 owners, director-managers and specialist engineers of these companies. From this group returned 36 questionnaires answered, were select 26 and refused 26 inconsistent and uncompleted. In this survey, exactly 50% of the proposed questionnaires were reached.

The answers of respondents were measured by a rating scale from “1” to “5” where, according to the statements proposals, companies that value their closest competitiveness strategies of “5” should be more likely to improve its factors compared to those whose valuation is closer to “1” [5]. The research was carried out through a survey, used a questionnaire form with assertions elaborated from a research developed by Lau et al. [12], which explored the determinants of competitiveness in the Turkish textile and clothing industry, which identified 27 items of competitiveness grouped in eight constructs.

An application of this research by Lau et al. [12] was proposed in order to evaluate and compare the results of this research in the Brazilian textile scenario. Due to the peculiarities and characteristic of the textile business in Brazil, an evaluation of the endogenous and exogenous factors that most influence competitiveness in the textile industry was proposed in parallel. A list of exogenous was carried from literature review.

A list of exogenous factors was drawn from a study by Saboniene et al. [19] as a reference to analyze the influence and interactions in industrial competitiveness. From these two studies, the influence of endogenous and exogenous factors can be evaluated from the constructs and determinants of competitiveness of the textile industry in Brazil.

72.4 Results and Discussion

After determining, the differences between the mean values of the competitiveness constructs listed in Table 72.1 demonstrated that they are statistically significant. In this paper, we present a list of factors and influence on competitiveness, as proposed

Table 72.1 Means of competitiveness of constructs or items

Competitiveness constructs/item	Factors	Origin	Average	SD
Product differentiation			4.26	0.732
Product differentiation	g1	Endo	4.44	0.567
Innovation, research and development	g2	Endo	4.07	0.813
Reliable utilities accesses			4.01	1.019
Reliable access to others utilities	d3	Endo	4.22	0.916
Reliable natural gas and coal access	d2	Exo	4.04	0.999
Reliable water access	d1	Exo	3.78	1.066
Focus of domestic markets			3.88	1.057
Sales and distribution network	e3	Endo	4.41	0.782
Domestic marketing	e1	Endo	4.22	0.875
Vertical integration	e4	Exo	3.89	0.875
Lack of volatile in domestic demand	e2	Exo	3.00	1.054
Quality management			3.78	1.122
Organization culture	a1	Endo	4.15	0.890
Quality management	a2	Endo	3.89	1.197
Employees training and education	a4	Endo	3.74	0.927
Intellectual right protection	a3	Endo	3.33	1.247
Cooperation program access			3.40	1.114
Industrial cooperation networking	F3	Exo	4.00	0.720
Networking with government's and politic agencies	f1	Exo	3.15	1.208
Social responsibility/charity	f2	Exo	3.04	1.071
Focus on foreign market			3.22	1.336
Working agreement with international standards	b2	Endo	3.89	1.030
Production according to international standards	b1	Endo	3.70	1.116
International marketing	b3	Endo	3.04	1.319
Access to sea port	b5	Exo	2.96	1.427
Lack of volatile in external market	b4	Exo	2.52	1.228
Government incentives			3.04	1.071
Preferential government policy	h2	Exo	3.04	1.071
Licensing and others restrictions			2.97	1.357
Export licensing requirements	c2	Endo	3.59	1.313
Bureaucracy and red tape issues	c4	Endo	2.81	1.123
Environmental restrictions	c3	Exo	3.19	1.218
Export quota	c1	Exo	2.30	1.383

by Lau et al. [12]. That performed an exploratory factor analysis (EFA) to test whether measures of a construct developed by the focus groups are consistent with a survey. This result and list discussed at turkey market was compared with survey applied in textile industry in Brasil. Exogenous and endogenous factors were determined based at literature review and selected in the list of proposed by Lau et al. [12]. Table 72.1 presents the mean scores received for each construct and their respective competitiveness factors. Considering the general mean of constructs, we can divide them into three groups:

(a) High level of competitiveness relevance—Averages above 4.0. In this group are the following constructs in descending order of relevance: Product differentiation (4.26) and Reliable access of resources (4.01);
(b) Moderate level of influence on competitiveness—Averages between 4.0 and 3.0. Focus on the domestic market (3.88); Quality Management (3.78); Access to cooperation programs (3.40); Focus on Exports (3.22) and Government Incentives (3.04).
(c) Low level of relevance in competitiveness—Average below 3.0. In this group only one Licensing and other incentives construct.

In general, the overall mean of all endogenous factors was higher than the global mean of exogenous factors, respectively, 3.82 and 3.24 averages. This result indicates that endogenous factors, which are easier to be controlled and managed by companies, are more relevant and therefore may be fundamental in improving the competitiveness of the Brazilian textile industry. According to the responses of the managers of the textile industries respondents to the survey the most relevant construct for competitiveness was product differentiation (4.26). This result is due to the high average achieved by the two endogenous factors: product differentiation (4.44) Research and development (4.01).

According to the managers of the Brazilian textile industries, respondents of the questionnaire companies are investing in research and development and product differentiation to remain competitive in the domestic and export scenario [12]. In the study of the factors, determining the competitiveness of the Turkish textile industry also found the product differentiation construct as the highest mean 4.51.

The second most relevant construct was reliable access to resources (4.01). In this construct, the endogenous factor reliable supply of other utilities (4.22) contributed to the high score. Exogenous factors had lower scores; reliable access to water (3.78) and reliable access to gas and coal (4.04) [12]. In the study of the factors determining the competitiveness of the Turkish textile industry, the construct reliable access of resources was the sixth in relevance, with an average of 3.91.

The third construct, focus on the domestic market, with average (3.88), presented a moderate level of influence on general average competitiveness. The endogenous factors that were more relavant scored; Domestic marketing (4.22) and Distribution and sales network had average (4.41). In case of the exogenous factors; Lack of volatility in the domestic market demand showed the lowest mean (3.0) and vertical integration presented mean (3.89). For comparasion, this construct in the study of Lau et al. [12] was the fifth in relevance with a average of (3.99).

In the fourth construct, Quality management with average (3.78). All factors are endogenous and presented the following average; Organizational culture with mean (4.15); Quality management mean (3.89); Education and training of employees with mean (3.74) and intellectual property protection with mean (3.33). This construct was not studied by Lau et al. [12]. In another study of the factors determining the competitiveness as of the Turkish textile indutry, observed this factor in the same position of relevance but with a higher average (4.18).

Access to cooperation programs with an average of 3.40 was the fifth most relevant construct. All the factors constituting this construct are exogenous: industrial cooperation network (4.00); proximity and connections with government agents or politicians (3.15); and social responsibility and care programs (3.04) [12]. In the study of the factors determining the competitiveness of the Turkish textile industry, the reliable access to resources construct was the sixth in relevance with an average of 3.91.

The sixth most relevant construct, focus on export; present an average (3.22). The endogenous factors that contributed to the highest average were; Creation of working conditions according to international standards with mean (3.89); Production according to export standards, mean (3.70) and international marketing with mean (3.04). Found that the exogenous factor less relevant were; Access to ports with mean (2.52). As well this construct was not studied by Lau et al. [12]. In our research it was the second most relevant construct with average (4.27). The seventh most relevant construct was government incentives with mean (3.04) as an exogenous factor related preferential government policy observe by Lau et al. [12]. As well at research of the determining the competitiveness of the Turkish textile industry the reliable access to resources construct stayed at sixth position in relevance with mean (4.22) for comparison.

The construct less relevant to competitiveness was the licensing and other incentives, with an average of (2.97). Endogenous factors contributed with the highest means; requirements export licenses, 3.59; and environmental restrictions 2.81. Exogenous factors contributed to the following averages; Bureaucracy problems 3.19 and Costs for export, with the lowest mean of the entire study 2.30. Same result was found in the Lau et al. [12]. However, in this study the mean of the least relevant construct was greater 3.77.

72.5 Conclusion

Adopted to the methodology applied by Lau et al. [12] for a research in the Turkish textile industry, which have certain characteristic of textile business with high degree of similarity to the textile industry of Brazil, except for the differences in the number of companies and business volume around 4 to 5 times higher in favour of the textile industry of Turkey. The same basis of determinants, constructs, and factors of industrial competitiveness was taken as reference in Table 72.1. Means of competitiveness of constructs or items.

Based on this study and with the objective of identifying which endogenous and exogenous factors are most relevant and influence the textile industrial competitiveness in Brazil, it can be observed that in general, the global average of all endogenous factors was higher than the global average of the exogenous factors, or it is the respondents' understanding that the internal actions of improvements of the determinants can contribute significantly with the textile industrial competitiveness of Brazil. Among the endogenous factors, the one that was most relevant, as well as the study in turkey was product differentiation and development, and this is justified due to the fact that the companies need to be innovative to search for new market niches.

It can be seen in the results that the endogenous factors, reliable access to resources, domestic marketing, and distribution and sales network have greater relevance for the textile industry in Brazil than in Turkey, and this is justified by the fact that the Turkish textile industry is more dependent European, external market; in contrast to Brazil, which is more concentrated in the domestic market and with lower turnover in the Mercosur market.

In a way, our findings show that endogenous factors are more relevant and exert greater influence in the textile industrial competitiveness of Brazil, which contradicts some research carried out in Eastern Europe as Saboniene et al. [19], which states that the exogenous factors has great relevance in industries.

Thus, our findings on the competitiveness of Brazilian textile and clothing companies can be related to the idea that there is still a vast field of improvement of endogenous factors to be implemented so that we have a greater degree of competitiveness of national and regional industrial. Future research on the subject can be directed to industries of the sector through case studies in the application and monitoring of measures of improvements of endogenous factors and/or exogenous of industrial competitiveness.

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Chapter 73
Effects on the Power of the Xbar Chart After Adjustments to Guarantee an In-Control Performance

Felipe S. Jardim, Subhabrata Chakraborti and Eugenio Kahn Epprecht

Abstract Process monitoring is an important part of Operations Management (OM). Xbar charts are used to detect changes in the process mean. Recently, researchers proposed control limits adjustments to guarantee the chart's desired in-control performance when parameters are estimated. We analyze the effect of these adjustments on its out-of-control performance. Recommendations are provided.

Keywords Parameters estimation · Xbar chart performance · False alarm rate

73.1 Introduction

The Xbar (or $\overline{X}$) control chart is widely used to monitor the mean of processes in many industries. Recently, several papers studied the performance of the $\overline{X}$ chart when parameters are estimated (i.e., the in-control process mean or the in-control process standard deviation are unknown and estimated) from m historical samples each of size n. For a detailed literature review on this topic, see Psarakis et al. [10].

The main performance measure of a control chart is the average run length (ARL), or in other words, the average number of monitoring samples (with size n also) until an alarm (or signal). When parameters are known, the number of samples until an alarm (also known as the run length, RL) follows the well-known geometric distribution with the parameter being the probability of a signal (PS). So, the average of this distribution (the ARL) is the reciprocal of the PS (see, Montgomery [9]).

However, when the in-control process mean or/and the in-control process standard deviation are estimated in order to calculate the control limits, the ARL is conditioned on these estimated parameters, and because of this, it is denoted CARL. Since estimators are a random variable, differently from the "known parameters case," the CARL is also a random variable varying from practitioner to practitioner. The

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variability of the CARL, when the process is in control, is known to be very large (see, for example, Saleh et al. [11, 12] and Jardim et al. [6]). This means that the in-control CARL (also denoted as CARL_0) values may be much different compared to the in-control ARL (or ARL_0) values in the unrealistic case where no estimation is needed.

Recognizing this deficiency, recently, some authors recommended adjust the control charts limit in order to have a large probability of the CARL_0 being greater than a specified value (close to the nominal desired one in the "known parameters case"). This is known as the exceedance probability criterion (EPC) proposed by Albers et al. [1]. For the $\overline{X}$ chart, exact adjustments were derived by Jardim et al. [6], while other authors relied on approximated adjustments (see Goedhart et al. [3, 4]).

In most situations, these EPC adjustments make the control limits wider (compared to the "known parameters case") which guarantee the in-control performance but deteriorate the out-of-control performance of the chart, since wider control limits may delay the detection of real changes in the process mean (a true signal). Given this, in the present paper, we study the out-of-control performance (also known as the power) of the $\overline{X}$ chart after the EPC adjustments by calculating some quantiles of the out-of-control CARL in order to provide the best trade-off between the adjustments that guarantee an in-control performance and a not considerable deterioration on the out-of-control performance.

We considered three cases: when both the process mean and standard deviation are unknown and must be estimated (this is denoted case UU), when only the process standard deviation is unknown and estimated (this is named case KU), and when only the process mean is unknown and estimated (this is case UK). Jardim et al. [6] also studied the power of the $\overline{X}$ chart after the EPC adjustments in case UU, but a similar study is not available for cases KU and UK in the literature.

73.2 The $\overline{X}$ Control Chart Control Limits

The upper and lower control limits (UCL and LCL) of the $\overline{X}$ control chart when the in-control process mean (μ_0) and the in-control process standard deviation (σ_0) are known, are given, respectively, by

$$\text{UCL} = \mu_0 + L\frac{\sigma_0}{\sqrt{n}}, \tag{73.1}$$

$$\text{LCL} = \mu_0 - L\frac{\sigma_0}{\sqrt{n}}, \tag{73.2}$$

where n is the size of the samples being monitored, L is the control limit factor. When $L = 3$, we have the most common 3-sigma limits. In the cases where μ_0 is unknown and must be estimated (cases UU and UK), the most well-established estimator for μ_0 is the sample grand mean $\left(\overline{\overline{X}}\right)$ defined as $\widehat{\mu}_0 = \overline{\overline{X}} = \frac{1}{m}\sum_{i=1}^{m} \overline{X}_i$, where $\overline{X}_i = \frac{1}{n}\sum_{j=1}^{n} X_{ij}$, $i = 1, 2, \ldots, m$, $j = 1, 2, \ldots, n$ and X_{ij} denotes the jth observation of the ith historical sample. For the cases where σ_0 is unknown (cases UU and KU), we choose the highly recommended pooled sample standard deviation (S_{p}), see Vardeman [13] and Mahmoud et al. [8], which is given by $\widehat{\sigma}_0 = S_{\mathrm{p}} = \sqrt{\frac{1}{m}\sum_{i=1}^{m} S_i^2}$, where $S_i^2 = \frac{1}{n-1}\sum_{j=1}^{n}\left(X_{i,j} - \overline{X}_i\right)^2$.

73.3 The Conditional Average Run Length and the Conditional Probability of a Signal

An alarm happens when the average $\overline{X}$ of one of the monitoring samples (each with size n) falls outside the control limits given in (73.1) and (73.2). Given the estimators $\overline{\overline{X}}$ and S_{p}, the conditional probability of a signal (CPS) for any Phase II sample can be written, respectively, for cases UU, KU, and UK, as

$$\mathrm{CPS}_{\delta,\mathrm{UU}} = P\left(\mathrm{Signal}|\overline{\overline{X}}, S_{\mathrm{p}}\right) = 1 - P\left(\overline{\overline{X}} - L\frac{S_{\mathrm{p}}}{\sqrt{n}} \le \overline{X} \le \overline{\overline{X}} + L\frac{S_{\mathrm{p}}}{\sqrt{n}}\right), \quad (73.3)$$

$$\mathrm{CPS}_{\delta,\mathrm{KU}} = P\left(\mathrm{Signal}|S_{\mathrm{p}}\right) = 1 - P\left(\mu_0 - L\frac{S_{\mathrm{p}}}{\sqrt{n}} \le \overline{X} \le \mu_0 + L\frac{S_{\mathrm{p}}}{\sqrt{n}}\right) \text{ and } \quad (73.4)$$

$$\mathrm{CPS}_{\delta,\mathrm{UK}} = P\left(\mathrm{Signal}|\overline{\overline{X}}\right) = 1 - P\left(\overline{\overline{X}} - L\frac{\sigma_0}{\sqrt{n}} \le \overline{X} \le \overline{\overline{X}} + L\frac{\sigma_0}{\sqrt{n}}\right), \quad (73.5)$$

where δ is the scaled shift in the process mean defined as $\delta = (\mu - \mu_0)/\sigma_0$, where μ denote the process mean during the motoring stage (being it in control or out of control). When $\mu = \mu_0$, we have $\delta = 0$ and the process mean is in control. Consequently, when $\mu = \mu_1 \ne \mu_0$, we have $\delta \ne 0$ and the process mean is out of control.

Given that the conditional run length (CRL) distribution of control charts is geometric with parameter CPS_δ (see Chakraborti [2]), then its expected value, the conditional average run length CARL_δ, is $\mathrm{CARL}_\delta = 1/\mathrm{CPS}_\delta$. Note that when the subscriptions UU and KU are not used, it means that the equations are general for the three cases.

CPS_δ and CARL_δ expressions apply to the in-control and out-of-control situations. In the in-control situation ($\delta = 0$), CPS_0 is also known as the conditional false alarm rate ($\mathrm{CFAR} = \mathrm{CPS}_0$). So, the conditional in-control average run length (CARL_0) is expressed for all cases (UU, KU, and UK) by $\mathrm{CARL}_0 = 1/\mathrm{CFAR}$.

73.4 Adjustments to Guarantee an In-Control Performance

As noted in the Introduction, CARL_0 has a large variability: the so-called practitioner-to-practitioner variability. Given this, several authors (see, for example, Saleh et al. [11], Goedhart et al. [3], and Jardim et al. [6]) proposed to replace the limit factor L in Eqs. (73.1) and (73.2) by a new one named $L^*(p, \alpha_{\text{tol}})$ that provide a low probability (p) that the conditional false alarm rate (CFAR) exceeds a tolerated value (α_{tol}) in the spirit of the EPC. In other words, the value of $L^*(p, \alpha_{\text{tol}})$ should be the one that guarantees that

$$P(\text{CFAR} \geq \alpha_{\text{tol}}) = p \text{ or } P(\text{CARL}_0 \geq 1/\alpha_{\text{tol}}) = 1 - p, \tag{73.6}$$

For case UU, Jardim et al. [6] proposed finding $L^*_{\text{UU}}(p, \alpha_{\text{tol}})$ by solving (numerically with a search algorithm) the following exact equation for a given value of α_{tol}, m, n, ε and p:

$$\int_{-\infty}^{\infty} F_{\chi^2_{m(n-1)}} \left(\frac{m(n-1) F^{-1}_{\chi^2_{1,\left[\frac{z^2}{m}\right]}}(1 - \alpha_{\text{tol}})}{L^*_{\text{UU}}(p, \alpha_{\text{tol}})^2} \right) \phi(z) dz = p, \tag{73.7}$$

where $F_{\chi^2_{m(n-1)}}(.)$ is the cumulative distribution function (c.d.f.) of a central chi-squared distribution with $m(n-1)$ degrees of freedom and $F^{-1}_{\chi^2_{1,\left[\frac{z^2}{m}\right]}}(1 - \alpha_{\text{tol}})$ denotes the $(1 - \alpha_{\text{tol}})$-quantile of a non-central qui-squared distribution with 1 degree of freedom and non-centrality parameter $\frac{z^2}{m}$ and $\phi(.)$ is the standard normal probability density function (p.d.f.).

In case KU, Jardim et al. [5] derived an exact closed-form expression for $L^*_{\text{KU}}(p, \alpha_{\text{tol}})$, which is

$$L^*_{\text{KU}}(p, \alpha_{\text{tol}}) = \Phi^{-1}\left(\frac{\alpha_{\text{tol}}}{2}\right) \Big/ \sqrt{\frac{F^{-1}_{\chi^2_{m(n-1)}}(p)}{m(n-1)}}, \tag{73.8}$$

where $\Phi^{-1}(\alpha_{\text{tol}}/2)$ denotes the $(\alpha_{\text{tol}}/2)$-quantile of a standard normal distribution and $F^{-1}_{\chi^2_{m(n-1)}}(p)$ denotes the p-quantile of a central qui-squared distribution with $m(n-1)$ degrees of freedom.

Finally, for case UK, Jardim et al. [7] proposed finding $L^*_{\text{UK}}(p, \alpha_{\text{tol}})$ by solving the following system of equations:

$$\begin{cases} \Phi(z_2) - \Phi(z_1) = 1 - p \\ \Phi\left(\frac{z_i}{\sqrt{m}} + L^*_{\text{UK}}(p, \alpha_{\text{tol}})\right) - \Phi\left(\frac{z_i}{\sqrt{m}} - L^*_{\text{UK}}(p, \alpha_{\text{tol}})\right) = 1 - \alpha_{\text{tol}}, \ \ i = 1, 2 \end{cases} \tag{73.9}$$

for $L^*_{\text{UK}}(p, \alpha_{\text{tol}})$, z_2 and z_1. This can be done numerically with a search algorithm.

73.5 Out-of-Control Performance Analysis After the Adjustments

In this section, we analyze the impact of the adjustments proposed in the previous works (and presented in the last section) on the out-of-control performance (the power) of the $\overline{X}$ chart for the three parameter estimation cases (UU, KU, and UK). As we noted in the Introduction, in most situations, the adjustment leads to widening the interval between the control limits (compared to the "known parameters case"). In these cases, the out-of-control conditional ARL (i.e., the CARL_δ with $\delta \neq 0$) will be larger with the adjusted limits ($L^*(p, \alpha_{\mathrm{tol}})$) than with the unadjusted limits (L).

Jardim et al. [6] showed that knowing the prediction bound (called here as $Q_{p_{\mathrm{OOC}}}$) for the CARL_δ, with adjusted ($L^*(p, \alpha_{\mathrm{tol}})$) and with unadjusted limits (L), is useful for assessing the deterioration (increase) in the CARL_δ. Formally, to access the out-of-control deterioration, one must find $Q_{p_{\mathrm{OOC}}}$ for

$$P\big(\mathrm{CARL}_\delta > Q_{p_{\mathrm{OOC}}}\big) = p_{\mathrm{OOC}},\ \ \delta \neq 0 \tag{73.10}$$

for a small value of p_{OOC} (such as 0.05). Thus, $Q_{p_{\mathrm{OOC}}}$ is the $(1 - p_{\mathrm{OOC}})$-quantile of the CARL_δ distribution. Since the $\mathrm{CARL}_{\delta,}$ is the realized average number of samples until a true alarm and p_{OOC} is small, the smaller the $Q_{p_{\mathrm{OOC}}}$ the better the chart's OOC performance.

For case UU, Jardim et al. [6] proposed finding $Q_{p_{\mathrm{OOC}},\mathrm{UU}}$ by solving the following equation:

$$\int_{-\infty}^{\infty} F_{\chi^2_{m(n-1)}}\left(\frac{m(n-1)F^{-1}_{\chi^2_1}\left(1 - \frac{1}{Q_{p_{\mathrm{OOC}}}}\right)\Big|\left(\frac{z}{\sqrt{m}} - \delta\sqrt{n}\right)^2}{L^{*2}}\right)\phi(z)dz = 1 - p_{\mathrm{OOC}}, \tag{73.11}$$

for $Q_{p_{\mathrm{OOC}},\mathrm{UU}}$, a given value of m, n, δ, p_{OOC}, and $L^* = L$ (for unadjusted limits) or $L^*_{\mathrm{UU}}(p, \alpha_{\mathrm{tol}})$ (for adjusted limits). For case KU, to find $Q_{p_{\mathrm{OOC}},\mathrm{KU}}$, there is the following exact equation:

$$Q_{p_{\mathrm{OOC}},KU} = 1 - F_{\chi^2_{1,\left[(\delta\sqrt{n})^2\right]}}\left(\frac{F^{-1}_{\chi^2_{m(n-1)}}(1 - p_{\mathrm{OOC}})}{m(n-1)}L^{*2}\right), \tag{73.12}$$

where and $L^* = L$ (for unadjusted limits) or $L^*_{\mathrm{UU}}(p, \alpha_{\mathrm{tol}})$ (for adjusted limits), where $F_{\chi^2_{1,\left[(\delta\sqrt{n})^2\right]}}(.)$ is the c.d.f. of a non-central qui-squared distribution with one degree of freedom and non-centrality parameter $\left(\delta\sqrt{n}\right)^2$. Finally, for case UK, one must solve the following system of equations

$$\begin{cases} \Phi(z_2) - \Phi(z_1) = p_{\text{OOC}} \\ \Phi\left(\frac{z_i}{\sqrt{m}} + L^* - \delta\sqrt{n}\right) - \Phi\left(\frac{z_i}{\sqrt{m}} - L^* - \delta\sqrt{n}\right) = 1 - Q_{p_{\text{OOC}}},\ i = 1, 2 \end{cases} \tag{73.13}$$

for $Q_{p_{\text{OOC}},\text{UK}}$, z_1 and z_2 and a given value of m, n, δ, p_{OOC} and $L^* = L$ (for unadjusted limits) or $L^*_{\text{UU}}(p, \alpha_{\text{tol}})$ (for adjusted limits).

Tables 73.1, 73.2, and 73.3, respectively for cases UU, KU, and UU, present the values of $Q_{p_{\text{OOC}}}$ with the adjusted limits (showed in the last sections) for $\alpha_{\text{tol}} = 0.0027$ and $p = 0.1$ (in gray) and with unadjusted limits, $L = 3$ (in white), mean shifts $|\delta| = 0.5$, $|\delta| = 1$ and $|\delta| = 1.5$, $p_{\text{OOC}} = 0.05$ and $p_{\text{OOC}} = 0.1$ for several values of m and n. Also, these tables show the differences (in bold) between the $Q_{p_{\text{OOC}}}$ values with the adjusted and the unadjusted limits, respectively, to enable a direct performance comparison. Table 73.1 was also presented by Jardim et al. [6], but the results for Tables 73.2 and 73.3 are new in the literature.

Table 73.1 (for case UU) shows some interesting behavior. For $|\delta| = 0.5$ (a shift in the mean of the size of half the process standard deviation), $Q_{p_{\text{OOC}}}$ is large in most cases. For example, for $p_{\text{OOC}} = 0.05$, $m = 25$ and $n = 5$, the $Q_{p_{\text{OOC}}}$ is 107.85 with unadjusted limits and 351.98 with adjusted limits, that is an increase of 224.13. This shows the significant negative effect on the OOC performance for this situation. However, it is well known that the $\overline{X}$ chart is not efficient for signaling mean shifts smaller than 1 standard deviation. Note that for $|\delta| = 1$, the situation gets better. For this shift, the maximum $Q_{p_{\text{OOC}}}$ increase is 10.87 (when $p_{\text{OOC}} = 0.05$, $m = 25$ and $n = 5$). Finally, for $|\delta| = 1.5$, the maximum $Q_{p_{\text{OOC}}}$ increase is of only 1.14 samples. This value corresponds to $p_{\text{OOC}} = 0.05$, $m = 25$ and $n = 5$. So, for shifts of this magnitude or larger (i.e., $|\delta| \geq 1.5$), the impact of the adjustment on the out-of-control performance is very small for any value of n and m.

Table 73.1 0.95 and 0.9 quantiles of $\text{CARL}_{\delta,\text{UU}}$ with adjusted limits ($\alpha_{\text{tol}} = 0.0027$, $p = 0.1$) in gray and unadjusted limits ($L = 3$) in white for different values of m, n and δ (case UU)

			25			50			100			300			1000		
δ	p_{OOC}	n	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference
$\delta = \pm 1.5$	$p_{OOC} = 0.05$	**5**	2.21	3.36	**1.14**	1.97	2.47	**0.50**	1.83	2.09	**0.26**	1.71	1.82	**0.11**	1.64	1.69	**0.05**
		10	1.10	1.17	**0.07**	1.08	1.11	**0.03**	1.07	1.08	**0.02**	1.05	1.06	**0.01**	1.05	1.05	**0.00**
		15	1.01	1.01	**0.01**	1.01	1.01	**0.00**	1.00	1.01	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**
		20	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**
	$p_{OOC} = 0.1$	**5**	2.02	2.95	**0.93**	1.86	2.30	**0.44**	1.76	2.00	**0.23**	1.67	1.78	**0.10**	1.62	1.67	**0.05**
		10	1.08	1.14	**0.06**	1.07	1.10	**0.03**	1.06	1.08	**0.02**	1.05	1.06	**0.01**	1.05	1.05	**0.00**
		15	1.01	1.01	**0.01**	1.00	1.01	**0.00**	1.00	1.01	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**
		20	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**
$\delta = \pm 1$	$p_{OOC} = 0.05$	**5**	9.27	20.14	**10.87**	7.37	11.50	**4.12**	6.33	8.27	**1.95**	5.45	6.21	**0.77**	4.99	5.32	**0.34**
		10	2.46	3.32	**0.86**	2.21	2.62	**0.40**	2.06	2.28	**0.21**	1.93	2.02	**0.09**	1.85	1.90	**0.04**
		15	1.45	1.66	**0.22**	1.37	1.48	**0.11**	1.33	1.38	**0.06**	1.29	1.31	**0.03**	1.26	1.27	**0.01**
		20	1.15	1.23	**0.08**	1.13	1.16	**0.04**	1.11	1.13	**0.02**	1.09	1.10	**0.01**	1.09	1.09	**0.00**
	$p_{OOC} = 0.1$	**5**	7.75	15.98	**8.23**	6.55	9.99	**3.44**	5.84	7.56	**1.72**	5.21	5.93	**0.72**	4.87	5.19	**0.32**
		10	2.27	3.00	**0.73**	2.10	2.46	**0.36**	1.99	2.19	**0.20**	1.89	1.98	**0.09**	1.84	1.88	**0.04**
		15	1.39	1.58	**0.19**	1.34	1.43	**0.10**	1.31	1.36	**0.05**	1.27	1.30	**0.02**	1.26	1.27	**0.01**
		20	1.13	1.20	**0.07**	1.11	1.15	**0.03**	1.10	1.12	**0.02**	1.09	1.10	**0.01**	1.08	1.09	**0.00**
$\delta = \pm 0.5$	$p_{OOC} = 0.05$	**5**	107.85	351.98	**244.13**	75.24	151.07	**75.83**	58.80	90.45	**31.65**	46.05	57.15	**11.10**	39.75	44.30	**4.55**
		10	29.02	56.41	**27.39**	22.55	33.35	**10.80**	18.99	24.16	**5.17**	16.03	18.06	**2.04**	14.47	15.36	**0.89**
		15	13.34	21.55	**8.21**	10.90	14.40	**3.50**	9.50	11.25	**1.75**	8.30	9.01	**0.72**	7.65	7.97	**0.32**
		20	7.72	11.23	**3.51**	6.52	8.08	**1.56**	5.82	6.61	**0.80**	5.20	5.53	**0.33**	4.86	5.01	**0.15**
	$p_{OOC} = 0.1$	**5**	81.29	249.12	**167.82**	62.14	121.44	**59.30**	51.59	78.40	**26.82**	42.82	52.94	**10.13**	38.23	42.56	**4.33**
		10	23.89	45.11	**21.22**	19.77	28.88	**9.11**	17.35	21.95	**4.60**	15.24	17.15	**1.91**	14.08	14.94	**0.86**
		15	11.42	18.08	**6.65**	9.81	12.85	**3.04**	8.84	10.43	**1.59**	7.97	8.65	**0.68**	7.49	7.80	**0.31**
		20	6.78	9.71	**2.92**	5.98	7.35	**1.38**	5.48	6.21	**0.73**	5.03	5.35	**0.32**	4.78	4.92	**0.14**

Table 73.2 0.95 and 0.9 quantiles of $\mathrm{CARL}_{\delta,\mathrm{KU}}$ with adjusted limits ($\alpha_{\mathrm{tol}} = 0.0027$, $p = 0.1$) in gray and unadjusted limits ($L = 3$) in white for different values of m, n and δ (case KU)

			m = 25			50			100			300			1000		
δ		n	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference
$\delta = \pm 1.5$	$p_{OOC} = 0.05$	**5**	1.99	2.70	**0.72**	1.84	2.20	**0.36**	1.75	1.96	**0.21**	1.67	1.76	**0.10**	1.62	1.67	**0.05**
		10	1.07	1.11	**0.04**	1.06	1.08	**0.02**	1.05	1.07	**0.01**	1.05	1.06	**0.01**	1.05	1.05	**0.00**
		15	1.00	1.01	**0.00**	1.00	1.01	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**
		20	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**
	$p_{OOC} = 0.1$	**5**	1.87	2.48	**0.61**	1.77	2.10	**0.33**	1.70	1.90	**0.19**	1.64	1.73	**0.09**	1.61	1.65	**0.05**
		10	1.06	1.10	**0.03**	1.06	1.08	**0.02**	1.05	1.06	**0.01**	1.05	1.05	**0.01**	1.05	1.05	**0.00**
		15	1.00	1.01	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**
		20	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**
$\delta = \pm 1$	$p_{OOC} = 0.05$	**5**	7.48	13.60	**6.12**	6.39	9.22	**2.83**	5.74	7.25	**1.51**	5.16	5.83	**0.67**	4.85	5.16	**0.31**
		10	2.12	2.56	**0.45**	2.00	2.26	**0.26**	1.93	2.09	**0.16**	1.86	1.94	**0.08**	1.82	1.86	**0.04**
		15	1.33	1.43	**0.10**	1.30	1.36	**0.06**	1.28	1.32	**0.04**	1.26	1.28	**0.02**	1.25	1.26	**0.01**
		20	1.10	1.14	**0.03**	1.10	1.11	**0.02**	1.09	1.10	**0.01**	1.08	1.09	**0.01**	1.08	1.08	**0.00**
	$p_{OOC} = 0.1$	**5**	6.60	11.56	**4.96**	5.87	8.33	**2.46**	5.42	6.80	**1.38**	5.00	5.64	**0.63**	4.76	5.07	**0.30**
		10	2.03	2.43	**0.40**	1.94	2.18	**0.24**	1.89	2.04	**0.15**	1.84	1.91	**0.08**	1.81	1.85	**0.04**
		15	1.30	1.40	**0.10**	1.28	1.34	**0.06**	1.27	1.31	**0.04**	1.25	1.27	**0.02**	1.25	1.26	**0.01**
		20	1.10	1.13	**0.03**	1.09	1.11	**0.02**	1.09	1.10	**0.01**	1.08	1.09	**0.01**	1.08	1.08	**0.00**
$\delta = \pm 0.5$	$p_{OOC} = 0.05$	**5**	77.10	195.57	**118.47**	59.81	107.25	**47.44**	50.20	73.35	**23.16**	42.14	51.51	**9.37**	37.90	42.06	**4.16**
		10	20.21	31.86	**11.65**	17.62	23.67	**6.05**	16.02	19.50	**3.48**	14.57	16.20	**1.64**	13.75	14.54	**0.79**
		15	9.45	12.69	**3.24**	8.62	10.46	**1.84**	8.08	9.20	**1.12**	7.58	8.14	**0.56**	7.29	7.57	**0.28**
		20	5.62	6.94	**1.32**	5.25	6.04	**0.78**	5.02	5.51	**0.49**	4.79	5.04	**0.25**	4.65	4.78	**0.13**
	$p_{OOC} = 0.1$	**5**	62.99	152.39	**89.41**	52.14	91.50	**39.36**	45.68	66.09	**20.41**	39.98	48.71	**8.73**	36.84	40.85	**4.01**
		10	18.15	28.13	**9.97**	16.37	21.82	**5.45**	15.23	18.46	**3.24**	14.15	15.73	**1.57**	13.53	14.31	**0.78**
		15	8.80	11.70	**2.90**	8.20	9.91	**1.71**	7.81	8.87	**1.06**	7.43	7.98	**0.54**	7.21	7.49	**0.28**
		20	5.34	6.54	**1.21**	5.07	5.81	**0.74**	4.89	5.37	**0.47**	4.72	4.97	**0.25**	4.62	4.74	**0.13**

Table 73.3 0.95 and 0.9 quantiles of $\mathrm{CARL}_{\delta,\mathrm{UK}}$ with adjusted limits ($\alpha_{\mathrm{tol}} = 0.0027$, $p = 0.1$) in gray and unadjusted limits ($L = 3$) in white for different values of m, n and δ (case UK)

			m = 25			50			100			300			1000		
δ		n	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference	unadj.	adj. $p = 0.1$ $\varepsilon = 0$	difference
$\delta = \pm 1.5$	$p_{OOC} = 0.05$	**5**	1.96	2.21	**0.25**	1.82	1.93	**0.11**	1.74	1.79	**0.05**	1.66	1.67	**0.01**	1.62	1.62	**0.00**
		10	1.09	1.11	**0.03**	1.07	1.08	**0.01**	1.06	1.07	**0.01**	1.05	1.05	**0.00**	1.05	1.05	**0.00**
		15	1.01	1.01	**0.00**	1.01	1.01	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**
		20	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**
	$p_{OOC} = 0.1$	**5**	1.86	2.08	**0.22**	1.76	1.86	**0.10**	1.70	1.74	**0.05**	1.64	1.65	**0.01**	1.61	1.61	**0.00**
		10	1.07	1.10	**0.02**	1.06	1.07	**0.01**	1.06	1.06	**0.00**	1.05	1.05	**0.00**	1.05	1.05	**0.00**
		15	1.01	1.01	**0.00**	1.00	1.01	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**
		20	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**	1.00	1.00	**0.00**
$\delta = \pm 1$	$p_{OOC} = 0.05$	**5**	7.29	9.25	**1.96**	6.27	7.06	**0.79**	5.66	6.00	**0.34**	5.12	5.22	**0.10**	4.82	4.85	**0.03**
		10	2.31	2.64	**0.34**	2.12	2.26	**0.14**	2.00	2.07	**0.06**	1.90	1.92	**0.02**	1.84	1.84	**0.01**
		15	1.42	1.53	**0.11**	1.35	1.40	**0.05**	1.31	1.34	**0.02**	1.28	1.29	**0.01**	1.26	1.26	**0.00**
		20	1.14	1.19	**0.04**	1.12	1.14	**0.02**	1.11	1.11	**0.01**	1.09	1.09	**0.00**	1.08	1.09	**0.00**
	$p_{OOC} = 0.1$	**5**	6.50	8.18	**1.68**	5.80	6.51	**0.71**	5.37	5.69	**0.32**	4.97	5.07	**0.09**	4.75	4.78	**0.03**
		10	2.16	2.46	**0.30**	2.03	2.16	**0.13**	1.95	2.01	**0.06**	1.87	1.89	**0.02**	1.82	1.83	**0.01**
		15	1.37	1.47	**0.10**	1.32	1.37	**0.04**	1.30	1.32	**0.02**	1.27	1.28	**0.01**	1.25	1.26	**0.00**
		20	1.13	1.17	**0.04**	1.11	1.13	**0.02**	1.10	1.11	**0.01**	1.09	1.09	**0.00**	1.08	1.08	**0.00**
$\delta = \pm 0.5$	$p_{OOC} = 0.05$	**5**	73.59	107.39	**33.80**	57.88	70.07	**12.20**	49.04	53.96	**4.92**	41.58	42.91	**1.33**	37.62	37.97	**0.35**
		10	24.85	34.15	**9.30**	20.28	23.79	**3.52**	17.65	19.11	**1.46**	15.38	15.78	**0.41**	14.15	14.26	**0.11**
		15	12.21	16.07	**3.85**	10.26	11.77	**1.50**	9.11	9.75	**0.64**	8.11	8.29	**0.18**	7.56	7.61	**0.05**
		20	7.29	9.25	**1.96**	6.27	7.06	**0.79**	5.66	6.00	**0.34**	5.12	5.22	**0.10**	4.82	4.85	**0.03**
	$p_{OOC} = 0.1$	**5**	61.35	88.67	**27.32**	51.06	61.61	**10.55**	44.96	49.41	**4.45**	39.59	40.84	**1.26**	36.64	36.98	**0.34**
		10	21.30	29.01	**7.71**	18.25	21.35	**3.09**	16.41	17.75	**1.34**	14.76	15.15	**0.39**	13.84	13.95	**0.11**
		15	10.70	13.95	**3.25**	9.38	10.72	**1.34**	8.57	9.16	**0.59**	7.83	8.01	**0.17**	7.42	7.47	**0.05**
		20	6.50	8.18	**1.68**	5.80	6.51	**0.71**	5.37	5.69	**0.32**	4.97	5.07	**0.09**	4.75	4.78	**0.03**

In summary, Table 73.1 clearly shows that the EPC adjustment limit factors proposed by previous authors, work well for a $|\delta| \geq 1$ in **almost** all the situations because it guarantees a desired in-control performance in terms of the EPC, and at the same time, will not have a great impact in the out-of-control performance. The exception is when $|\delta| = 1$, $m = 25$ and $n = 5$.

In Tables 73.2 and 73.3, for cases KU and UK, the situation is slightly different when $|\delta| = 1$. For these shift size, the maximum difference between the $Q_{p_{\text{OOC}}}$ values, with and without the adjustment, is of 6.12 samples on average (this is for $p_{\text{OOC}} = 0.05$, $m = 25$ and $n = 5$, a small number and size of samples). If the user considers that an increase of less than 10 samples on average on the $Q_{p_{\text{OOC}}}$, a satisfactory impact on the OOC performance, in cases KU and UK, the impact when $|\delta| = 1$ is satisfactory for any value of n and m. When $|\delta| = 0.5$ and $|\delta| = 1.5$ the conclusion for cases KU and UU is similar for cases UU.

Hence, we recommend to adjust the limits in terms of the EPC for "$n \geq 10$ and $m \geq 25$" or for "$n \geq 5$ and $m \geq 50$" in case UU and for "$n \geq 5$ and $m \geq 25$" in cases KU and UK in order to guarantee a high probability (such as 0.9) that the conditional in-control average run length is greater than a nominal in-control average run length value (such as 370.4) and to guarantee that $Q_{p_{\text{OOC}}} \approx 10$. We highlight that the $\overline{X}$ chart should not be used to detect $|\delta| < 1$.

73.6 Conclusions

Recently in the literature, adjustments to the control limits were proposed to compensate the effect of parameters estimation on the conditional in-control performance of the $\overline{X}$ chart. However, these corrections also deteriorate the out-of-control performance (also known as the power) of this chart. In this paper, we analyzed this deterioration due to the limit's adjustments for three cases: (1) when both the process mean and standard deviation are estimated (case UU), (2) when only the process standard deviation is estimated (case KU) and (3) when only the process mean is estimated (case UK).

As expected, the deterioration is more severe for smaller sample sizes (n) and smaller number of historical samples (m) used to estimate the parameters, such as $n = 5$ and $m = 25$. It is also substantial for smaller shifts in the mean (such as a shift of 0.5 standard deviations). On the other hand, if one considers a 1 or more standard deviation shift in the mean, the impact on the out-of-control performance is not that substantial in most situations for the three cases (UU, KU, and UK). This impact is reduced with larger sample sizes n and larger numbers of historical samples m. For case UU, the results presented here leads to a recommendation of using the adjusted limits for at least "$n = 10$ and $m = 25$" or "$n = 5$ and $m = 50$" (a total of 250 reference data points). This was also recommended by Jardim et al. [6]. For cases KU and UU, the recommendation is using at least $n = 5$ and $m = 25$ to estimate the parameters (125 reference data points). With these recommended amounts of data and the adjusted limits, the user can strike a balance between a desired nominal in-control conditional performance and a reasonable out-of-control shift detection capability.

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Chapter 74
Design Comparison Between One- and Two-Sided S2 Control Charts with Estimated Parameter

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Abstract The S2 (or S^2) chart is one of the most useful tools in Operations Management (OM) for monitoring process variability. Previous studies on this chart with estimated variance did not compare their one- and two-sided designs. We make this comparison, revealing the large performance difference between them and providing new insights for the users.

Keywords Parameter estimation · S2 chart performance · Average run length

74.1 Introduction

The S2 (or S^2) control chart with probability limits is one of the most well-known tool to monitor the variance of a quality characteristic of a process in many industries. To design the S^2 control chart, one must estimate the in-control variance (σ_0^2) of the process quality characteristic (with m samples each one of size n) in what is called the Phase I analysis (for an overview of Phase I analysis see Chakraborti et al. [3] and Jones-Farmer et al. [12]). Then, this estimate is used to calculate the chart's control limit(s) which is (are) used in a Phase II moment when samples (also of size n) are collected at regular intervals. From this Phase II samples, the sample variance (which is the plotting statistic) is calculated and compared with the control limit(s). It has been noted by many researchers that when parameters (like the σ_0^2) are estimated with reference samples in Phase I, the Phase II performance of any control charts (like the S^2 chart) deteriorates compared to the unrealistic case where the parameters (such as the σ_0^2) are known (and hence no Phase I would be needed); see for example Quesenberry [17] and Chen [4]. For more detail of some of the works on the effect on the performance of control charts in general when parameters are estimated, see Jensen et al. [11] and Psarakis et al. [16].

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The main performance measure of the S^2 control chart (or any other chart) is the average run length (ARL), or in other words, the average number of Phase II samples until an alarm (or signal). When process variance $\left(\sigma_0^2\right)$ is known, the number of samples until an alarm (also known as the run length, RL) follows the well-known geometric distribution with parameter being the probability of a signal (PS). So, the average of this distribution (the ARL) is the reciprocal of the PS (see Montgomery [15]). However, when the in-control process variance $\left(\sigma_0^2\right)$ is estimated (to calculate the control limits), the ARL is conditioned on this estimated variance, and because of this, it is denoted CARL. Since estimators are random variable, the CARL is also a random variable varying from practitioner to practitioner, the so-called *practitioner-to-practitioner variability* (see Saleh et al. [18]). When the process is in control, the variability of the CARL is known to be very large (see, for example, Chen [4]). This means that the in-control CARL (also denoted as CARL_0) values may be much different compared to the in-control ARL (or ARL_0) values in the unrealistic case where no estimation is needed.

Since the CARL_0 is a random variable when the σ_0^2 is estimated, some authors measured and designed the S^2 control charts focusing on the expectation of the CARL_0, i.e., on the $E(\text{CARL}_0)$. This is denoted the unconditional perspective (see, for example, Chen [4], Maravelakis et al. [14], Castagliola et al. [2], and Diko et al. [5]). These authors realized that when the amount of Phase I data (m and n)—to estimate σ_0^2—is small, the $E(CARL_0)$ is much different from the ARL_0 value when σ_0^2 is known. However, even though one can adjust the S^2 control charts for a specific desired value of $E(CARL_0)$, the variability of CARL_0 may still be large. Thus, recently, an alternative point of view has emerged that advocates measuring control charts by the probability (p) of the CARL_0 be smaller (or greater) than some desired value. This is called the exceedance probability criterion, EPC (proposed by Albers et al. [1]), also known as the conditional perspective. The authors who focused on the conditional perspectives of the S^2 control charts are: Epprecht et al. [6], Faraz et al. [8], Faraz et al. [7], Goedhart et al. [9], and Guo and Wang [10].

Much for our surprise, we found that all authors on the effect of parameters estimation on the performance and design of the S^2 control chart under the unconditional perspective studied just the case where the chart is designed with two control limits (named the two-sided S^2 control chart). On the other hand, the authors who focused on the conditional perspective only studied the case where the chart is designed with just one (upper) control limit (named the one-sided S^2 control chart) except for Guo and Wang [10]. There is no study showing explicitly the in-control performance differences between these two limits' designs.

The justification to use just one upper control limit is that in many processes, small variances are always tolerated. In such cases, the major concern is to detect only increases in the process dispersion. However, detecting small variabilities may be important in some situations. For example, if the S^2 chart is used together with the $\bar{X}$ control chart (which is used to monitor the man), it is important to detect if the process dispersion decreased since both charts depend on the process variance estimation. A decrease in the process dispersion will affect the performance of the $\bar{X}$ control chart which may take longer to detect a shift in the mean if the variance is not reestimated and the $\bar{X}$ chart control limits not recalculated. This show the importance of the two-sided S^2 control chart since only it can detect decreases in the process dispersion.

Given this background as motivation, in this paper, we study and analyze side-by-side the use of one and two control limits to design the S^2 control chart. We show that the CARL_0 distribution and the $E(\mathrm{CARL}_0)$ value for the two-sided case are much different compared to the one-sided case. The results presented here will be useful for the practitioner to understand the performance differences between both limits' configurations helping them to choose the appropriate chart's design.

Finally, it should be noted that the present paper is part of a larger work, where we also compare some adjustments to guarantee an in-control performance of the S^2 control chart considering both perspectives (conditional and unconditional) and both control limits designs (one- and two-sided) and also the comparison of the out-of-control performance with unadjusted and adjusted limits for both limits' designs.

74.2 The S^2 Control Chart Control Limits

Below we show how the control limits of the one- and two-sided S^2 control charts are calculated when the in-control process variance $\left(\sigma_0^2\right)$ is estimated (denote the estimator by $\hat{\sigma}_0^2$). The upper control limit $\left(\widehat{\mathrm{UCL}}_{\mathrm{one}}\right)$ of the one-sided S^2 control chart is given by:

$$\widehat{\mathrm{UCL}}_{\mathrm{one}} = \hat{\sigma}_0^2 \frac{\chi^2_{n-1,\alpha}}{(n-1)}. \tag{74.1}$$

The upper $\left(\widehat{\mathrm{UCL}}_{\mathrm{two}}\right)$ and lower $\left(\widehat{\mathrm{UCL}}_{\mathrm{two}}\right)$ control limits of the two-sided S^2 control chart are given by

$$\widehat{\mathrm{UCL}}_{\mathrm{two}} = \hat{\sigma}_0^2 \frac{\chi^2_{n-1,\alpha/2}}{(n-1)}, \text{ and} \tag{74.2}$$

$$\widehat{\mathrm{LCL}}_{\mathrm{two}} = \hat{\sigma}_0^2 \frac{\chi^2_{n-1,1-(\alpha/2)}}{(n-1)}. \tag{74.3}$$

In the remainder of this paper, subscripts one and two will be used when necessary to indicate, respectively, the results regarding the on-sided and two-sided S^2 control charts. In Eqs. (74.1), (74.2), and (74.3), n is the sample (subgroup) size in both Phase I and II, $\hat{\sigma}_0^2$ is the Phase I estimator of the in-control process variance σ_0^2, $\chi^2_{n-1,a}$ denotes the $(1-a)$-quantile of the distribution of a central chi-squared random variable with $n-1$ degrees of freedom. α is the nominal false alarm rate (frequently, $\alpha = 0.0027$).

To calculate $\widehat{\sigma}_0^2$, the user must choose an estimator. In this paper, we considered the pooled sample variance $\left(S_\mathrm{p}^2\right)$ to estimate σ_0^2, where $S_\mathrm{p}^2 = \frac{1}{m}\sum_{i=1}^{m} S_i^2$, $S_i^2 = \frac{1}{n-1}\sum_{j=1}^{n}\left(X_{i,j} - \bar{X}_i\right)^2$, $\bar{X}_i = \frac{1}{n}\sum_{j=1}^{n} X_{ij}$, $i = 1, 2, \ldots, m$ and $j = 1, 2, \ldots, n$. X_{ij} denotes the jth observation of the ith sample. X_{ij} is considered normally distributed with mean μ_0 and variance σ_0^2. Polling the sample variance is highly recommended in the literature (see, for example, Mahmoud et al. [13]).

74.3 The In-Control Conditional Average Run Length

Epprecht et al. [6], Guo and Wang [10], among others, showed that the conditional in-control average run length CARL_0 (or in other words, the average number of samples until a false alarm when the in-control process variance is estimated by S_p^2) for the one- and two-sided S^2 control chart can be written respectively by

$$\mathrm{CARL}_{0,\mathrm{one}}(Y) = \left[1 - F_{\chi^2_{n-1}}\left(\frac{Y}{m(n-1)}\chi^2_{n-1,1-\alpha}\right)\right]^{-1}, \text{ and} \tag{74.4}$$

$$\begin{aligned}\mathrm{CARL}_{0,\mathrm{two}}(Y) = \Bigg[1 - \Bigg(&F_{\chi^2_{n-1}}\left(\frac{Y}{m(n-1)}\chi^2_{n-1,1-\alpha/2}\right) \\ &-F_{\chi^2_{n-1}}\left(\frac{Y}{m(n-1)}\chi^2_{n-1,\alpha/2}\right)\Bigg)\Bigg]^{-1},\end{aligned} \tag{74.5}$$

where $Y = m(n-1)S_\mathrm{p}^2/\sigma_0^2$ follows a central chi-squared distribution with $m(n-1)$ degrees of freedom and $F_{\chi^2_{n-1}}(.)$ is the cumulative distribution function (c.d.f.) of a central chi-squared random variable with $n-1$ degrees of freedom. Note that Y is directly related to S_p^2 and σ_0^2.

To visualize the effect of the number of Phase I samples (m) on the performance of the S^2 control chart, we present the $\mathrm{CARL}_0(Y)$ curves parametrized by m by plotting $\mathrm{CARL}_0(Y)$ as a function of the order (U) of the quantiles of Y. To do this, following Epprecht et al. [6], we use the probability integral transformation, which yields the fact that the c.d.f. of Y $\left(F_{\chi^2_{m(n-1)}}(Y)\right)$ has the same distribution of a random variable U, uniformly distributed between 0 and 1. So, one can express Y in term of U as $Y = F^{-1}_{\chi^2_{m(n-1)}}(U)$, where $F^{-1}_{\chi^2_{m(n-1)}}(U)$ is the U-quantile of a central chi-squared distribution with $m(n-1)$ degrees of freedom. The advantage of this approach is that U (differently from Y) does not depend on m or n. Figure 74.1 illustrates the curves of $\mathrm{CARL}_{0,\mathrm{one}}(Y) \times U$ in the left and $\mathrm{CARL}_{0,\mathrm{two}}(Y) \times U$ in the right for $n = 5$, $m = 10, 25, 50, 200, 500$ and $\alpha = 0.0027$.

Figure 74.1 shows some interesting behaviors. The curve of the $\mathrm{CARL}_{0,\mathrm{one}}$ is monotonic (non-decreasing function) varying from 1 to infinity. In the other hand, the $\mathrm{CARL}_{0,\mathrm{two}}$ curve is a non-monotonic function. For a given n, $\mathrm{CARL}_{0,\mathrm{two}}$ has always the same maximum value. For example, in the case of $n = 5$, one can see in

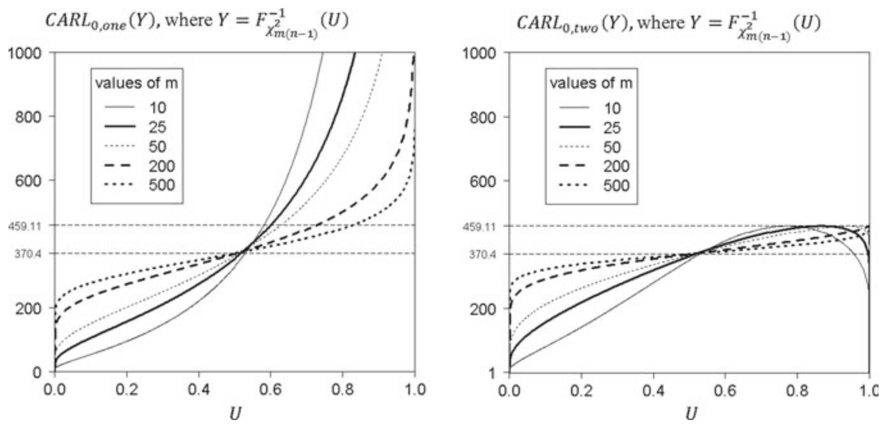

Fig. 74.1 $\mathrm{CARL}_{0,\mathrm{one}}$ and $\mathrm{CARL}_{0,\mathrm{two}}$ as functions of order quantile of Y (U), such that $Y = F^{-1}_{\chi^2_{m(n-1)}}(U)$, for $m = \{10, 25, 50, 200, 500\}$, $n = 5$ and $\alpha = 0.0027$

Fig. 74.1 that $\max\left(\mathrm{CARL}_{0,\mathrm{two}}\right) = 459.11$ regardless of the value of m. This is one of the most important differences between the one- and two-sided configurations. Note that since the CARL_0 is the conditional average number of samples until a false alarm, the larger the $CARL_0$, the better is the in-control performance. So, the fact that $\mathrm{CARL}_{0,\mathrm{two}}$ cannot be larger than a specific value (e.g., 459.11 according to the parameters in Fig. 74.1) may be a problem of the two-sided design.

Also, the plots in Fig. 74.1 clearly show the effect of the number of Phase I samples (m) on the performance of the S^2 control chart (with estimated in-control process variance) with one and two control limits. The curves of CARL_0 are significantly closer to the horizontal line $\mathrm{ARL}_0 = 370.4$ (which can be considered the target) when m is larger (compare, for example, the curves for $m = 10$ and for $m = 500$). This means that the difference between the ARL_0 and the actual CARL_0 is considerably more likely to be larger when m is small. It is also interesting to note that the effect is different on the two sides of $u = 0.5$ (the 0.5-quantile of Y).

74.4 Expectation and Standard Deviation of the In-Control Conditional Average Run Length

Since CARL_0 is a random variable, it is important to access its expectation and standard deviation for both cases: The S^2 control chart with one upper limit and the S^2 control chart with two limits. The expectation of the CARL_0 for both cases can be written as

$$E(\mathrm{CARL}_0(Y)) = \mathrm{ARL}_0 = \int_0^{\infty} \mathrm{CARL}_0(y) f_Y(y)\mathrm{d}y, \tag{74.6}$$

The standard deviation of CARL_0 can be calculated as

$$\mathrm{SD}(\mathrm{CARL}_0(Y)) = \mathrm{SDARL}_0 = \sqrt{E\left(\mathrm{CARL}_0(Y)^2\right) - (E(\mathrm{CARL}_0(Y)))^2}, \tag{74.7}$$

where

$$E\left(\mathrm{CARL}_0(Y)^2\right) = \int_0^{\infty} \mathrm{CARL}_0(Y)^2 f_Y(y)\mathrm{d}y \tag{74.8}$$

where $f_Y(.)$ is the probability density function (p.d.f.) of Y (a central chi-squared random variable with $m(n-1)$ degrees of freedom). For the one-sided case, one must use $\mathrm{CARL}_0(Y) = \mathrm{CARL}_{0,\mathrm{one}}(Y)$ according to Eq. (74.4) and, for the two-sided case, $\mathrm{CARL}_0(Y) = \mathrm{CARL}_{0,\mathrm{two}}(Y)$ according to Eq. (74.5).

Table 74.1 shows the ARL_0 and the $SDARL_0$ values for the one- and two-sided limits for $\alpha = 0.0027$ (i.e., a nominal ARL_0 of 370.4) and several values of m and n. The differences between the one- and two-sided are remarkable. While for the one-sided limit, the $\mathrm{ARL}_{0,\mathrm{one}}$ values are always larger (in some cases, significantly larger) than the nominal 370.4 (note that $\mathrm{ARL}_{0,\mathrm{one}} = 674.2$ for $m = 25$ and $n = 5$, 82% larger than 370.4), for the two-sided limits $\mathrm{ARL}_{0,\mathrm{two}}$ are always smaller than the nominal 370.4, but, compared to the one-sided chart, not so much smaller (note that $\mathrm{ARL}_{0,\mathrm{two}}$= 331.9 for m = 25 and n = 5, 10% smaller than 370.4). Also note

Table 74.1 ARL_0 and SDARL_0 values for the one- and two-sided S^2 charts for $\alpha = 0.0027$ (i.e., a nominal ARL_0 of 370.4) and several values of m and n

		One-sided		Two-sided				One-sided		Two-sided	
m	n	$ARL_0 = E(CARL_0)$	$SDARL_0 = SD(CARL_0)$	$ARL_0 = E(CARL_0)$	$SDARL_0 = SD(CARL_0)$	m	n	$ARL_0 = E(CARL_0)$	$SDARL_0 = SD(CARL_0)$	$ARL_0 = E(CARL_0)$	$SDARL_0 = SD(CARL_0)$
25	*3*	852.9	2889.9	336.4	141.8	**150**	*3*	417.5	224.0	363.2	76.9
	5	674.2	1292.9	331.9	113.4		*5*	405.3	182.6	362.1	59.4
	9	587.4	823.5	327.1	90.6		*9*	397.8	155.8	361.0	44.8
50	*3*	541.6	658.9	351.1	116.0	**200**	*3*	404.9	183.0	365.0	68.1
	5	490.8	458.1	348.3	91.2		*5*	396.2	151.6	364.1	52.4
	9	461.7	357.1	345.4	70.9		*9*	390.7	130.6	363.2	39.4
75	*3*	473.8	406.5	356.9	100.8	**250**	*3*	397.7	158.1	366.0	61.7
	5	445.2	308.6	354.8	78.7		*5*	390.8	132.2	365.3	47.4
	9	428.1	252.5	352.7	60.4		*9*	386.5	114.5	364.6	35.5
100	*3*	444.4	309.7	360.0	90.5	∞	*3*	370.4	0.0	370.4	0.0
	5	424.6	244.1	358.4	70.3		*5*	370.4	0.0	370.4	0.0
	9	412.6	204.1	356.7	53.5		*9*	370.4	0.0	370.4	0.0

the large differences in the standard deviation of the $\mathrm{CARL}_0(Y)$ (SDARL_0) between the one- and two-sided limits. The variability of the $\mathrm{CARL}_0(Y)$ is much larger in the one-sided limit than for the two-sided limits. Finally, the ARL_0 converges to the nominal 370.4 value "much quicker" (i.e., with much less Phase I data) in the two-sided design than in the one-sided design. All the values in Table 74.1 are exact (calculated numerically). The values in the gray column (i.e., for the one-sided limit) were also calculated by Faraz et al. [8] using simulations and the values in the white column (i.e., for the two-sided limits) were calculated numerically by Guo and Wang [10] and others. But here is the first time both limits' designs are compared.

74.5 Conclusions

In this note, we analyzed side-by-side the in-control performance of the S^2 chart—with estimated process variance from a Phase I data—between one and two control limits designs. Previous authors just analyzed one of these control limits configuration alone. We showed that there is a large difference between the in-control performance of these designs: For the two-sided limits' case, the most common performance measure of a control chart, named the conditional in-control average run length (CARL_0) is limited to a maximum value, while for the one-sided limit case, the CARL_0 can vary (theoretically) from 1 to infinity. The limitation of a maximum value for the CARL_0 may be a problem for the two-sided case, since the larger the CARL_0 value, the better is the in-control performance. However, the two-sided S^2 chart achieves a desired $E(\mathrm{CARL}_0)$ with much less Phase I data compared to the one-sided limit S^2 chart. Finally, the variability of the CARL_0 is much smaller for the two-sided case than it is for the one-sided case.

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Chapter 75
Implementation of the IHP—Internal Happiness Programme of Cooperativism as a Management Tool

Valquiria Demarchi Arns and Andressa Barreto Lima

Abstract FIC—Internal happiness of cooperativism as a management tool, aiming to stimulate the well-being and quality of life of employees, increasing productivity, with results in personal and professional life and reflection for the community. A questionnaire divided into nine dimensions of the program was applied, of 97 questions.

Keywords GNH—gross national happiness · IHP—internal happiness programme of cooperativism

75.1 Introduction

Happiness, in the professional field, influences the performance and final results. According to the Human Resources specialist Jessyca Price Jones [4], happy employees are more successful, efficient and healthy.

The Gross National Happiness indicator (GNH) was introduced in Bhutan, in 1972, as a counterpoint to the Gross Domestic Product (GDP), which considers only economic and financial data to quantify national success.

Based on GNH, the 'Internal Happiness of Cooperativism' (IHP) indicator was developed and modelled to the cooperative system by the 'National Board of Social Promotion' members, composed of representants of the state units of 'Serviço Nacional de Aprendizagem do Cooperativismo' (Sescoop). The aim of the group is to promote the IHP as a well-being and quality-of-life tool to employees, cooperative members and their relatives.

The tool application starts with a presentation of the concept and objectives. Then, a questionnaire is applied, as well as evaluation and analysis. From that analysis, improvement plans, implantation, follow-up and a new evaluation are elaborated. Thus, the cooperative makes a strategic plan and a schedule with technical support of OCB national system assistance and state units as well. The idea is to achieve a

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balance between social concern with the cooperative members and economic results of the cooperative, obtaining, in 2025, an overview of happiness created by the cooperativism system.

The research utilizes the research-action method as a procedure of data gathering. This approach will allow working with both qualitative and quantitative data, enabling analysis and active participation of researchers in the development and deployment of proposals [7].

Therefore, the objective of this paper is to analyse the 'Internal Happiness of Cooperativism' (IHP) indicator, which uses a measure of both economic and human developing to evaluate the quality of life of employees and cooperative members.

75.2 Theoretical Reference

Studies about quality of life and well-being have established a research field throughout decades, evolving in the philosophical and psychological field, which ideas have contributed to the comprehension of what now is understood as happiness in the social field [11].

Happiness can be defined as a public asset that all of us desire to achieve, and should be on the same page of governmental planning [5].

To Andrews [1], emotional ties with family and friends and having a meaning in life are two factors that could influence long-lasting happiness. Happiness shall be found from an individual perspective, presenting one's point in relation to their environment, for only they know themselves and what happens around them [6].

This discussion has been increasing every year, recently the UN adopted the resolution '**Happiness**: towards a holistic approach to **development**', recognizing the pursuit of happiness as a universal aspiration. From that, the UN member countries developed public policies to think better about this objective. In Brazil, a proposal (PEC) was established in 2010, changing the Article 6 of Brazilian constitution, where social rights to happiness pursuit have been included [2].

With the Second World War ending, the gross domestic product was the tool found to quantify national progress. Thus, in the 60's, the concern about individual well-being increases, mainly because of the universal and indirect way of measuring development assigned to the GDP [3].

Based on the GDP, the gross national happiness (GNH) is created and has the aim of measuring happiness, but in a way that the results have an effect over the citizen's well-being, through public policies adapted to it [10].

The IHP indicator was inspired by the GNH model, which instead of measuring a nation progress by the economic growth is based on the principle that a society development arises when both emotional and material development are simultaneous [8].

The IHP programme is based on the four pillars of GNH (sustainable and equitable socio-economic development; environmental conservation; preservation and promotion of culture; and good governance) and linking it to the cooperative principles. The programme gathers methodologies and tools to help the cooperatives move forward with their strategies [8].

It is important to emphasize that questions that involve feelings (well-being and happiness) are challenging, due to the difficulty of measuring it. The use of indicators could help with standardization and results classification, which are tools that help with plans formulation, actions and public policies, being important improving them so that bigger advances are made [9].

75.3 Methodology

The IHP is being implemented by cooperatives, aiming to use the programme as a management tool, stimulating employees' well-being and quality of life, contributing to increase the company productivity.

The indicator was inspired by the GNH model and is based on emotional, material and economic growth simultaneous, contemplating the individual mutually.

The programme implementation includes many steps, which were followed according to the description below:

Step 1: Programme understanding and formulation of the implementation strategy. The concept was spread, a plan of action was made as well as raising leadership awareness and the pilot area was chosen. The chosen area was one of the industrial units of sustainable textile yarn, where there are 322 employees.

Step 2: Launching event. First programme milestone, a cultural event was held to seek the support of all the employees and a presentation about what IHP has also happened.

Step 3: Training of the programme multiplication agents. Setting equipment of eight members. Qualifying in how happiness can interfere in productivity, how to measure it, what the programme objectives are and how the monitoring platform works.

Step 4: Diagnosis application. It was followed up by the multiplication agents to raise awareness about the questionnaire application, where each participant would receive a general diagnosis as well as their own diagnosis.

Step 5: Data compilation and results. Presentation of the general data to the cooperative leaders, with considerations, defining which dimensions will be worked on and a strategy to the implementation of next steps was made.

Step 6: Improvement workshop. All employees that answered the questionnaire attended, receiving the diagnosis and discussing action proposals. At this moment, employees gave out ideas and suggestions, through group activities (25 people each).

Step 7: Preparation of an action plan for the implementation through a proposal of platform, with indicators, goals, deadlines and actions to be implemented. Approaching the pillars of creativity maintenance and spreading improvement agenda.

Table 75.1 Programme dimensions

Dimension	What is it?
Psychological well-being	Measure of the degree of satisfaction and optimism related to their own lives
Health	Evaluation of health policies effectiveness, conditions of self-evaluation, physical activity, quality of sleep, nutrition and others
Time-use	Evaluation of leisure and socialization with family and friends' time, management of time, work, cultural and educational activities
Community vitality	Interaction with community, confidence level, feeling of belonging, affective relationship, security and volunteering practices
Education	Formal and informal education, competences, engagement on their children education, beliefs and environment
Culture	Local tradition, festivals, cultural events participation, opportunity of developing artistic capacity and discrimination
Environment	Evaluation of individual perception regarding air quality, soil, water, biodiversity, waste collection system and others
Governance	Evaluates how the company leadership is felt, people involvement and interactivity level, organizational environment aspects
Life standard	Evaluation of family income, financial security, level of debt, house quality and others

Source Adapted from [5, p. 37, e 38]

Step 8: Objectives map delivery and validation. Presentation of the platform to the leaders, with objectives, indicators and tools that will be used as well as deadlines.

Step 9: Programme monitoring. Programme evolution follow-up, platform monitoring, advances achieved and reapplication of the diagnosis one year after the programme implementation.

Diagnosis: the questionnaire is made up of 97 questions related to nine dimensions, which are psychological well-being, health, time-use, community vitality, education, culture, environment, governance and life standard, as presented in the chart below (Fig. 75.2).

The questionnaire was created to map the surveyed socio-functional profile, allowing them to be filtered by sector, function, shift, wages, company time, age, genre, marital status, number of dependents and schooling. It can be filled in electronically or in paper, being individual and private. In total, 323 people filled in the questionnaire and the results comprise 321 surveyed, almost 100% of attendance.

75.4 Analysis and Results

The result of the employees' socio-functional profile are showed below:

To the method application, filters were applied related to the socio-functional profile, as presented in Fig. 75.1, and from the answers, it is possible to open it into categories, where there are eight answers at least. From the 321 answers, the interviewed profile were obtained, where 58% were women, 42% men and 72% of them are older than 31 years old.

The IHP rating is a tool used to achieve a bigger goal: the development of full cooperativism. As presented in the Figs. 75.2 and 75.3, the result of the overall assessment was 2.11.

Result by dimensions:

The world-class result should be over 2; therefore, the dimensions chosen had results below this grade.

Three dimensions had results under 2: life standard, governance and health.

Fig. 75.1 Perfil socio-funcional dos colaboradores

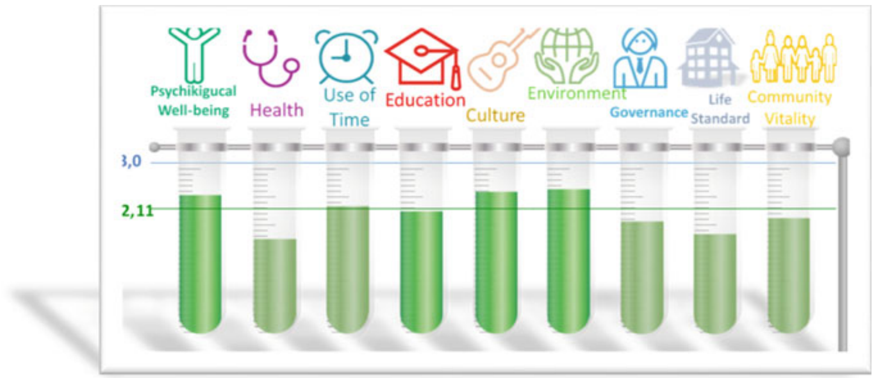

Fig. 75.2 Result of the overall assessment—thermometry

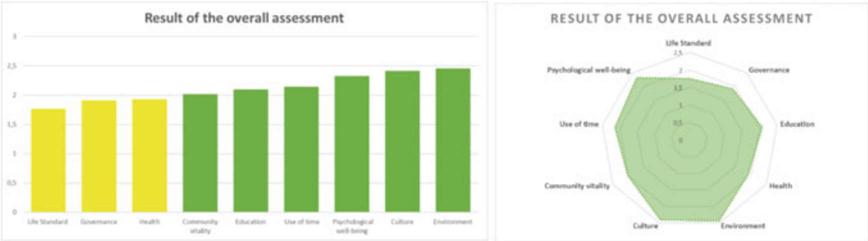

Fig. 75.3 Result of the overall assessment

Dimensions with results below two are treated with actions proposed in workshops by employees, involving people responsible by the actions that can bring a better result.

It is possible to get results by sector, shift, age, marital status, genre, schooling, company time and number of dependents, using filters, facilitating the elaboration of action plans, thinking of different demands.

As presented in the Fig. 75.4, the main actions to be approached thinking of life standard are: how to help people think of family planning, family administration orientation programmes, how to save up money, how to control consuming impulses, developing a career plan and what they can do thinking about professional growth.

To governance actions, as presented in Fig. 75.5, it is possible to work on many items within the workplace: how to participate with suggestions and new ideas,

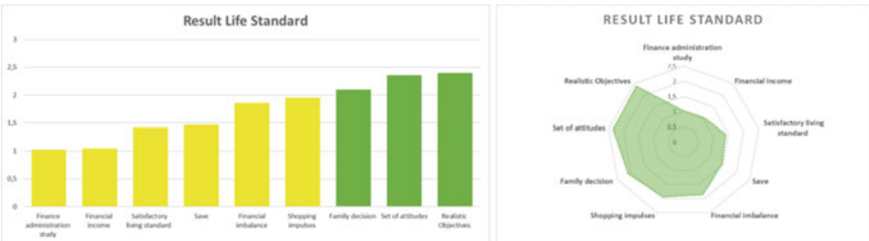

Fig. 75.4 Result of life standard

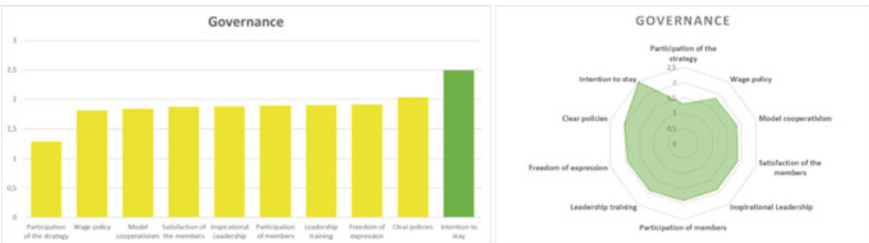

Fig. 75.5 Result of governance

Fig. 75.6 Result of health

instructing how the leadership model is, stimulating the participation of the cooperative members in daily routine, leadership formation, dissemination of the planning and strategies and finally how people participated on building the company's future in a daily basis.

In Fig. 75.6, we have the result obtained with the health field, and the main points are: how to have a balanced nutrition suitable to height and age; how to have encouraging physical activities regularly; how to have a better quality of sleep; how to rest and especially, actions to manage employees' stress level.

75.5 Final Considerations

The research was applied as a tool for helping the management achieve performance indicators goals. Analysing the results regarding genre, age, marital status and other socio-functional classification, it is noticed a low variation to the result, however when filtering by schooling, it is noticed a high difference, because of the high demand that graduated employees have towards their career, and it allow us to work with different needs of the group.

The class that embraces graduated people only had two dimensions with results lower than two, which are health and time-use, and by this reason, some actions related to time-use were chosen to be worked on when approaching the company´s commitment programme.

This study is a general diagnosis of the current situation and enables the use of tools with actions that will help a performance increase. In a future stage, the achieving of performance goals will be approached as the growth of happiness indicators, using this research as a tool to help develop employees and company.

The general result shows how the actions of each individual interfere in their mental status, their engagement, their dedication to studying, physical activities practices, good nutrition and instruction. The collaboration between individuals and equipment is a simple thing, but hard to accomplish, since they need to become routine, making it a daily habit, those are some examples showing how we can improve.

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Part VII
Product Innovation and Technology in Operations Management

Chapter 76
The Study of Innovation Process in Civil Construction Through BIM Technology

Leticia Mattana, João Carlos Souza and Maria Luiza Tremel de Faria

Abstract Building Information Modelling has been recognized as an innovation in the buildings' life cycle around the world. This paper shows the contribution of this technology to the civil construction process. The methodology used was bibliographical research. The results show that BIM is improving the process and enabling teams to collaborate effectively.

Keywords BIM · Process · Innovation · Civil construction

76.1 Introduction

Building Information Modelling, known around the world as BIM, has been adopted in many countries through job market experiences and academic researches [6]. Kassem and Amorin [16] say that BIM processes enable the creation of 3D parametric models, which is the virtual construction of these buildings. The parametric models refer to the information put inside the models, to attribute proprieties to BIM objects during the virtual construction.

Eastman et al. [7] describe BIM as a technological innovation at Architecture, Engineering and Construction sector, and they complement that BIM happens in the life cycle of the buildings and it causes a lot of changes in the process of the buildings. Some changes are the collaboration through teams, interoperability in BIM models and the possibility to improve control, also the quality of the projects and financial results [7, 19].

In the way, BIM is a recent technology that changes the process in the sector, and there is still a lot to improve and to study in the BIM implementation. One example is the laws to regulate the BIM practices, that is, still limited around the world [16]. This paper aims to show how Building Information Modelling can contribute to the lifecycle process of buildings.

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76.2 Bibliographical Review

A lot of authors are researching Building Information Modelling in the world. Eastman et al. [7] say that BIM is a process that is developed with the information obtained in the software BIM that enables the analysis, fabrication, budget, schedule and other phases and uses for civil construction. Fadeyi [8] explains that a lot of phases during the life cycle of a building exist, and these phases are modelled by information included in the BIM models.

Figure 76.1 represents the building life cycle through BIM use. In fact, Abanda et al. [1] concluded that data attached to a BIM model is quite important for the process of a building. The contribution of this information in different phases of the civil construction sector is shown by authors around the world.

Hong et al. [14] discussed how productivity could be improved in the civil construction industry and concluded that it is necessary for a flexible and adaptive process like BIM. Fernandes [10] describes that BIM could be used to simulate the work sequence of building construction, with the schedule and the time parameters.

Abanda et al. [1] show that BIM contributes with the automation of cost estimation process, and they propose a standard measurement method to avoid inaccuracies in this process and to comply with UK New Rules of Measurement. Besides that, Sakamori [19] made research in Brazil considering the introduction of BIM in the building budget process.

“Akinade et al. [2, p. 6] noted that support for waste analysis throughout the building lifecycle is important to understand the waste performance from the design to the end of life of buildings”. These authors comment that BIM does not contribute to construction and demolition waste management in the design stage, and they studied how BIM could be employed for it.

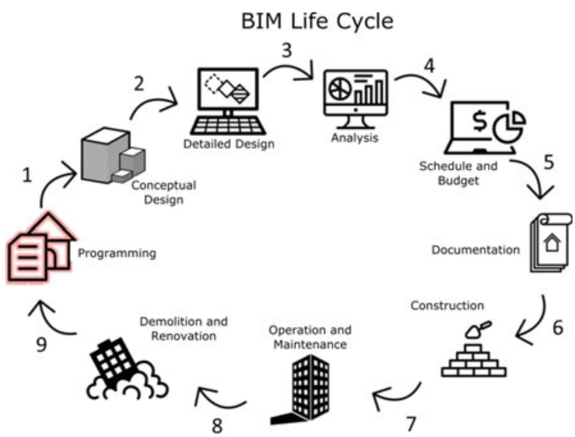

Fig. 76.1 Building life cycle through the use of BIM process. Cited by Mattana and Librelotto [18]

Ge et al. [12] explained BIM as an application for deconstruction or demolition through the modelling. Additionally, they showed BIM as a technology used to improve the efficiency of design, construction and maintenance throughout the entire life cycle.

As shown in this text, a lot of authors are researching the BIM process around the world. BIM is showed as a solution for many problems in civil construction. One example is described by Jordan-Palomar et al. [15] that BIM could be used to solve problems in the sector, as the common workflow used at architecture projects that present some problems, like the lack of clarity processes, dispersion of information and the use of outdated tools.

About the building delivery process, Fadeyi [8] comments BIM is important to provide collaborative teams and to potentially reduce the fragmentation among professionals. This is extremely important to improve the process for civil construction.

76.3 Method

The method used in this research is a literature review made following the systematic search flow (SSF) proposed by Ferenhof and Fernandes [9]. SSF method is composed of four phases and eight activities, as shown in Fig. 76.2, and proposes to systematize the search and to analyse the results obtained.

The first step used in this paper was to define the protocol of this research through the objective and the creation of a search query. The strategy used for this query was the words “BIM and Process”, in order to discover how the BIM innovation process contributes to the civil construction.

In the sequence, a search was made in the database choose for this paper, called Scopus. Some general filters were used in the Scopus database, as shown in Fig. 76.3:

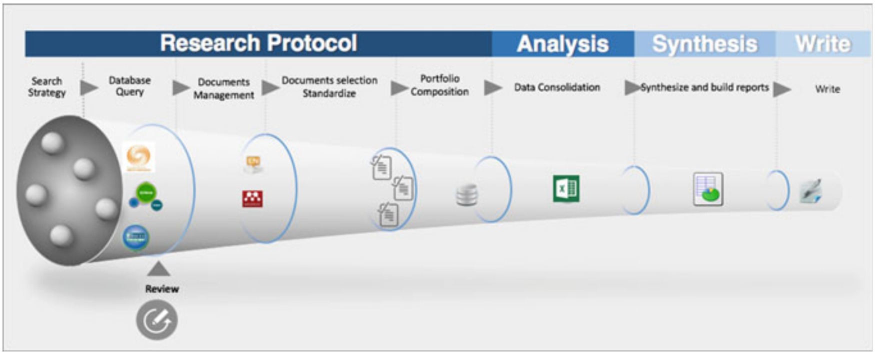

Fig. 76.2 SSF method. Cited by Ferenhof and Fernandes [9]

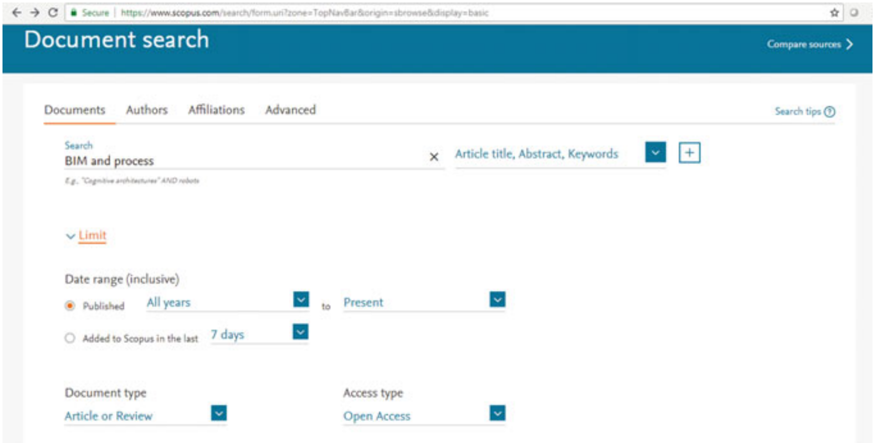

Fig. 76.3 First step of method: filtering the documents. Authors

(1) the period of publication for "all years to present"; (2) document type as "article or review", only; and (3) access type as "Open Access". The database search occurred on 8 September 2018. It was possible to find 144 total documents in the first step of this literature review.

In addition, new filters were applied in the search: (4) the subject area was filtered for "engineering and social sciences"; (5) the language was filtered for "English" only. The results for this second filtering were 61 documents found.

These 61 documents were exported for a bibliographical organizer called Endnote®. Then, all titles, abstracts and keywords were read to filter the documents aligned with the theme of this research. In this phase, 43 documents were discarded resulting in 18 aligned papers.

Likewise, the last filtering in the documents was made through the reading of the full 18 texts selected. As a result, nine papers aligned with the theme and objective of this research remained. Figure 76.4 shows the bibliographic portfolio as described in this method.

76.4 Results

The results are presented in Table 76.1, which contain the main information about the documents selected using the SSF Method. The first column is organizing the papers selected in alphabetical order. The second column shows the paper reference, with information about authors' names, paper title and year of publication and the scientific journal of each document. The third column shows the main topic and theme of each research and the contribution of the study for the objective of this paper.

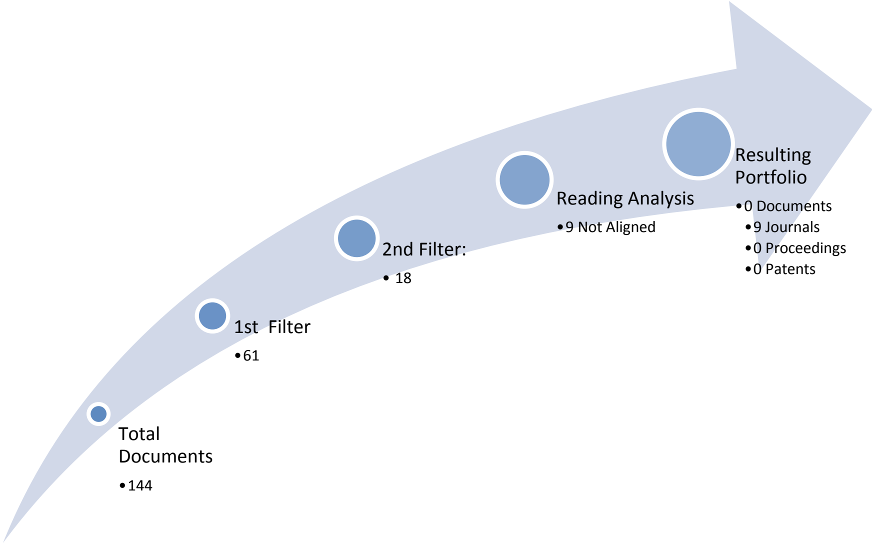

Fig. 76.4 Bibliographic portfolio. Adapted from Ferenhof [11]

Analysing the year of publications, it was realized that the greater part were recent papers, published this year (2018—two papers) or last year (2017—five papers). The others are from 2015 (one paper) and 2013 (one paper). Only the Journal "Building" was repeated more than one time in this literature review result, where three papers that contribute to this study were found.

76.5 Conclusion

As shown in this paper, a lot of authors are researching about BIM process throughout the world. BIM can contribute to the entire life cycle of a building, during the phases for: (1) design the building (from the beginning to the end of life of buildings, like for the deconstruction process), (2) schedule and productivity performance, (3) cost estimation or budget, (4) construction and demolition waste management, and (5) facilities management, and others.

Some benefits are the possibility to do the clash detection during the design phases, improving the compatibility through different designs before construction and the use of IFC format to send information related to a building project by interoperability between BIM tools.

The conclusion of this literature review is that BIM could improve collaboration through the teams in the process and allow the creation of a federated model that could be assessed and updated by all the project team during the life cycle of buildings, as cited by Akinade et al. [2].

Table 76.1 Results of the literature review

Paper	References	Contribution
1	Abanda et al. [1]	This paper aims to structure a standard measurement method in an ontologically and machine-readable format for using in a BIM software. Authors say it can greatly facilitate the process of improving inaccuracies in cost estimation for civil construction in UK, using BIM technology
2	Akinade et al. [2]	This research supports the waste analysis throughout the life cycle of the building trying to adopt BIM from the design to the end of life of the buildings. The authors made bibliographical research and applied some surveys with stakeholders to understand how BIM could contribute to the management of construction and demolition waste. One of their discoveries is that the adoption of BIM could improve collaboration for waste management and the major benefit is that it enables the creation of a federated model that could be assessed and updated by all the project team during the life cycle of the building
3	Akinade et al. [3]	The aim of this research is to improve the building design for deconstruction (DfD). None of the existing BIM software offers DfD functionalities because it is not a common practice. The discussion and analysis were made with Focus Group Interviews, about improving building lifecycle management and visualization of deconstruction process. The results suggest that it is important to adopt solutions available within tools used throughout the entire life cycle of buildings
4	Akponeware and Adamu [4]	This paper investigates how the clashes could be avoided in the automation processes through Building Information Modelling. It can happen with the 3D design coordination, collaborative work, training for the professionals involved in the process and collaborative work through the cloud-based structure
5	Cavka et al. [5]	This research objective is to understand the facility management (FM) practices across organizational and project contexts through a case study analysis. It was used a large owner-operator institutional organization to investigate the transitioning from a paper-based to a model-based approach in a BIM process
6	Hernandez et al. [13]	This paper presents a study in which the IFC format was used to send information related to a building project. One of the objectives of this study is to promote a framework for self-inspection during the entire construction process, using IFC format

(continued)

Table 76.1 (continued)

Paper	References	Contribution
7	Liao et al. [17]	This paper aims to propose a project management framework for enhancing the productivity of building projects, by two approaches in Singapore, validated with case studies. The results show that this framework help teams to enhance productivity performance in the BIM-based process
8	Tolmer et al. [20]	This research proposes the use of "System Engineering and Requirements Engineering", based on two different approaches, to define BIM uses and the relevant level of detail (LOD) of information and its modelling. The authors concluded that it was necessary to redefine the LOD concept in order to make it compatible with the methods of requirement management, for infrastructure projects
9	Wang et al. [21]	This paper shows a framework of how facilities management can be considered in the design stage through the use of BIM. The authors concluded that the early adoption of BIM through facilities management analysis in the design phases can contribute to reduce the costs of building life cycle

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Chapter 77
Lean Manufacturing and Industry 4.0—Are There Interactions? a Multiple Case Study

Luiz Reni Trento, Reno Schmidt Junior and Anderson Felipe Habekost

Abstract This study intends to show the interactions between lean manufacturing (LM) and Industry 4.0 (I4.0). We used multiple case studies of Brazilian and German companies. German companies use I4.0 to improve the benefits of LM further. However, Brazilian companies need to consolidate LM before considering the investment in I4.0.

Keywords Lean manufacturing · Industry 4.0 · Toyota production system

77.1 Introduction

Lean manufacturing (LM) can benefit manufacturers of any product [35]. As described in the literature, such benefits may arise from the development of the continuous improvement culture [11]; of the application of just-in-time practices, supplier delivery, kanban, reduce time set-up, EDI communications, etc. [13]; from the transformation of mass-production thinking to lean thinking [31]. Also, these benefits can contribute to strengthening the competitive advantage [23]; increase productivity and reduce waste [35]; develop a culture of creativity and innovation [11]. However, barriers may hinder the collection of these benefits. Such barriers can arise in the management of change, organizational issues (leadership, culture, finance, resources, etc.), systems (forecasting, infrastructure, logistics, support), technology [11]; may also pose obstacles in the highly fluctuating demand volume [10]; lack of resources and involvement of senior management; resistance of workers; in cultural difference; in weak leadership; and lack of perseverance that may lead to regression [12].

However, in recent years, the industry phenomenon 4.0 (I4.0) has been consolidated in the agenda of researchers and governments [15]. The focus of I4.0 is to combine production, information technology, and the Internet [24]. Besides, this phenomenon favors flexibility and speed, mass customization, and the improvement

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of quality and productivity. Such favors allow companies to launch more individualized products in the shortest time [37]. Companies can reap such benefits through the network of manufacturing of products, services, data, and people on the Internet [16]. However, it is highlighted in the literature that the development of I4.0 is a challenge for companies [9]. This challenge involves rethinking the business model involving all internal and external stakeholders. Besides, this review of the business model contributes to avoiding that leaders think that I4.0 is only to develop technology [9]. Another challenge lies in the difference between a traditional factory and the I4.0. In I4.0, connected systems can monitor conditions and provide a fault diagnosis [32]. Despite these differences, it is observed that the LM and I4.0 phenomena are not contradictory despite the progressive application of the scanning in the industries [17]. In a study published in 2016, Martinez et al. [20] address the low correlation in LM and I4.0 publications. This same author calls for research that includes LM in this new revolution [20]. Notably, there is a shortage of literature on interactions between LM and I4.0. The desire to focus on these topics has generated the following research question:

R.Q. "Lean manufacturing and Industry 4.0—are there interactions?"

To answer this question, this study investigated LM and I4.0 interactions in large companies in differentiated segments located in Brazil and Germany. Identifying these interactions can help companies in emerging countries target their efforts, resources, and investments. The remainder of the article is structured as follows. The next session presents the theoretical basis of research based on two fundamental concepts: issues related to LM and I4.0. In the sequence, the research method based on multiple case study is presented, paying particular attention to the interactions, requirements, benefits, and barriers. Finally, discussion and results are presented.

77.2 Literature Review

The first part of the literature review focuses on the issues surrounding LM. For many years, many companies use LM based on Toyota Production System (TPS) concepts to reduce inventories in the process and increase value added [17]. It methodologies focus on lean production thinking. The second part of the literature review focuses on the concepts of I4.0. It is identified in the literature that I4.0 consists of a major technological revolution that will reshape manufacturing industries, social and economic life more broadly [26].

The pillars of LM and TPS are just-in-time (JIT) and autonomation [33]. Taiichi Ohno developed JIT at Toyota Motors. Being that, at the heart of the concept is the availability of the right piece to the assembly at the right time [33]. It has been found in the literature that a workforce and flexible machines are equally vital to achieving JIT [1, 2]. This flexibility contributes to an integrated problem-solving management to improve quality, punctuality, production, and distribution [11]. Also, the JIT concept is supported by "zero concealments": zero defect, zero queues, zero breaks, zero inventory, and so on [18]. The literature draws our attention to machines that can avoid errors autonomously [33]. This concept emerged in the early twentieth century from the ideas of Sakichi Toyoda. Such ideas were applied in the development of the self-activated loom. This equipment was quick and ready to interrupt the operation when one of the wires broke, or the thread of the weft was finished [6, 33].

The LM focuses on the production of small batches [12, 22] and set-up time reduction [7, 22]. The production in small batches allows the quickest replacement of the materials. This constant flux contributes to reduced cycle time and increased productivity [35]. Shingo developed the set-up time reduction to reduce and simplify configuration time during tool change [22]. The benefits can be observed in increasing machine operating rates, reducing inventories of finished and intermediate products, rapid response to fluctuations in demand and production in small batches [7]. All elements are critical to success [14, 28]. However, differentiation is found in how each element reinforces the other [14]. JIT removes as much stock as possible toward the unit flow of a unit at a customer demand rate. Such removal promotes the visibility of quality defects by requiring workers to unite to solve such problems quickly in order to avoid production stoppages [14]. Also, the management of the factory floor needs to have people trained for continuous improvement [1].

However, it has been identified in the literature that despite the intensely discussed concepts, there are still barriers to LM. Such barriers prevent companies from reaping the benefits inherent in LM. These barriers include human, cultural, and resource factors [10, 12]. The lack of autonomy and communication can contribute to the end of LM projects [11]. Such questions may arise from the difficulty of delegating, listening, and establishing a different relationship [11]. Another problem lies in the lack of cooperation and trust between management and employees [11]. The fear factor related to job loss may increase resistance [3, 35]. It is identified in the literature that productivity gains are often unemployment [30]. Other barriers may arise from the inability to develop stability in production [19]. This lack of stability affects JIT performance [19]. Such lack of stability may also affect the implementation of pulled production [2] or the process of direct communication of information sharing related to the production schedule [13].

The second part of the literature review addresses the concepts of I4.0. It can be said that we can for another moment of advance in the productive processes. Taking as starting point the Industrial Revolution begun in England (1766), advancing toward the introduction of electric light (late nineteenth century), through the development of the semiconductors and computers as we know it today, and industrial revolution based on the internet, artificial intelligence, and embedded system [9]. It is discussed in the literature that I4.0 consists of the discourse of policy-oriented innovation. These guidelines aim to develop systems of innovation that cover business, academia, and politics. These systems are based on Helix's triple innovation mode emphasizing how universities, business, and politics co-generate innovation [26]. Such innovation has the objective of creating stable processes that bring the expected cumulative benefits of digitalization in the form of lower costs and revenue increases [4]. This digitization provides decentralized production through networks that operate autonomously and can efficiently control factory operations

[9]. The literature highlights that the latest advances can transform today's complex automated, self-manageable, and sustainable process–manufacturing processes [25]. Such breakthroughs involve a combination of engineering and technology. The engineering focuses on machines, processes, and factory; and technological in controls, integration, and intelligence [25].

The I4.0 consists of a state to be reached where omnipotent cybernetic systems are created by integrating different technologies to allow a fully automated and interconnected production [27]. It is identified in the literature that this integration can occur through the positive synergy between LM and I4.0. This synergy may allow the plant to reach a lean and intelligent footprint [29]. It has also been found in the literature that there is no contradiction between LM and I4.0 [17]. There is an excellent potential to be gained by combining these two approaches. Many difficulties identified in the static value stream mapping (VSM) can be overcome by the availability of actual data from the manufacturing execution system placed together with the geographic data collected by a radio-frequency identification (RFID) system. Thus, the current value stream can be permanently displayed and bottlenecks, as well as improvements, can be continuously verified. In this way, a dynamic VSM can be obtained [17].

77.3 Method

The empirical research carried out in this study employed the method of multiple, qualitative, and exploratory case study. This method was chosen to contribute to the literature on LM and I4.0 interactions in Brazilian and German companies. The analysis of the case study developed occurred in organizations of the industrial branch. The case study is strategic for examining contemporary events and provides researchers with an opportunity to understand the conditions that are present in a particular situation [36]. While the individual analyzes consolidate the information of each case, the analyses between the cases identify patterns, providing elements for the construction of hypotheses and the development of theories [8, 36]. The present multiple case study presents the implications that can contribute to evidence actions, requirements, and issues pertinent to the implementation of lean production and manufacturing models 4.0. The study analyzes Brazilian and German companies to make recommendations to mitigate such problems. In a case study, it is recommended to combine a variety of sources. These sources include interviews that are one of the most critical sources of facts and opinions, file analysis, questionnaires, and quantitative records [36].

The multiple case study was conducted in large companies that work in the manufacture of agricultural and automotive products. Table 77.1 shows the characteristics of the companies.

The interviews were conducted with professionals involved with manufacturing. The criteria for selection of the professionals were their experience with the man-

Table 77.1 Characteristics of the investigated companies

Case	Characteristics	Location	Marketplace
A	Multinational—Global revenues around $9.0 billion	Brazil	Agriculture
B	Brazilian Company—Revenues around $0.2 billion	Brazil	Automotive's parts
C	Multinational—Global revenues around $35 billion	Brazil	Automotive's parts
D	Multinational—Global revenues around $28.0 billion	Germany	Automotive
E	Multinational—Global revenues around $112.5 billion	Germany	Automotive
F	Multinational—Global revenues around $68.0 billion	Germany	Automotive

agement of industrial operations. Thus, most respondents are production managers with an average of ten years of experience.

The data collection was performed through unstructured interviews with professionals from the groups already mentioned: industrial managers. An interview guide was developed to ensure the consistency of the interview content and procedure. The interviews took place from March to July of 2018. The interviews were performed through site visits, recorded, and transcribed [36]. The perceptions and conclusions of each interview were shared and discussed in pairs. Any remaining doubts of the interviews were clarified directly with the interviewees in an informal way, e-mail, and personal contact. Additional data were collected through participant observation [36]. The combination of the different sources of evidence provided the triangulation of the data [8]. The companies were very open to the discussion, but they demanded confidentiality regarding the disclosure of their names.

77.4 Discussions and Results

The results of this study identified that LM might be a pioneering methodology for the application of I4.0. The literature has already addressed the synergy of LM and I4.0 [29]. Another study pointed out that German executives positively appreciate the application of lean and Industry 4.0 together [17]. It was also identified that the Brazilian companies studied face difficulties to apply the precepts of LM fully. The results revealed that shortcomings in the lean might make it unfeasible for I4.0 due to the long return on investment. From the results obtained in this study, we intend to evaluate the implications and contribute to the development of LM and I4.0. The key findings of Brazilian cases are presented in Table 77.2.

The findings reveal that the German companies studied use I4.0 technologies to further improve the benefits of LM application in the process, that greater access and lower cost of technologies have extended the modernizations in companies. This finding corroborates the affirmation of [17] that significant gains can arise from the combination of LM and I4.0 methods. I4.0 actively contributes to JIT inventory minimization; this finding is in line with the LM principle that seeks to minimize in-

Table 77.2 Key findings of Brazilian cases

Case	LM	I4.0	Issues
A	VSM, meetings solution problems, employee training, zero defects (quality gates), standard work	Focus on investment in tools (Google glass, smartphones)	Investment training in concepts LM and I4.0 to identify opportunities; Inventory >30 days
B	External consultancy; focus on cultural change; poor results	Focus on investment scan layout; initiating investment sensing jobs	Knowledge and adoption of LM and I4.0 limited to some people. Not yet in the company's usual practices; Inventory >30 days
C	Focus on the search for zero defect; teams focused on waste reduction; applies visual management	There are no initiatives	Inventory management problems (53 days); precarious equipment make standard work and stability difficult; conflicts with clients and employees; unfavorable economic environment

process stocks by establishing frequent replenishments in line with customer demand [2, 29]. Table 77.3 shows the main findings identified in the German cases. It is noteworthy in these findings that LM is the cornerstone of the initiatives of I4.0.

Another contribution of the findings is the total visibility of the supply chain. The findings reveal that Industry 4.0 allows access to online information. This full connectivity is aligned with the JIT principle that allows customers to make requests' modifications without involving people [2, 11]. It can be concluded that this finding contributes to the literature revealing that this total connectivity is fundamental for the supply chain management [11]. A significant gain in total connectivity is the ability for customers to streamline production online. Besides, they can make changes to the products before production. This finding is in line with Toyota's pull system: giving the customer (which may be the next step in the production process), what he or she wants when he or she wants it, and in the same amount he or she wants [2, 11].

Industry 4.0 contributes to the total automation of processes, machines, and database [4, 21]. The findings also reveal that German companies are heavily using visual controls. However, these visual controls are connected to the database by providing online information to all stakeholders. The ability of autonomous equipment to identify problems and visual management of the productive system aligns with the LM principles [2, 11]. This ability appears in the computational capacity to evaluate the conformity of the parts in the process. Likewise, the connectivity, flexibility, and access to the database allow the equipment to make decisions [16, 34].

The Brazilian companies studied present difficulties in understanding this new precept known as Industry 4.0 and in the application of the technologies offered. This finding is in line with a recent publication that states that the Brazilian industry has not yet taken advantage of some promising technologies, such as Big Data analysis,

Table 77.3 Key findings' German cases

Case	LM	I4.0	Issues
D	Focus on LM: MUDA, 5 s, and SMED; JIT efficiency: production only upon request (3 days); maximum stock: 2 h;	Objective: reduce costs and waste; unfeasible without the LM (return very long investment); total connectivity through smartphones (customer can change the product); visual controls	Standardization of information; position the processes; interconnect them in the conventional data a network between all companies
E	Focus on LM: 5 s and SMED; JIT efficiency: production only upon request (40 h); maximum stock: 6 h; interconnected supply chain	Objective: Natural advancement of technology; benefits: efficiency and time savings in all processes; exchange of information between machines; automatic, assertive, and fast process	Enable database to handle product customization
F	Focus on LM: 5 s, Pokayoke, and SMED; Efficiency JIT: the process of stamping and injection interconnected; maximum stock: 2 h; interconnected databases generate automatic orders after the sale generation	Contributed to automatic quality decision process; power generation by turbines driven by the impact of stamping machines; the LM is the cornerstone of I4.0—it would not be possible to apply the concepts I4.0 without the consolidated LM	Standardization of information and unification of databases

cloud services for manufacturing, among other technologies, for the digitization of the plant and performance analysis of product [5]. We cannot conclude if this difficulty is referred to the scenario of economic recession passed by the country or by the little knowledge of what this technology is. As the cases studied were not from companies of the same branch faithfully, we used the context common to all. We can perceive the difference of interactions between the "links" of the productive chain in the different countries, especially in what refers to the communication between their banks of information and mainly in the maturing of the stages of the processes concerning to the applied methods. We do not enter the issues of political scenario and infrastructure offered, but it is known that these items also have a direct impact on the applications. The results of this study point out that Brazilian companies need to manage and consolidate their processes before directing efforts and investing resources in Industry 4.0. These two items should be handled together with the same degree of importance and productive impact so that it can indeed bring the essential benefits: connectivity, flexibility, and cost reduction. Future studies can help create a framework that enables companies in emerging countries to overcome process problems and reap the benefits of I4.0.

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Chapter 78
Business Model Innovation and Modularity: Overview of the Literature

Diego Honorato Clemente, Juliana Hsuan and Marly Monteiro de Carvalho

Abstract This article aims to analyze the intersection between the constructs of modularity and business models. For this purpose, a systematic literature review was carried out, merging bibliometric and content analysis. As a result, the main research themes and gaps are identified, and a panorama of the literature is drawn. The literature within this research field is rather recent as the majority of publications have been published after 2014. Also, the theme is published sparsely in a wide range of journals as there are no dominant research outlets. Although the concept of modularity has been widely discussed in terms of product, process, and organizational levels, recent developments point out to the application of this concept to service and business models.

Keywords Business models · Modularity · Bibliometrics

78.1 Introduction

Modularity is a construct that can be related to different fields. Modularity as a general systems concept refers to the "degree to which a system's components can be separated and recombined" [36] in order to allow for the decomposition of complex tasks into simpler ones [31] aimed to reduce the complexity of a structure [18]. Traditionally, modularity has been concentrated around product architecture modularity, production systems modularity, and organizational design modularity [8], in which the original perception of modularity falls into product architecture [29–31, 35, 36]. More recently, modularity concept has been applied to services [3, 7, 45] and business model [2, 19, 39, 43].

Although there is a lack of consensus on the definition of business model in the literature [13, 42, 48], business model is often defined as the way firms create and

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deliver value to customers [4, 10, 13, 15, 42, 48]. The concept of business model states that a firm needs to integrate a wide range of elements into a consistent combination in order to be successful [6]. The concept also entails how a firm organizes itself [4, 15] and defines the governance of transactions [10] to deliver that value and be profitable.

Customers and their needs are targeted in business models [19] as value is at center stage for business models. Given this scenario, modularization of business models can lead to strategic flexibility and provide firms with greater potential for business model innovation [19]. Thus, this article aims to analyze the intersection between the constructs of modularity and business model. For this purpose, a systematic literature review was carried out merging bibliometric and content analysis. As a result, the main research themes and gaps are identified, and a panorama of the literature is drawn. This article is organized as follows. Section 78.1 brings the introduction. In Sect. 78.2, the research methods are presented. Section 78.3 brings the main results and discussions, while in Sect. 78.4, the main conclusions are drawn.

78.2 Research Methods

This research combines quantitative and qualitative methods, as it combines bibliometric and content analysis due to the complementarity of both methods [9]. From quantitative techniques, the bibliometric analysis was utilized in order to identify the main citation patterns and fields within the business model and modularity. In terms of qualitative techniques, content analysis was carried out to identify and understand themes and patterns in the articles [17, 25].

The sampling process was carried out in ISI Web of Science Core Collection and Scopus, processed in June 2018, as both databases provided complete metadata for bibliometric analysis [9]. The search query for this research was "business model*" AND "modular*," selected as "topic" in ISI Web of Science and as "article title, abstract and keyword" in Scopus. The only applied filter was "type of document" as "articles," and "reviews," and "articles in press" (only in Scopus) were the documents selected to compose the final sample. In total, 119 articles in ISI Web of Science and 202 articles in Scopus were found, and after filters were applied, there were 59 and 84 articles, respectively. There was an overlapping of 42 articles (articles that were found in both databases). We opted to select the final sample in the ISI Web of Science Core Collection. The remaining Scopus-only articles contained 42 articles, in which were verified subsequently also in ISI Web of Science. Out of the 42 Scopus-only articles, four were also at ISI Web of Science but did not appear in the first research in this database. They were included in the final sample, resulting in a total of 63 articles for analysis.

78.3 Results and Discussion

The final sample from ISI Web of Science Core Collection contained 63 articles with a total citation of 698, comprising an average of 11.08 citations per article. The h-index for this sample is 13. The first article was published in 1996 by Sherwood [38] that described a method for enterprise security architecture and strategy. In Fig. 78.1, the yearly publication pattern shows that there has been the inconsistent number of publications with peaks and valleys alternating throughout the years. However, it is noticeable that the period of 2014–2018 comprised of 52.38% of the articles in the sample. The year 2017 alone had the highest number of publications, peaking at 13 articles. This may be evidence of the recent interest in the discussion about modularity and business models.

In total, 58 journals published articles related to the business model and modularity field. There was no major concentration of publications in a few journals as only five journals had two publications each, while the remaining 53 journals published one article each. Journals include, for instance, *ChemBioEng Reviews*, *Chemie Ingenieur Technik*, *International Journal of Operations & Production Management*, *International Journal of Technology Management*, and *Journal of Cleaner Production*.

The adjusted article impact factor (AIF) was calculated for the articles in the sample. The AIF was proposed by Carvalho et al. [9] in order to identify the most relevant publications within a sample as it is based on the average yearly citation and Journal Citation Report (JCR). The adjusted article impact factor is presented in Eq. 78.1:

$$\text{AIF} = \text{Average yearly citation} * (1 + \text{JCR}) \tag{78.1}$$

As pointed out by Homrich et al. [24], considering the yearly average citation, this calculation reduces considerable weight on older articles. The articles with the ten highest adjusted article impact factor (AIF) are presented in Table 78.1.

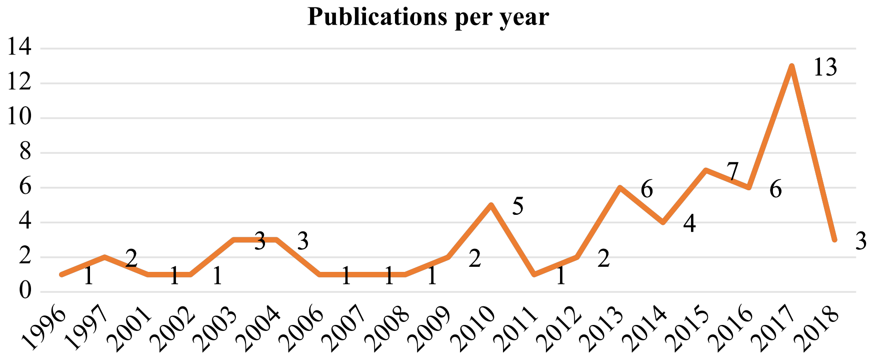

Fig. 78.1 Publications per year

Table 78.1 List of the ten highest article impact factor (AIF)

Article	Journal	JCR (2017)	Total citation	Average yearly citation	AIF
Spring and Araujo [40]	*International Journal of Operations & Production Management*	2.955	123	12.3	48.65
Richter [34]	*Renewable Energy*	4.900	41	6.83	40.30
Handel et al. [21]	*IEEE Systems Journal*	4.337	26	5.2	27.75
Tsvetkova and Gustafsson [43]	*Journal of Cleaner Production*	5.651	27	3.86	25.67
Meier et al. [28]	*International Journal of Advanced Manufacturing Technology*	2.601	52	6.5	23.41
Christensen et al. [14]	*Industrial and Corporate Change*	2.198	110	6.47	20.69
Hessel et al. [23]	*Chemical Engineering and Processing*	2.826	32	5.33	20.39
Leurent et al. [27]	*Energy Policy*	4.039	6	3	15.12
Cenamor et al. [11]	*International Journal of Production Economics*	4.407	5	2.5	13.52
Ray and Ray [33]	*IEEE Transactions on Engineering Management*	1.416	42	4.67	11.28

The article of Spring and Araujo [40] had the highest total citation and average yearly citation in the sample and, consequently, remained as the article with the highest adjusted article impact factor (AIF). The articles of Richter [34], Meier et al. [28], Christensen et al. [14], and Hessel et al. [23] completed the remaining list of the five articles with the highest average yearly citation. However, considering the adjusted article impact factor, for example, Richter [34] remained in the second place, while Meier et al. [28] went from the third to the fifth position, Christensen et al. [14] moved down from fourth to sixth position, and Hessel et al. [23] moved down from fifth to seventh position. On the other hand, Handel et al. [21] moved up the

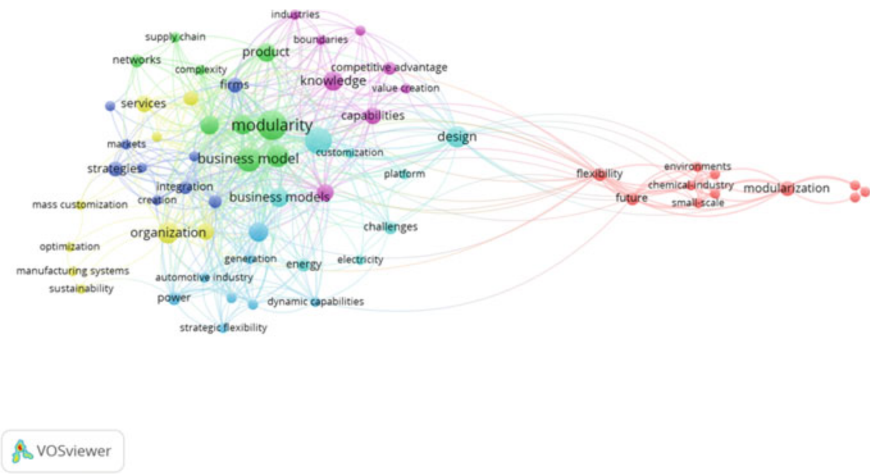

Fig. 78.2 Keywords co-occurrence network considering a minimum of two citations

list from sixth to third position and Tsvetkova and Gustafsson [43] went from eighth place to the fourth.

The keywords network is presented in Fig. 78.2. The objective of this network is to show the common relationship pattern of keywords which indicates the themes discussed in the articles. The cluster indicates the association of keywords and main themes within the business model and modularity field. In total, seven clusters were identified in which two are the most relevant ones. The first is the green cluster whose keywords entail the discussion of modularity as a way of managing complexity through networks of firms (entailing organizational modularity). The second cluster is the purple one which indicates a discussion toward capabilities and business models for competitive advantage and for value creation, considering expanding the boundaries of the company.

In Fig. 78.3, the co-citation network is shown. This network aims to identify the theoretical pillars [9, 24] of the articles in the sample. In total, three main clusters were identified. The blue cluster deals with organizational aspects of modularity and business models, such as the modularity in organizational systems, interfirm governance and networks [20], networks and innovation in modular systems [26], modular organizational forms [37], business model design for a firm's exchange with external stakeholders (boundary-spanning transactions) [46], and the fit between product market strategy and business model as boundary-spanning activities of a firm [47].

The green cluster has two main sides. The first one deals with dynamic capabilities [16], while the second one discusses the business model in a wide range of topics such as its ability to capture value from technologies [13], differences between strategy/business model/tactics [10], the relations between business model, business strategy, innovation management and economic theory [42], business model concept based on a Penrosian-based view [15], barriers and opportunities to the business

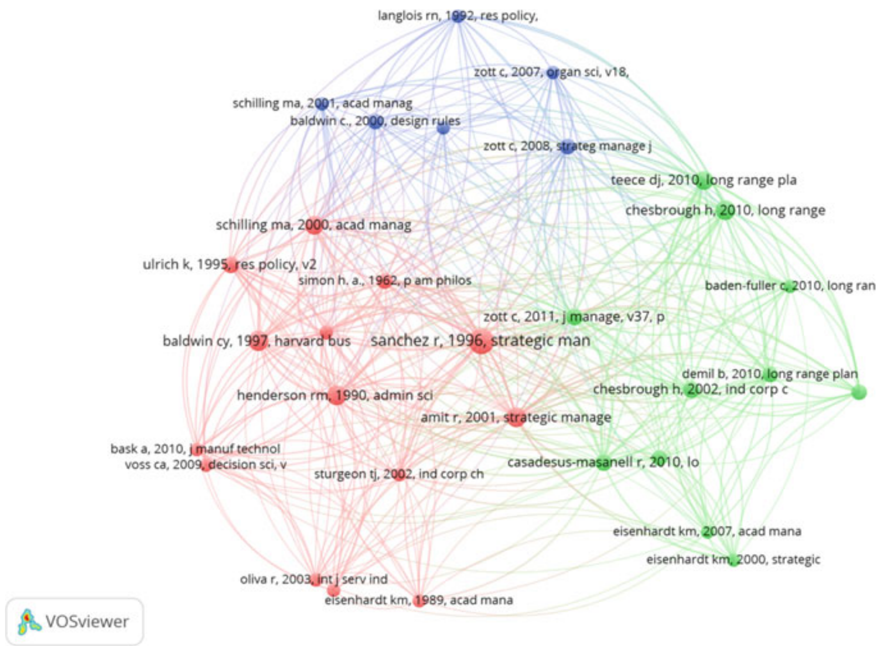

Fig. 78.3 Co-citation network considering a minimum of 32 citations per document

model innovation [12], the concept of business model as having a multivalent character [4], and an overview of the business model literature [48].

The red cluster is composed of articles that deal with product and modularity in a variety of ways such as architectural innovation [22], product architecture [44], modular production networks [41], transition from products to services of manufacturing industries [32], service architecture through modularity lens [45], assessing the current state of modularity within the literature [5], and review of the modularity concept in the management literature [8]. One article in this cluster does not discuss modularity—whether related to product, service, or organizational modularity—as it focuses on delimitating the process of value creation in e-business [1].

78.4 Conclusions

This article contributes to the literature by investigating the intersection between the constructs of modularity and business model in twofold. Firstly, a panorama of the literature is drawn, showing the increasing academic interest on the intersection between modularity and business model in recent years, 2014–2018, which comprised of 52.38% of the total publications. The panorama also shows an emergent pattern of the literature and composes with a small sample of 63 articles in ISI Web of Science Core Collection spread in a large range of journals.

Secondly, the article shows the key topics and trends. The literature shows that modularity has been used in three main domains: product, production, and organization design. However, recent researches on modularity have been applying the concept to service design and, even more recently, to business model, entailing modularization of business models. The key topics identified show modularity as a way of managing complexity as well as business models and capabilities for value creation and for competitive advantage. Besides, the literature utilized by the articles in the sample, as shown in the co-citation network, can be grouped in three main clusters as follows: (i) dynamic capabilities and business models, (ii) modularity in a wide range of topics, and (iii) modularity considering an organizational perspective.

Therefore, future research should focus on applying the concept of modularity to business models and business model innovation, focusing not only on the product, production, and organizations but also explore the trend on modularity in services. Another interesting relation that could be explored is how does this intersection between modularity and business model can impact firm performance, especially in manufacturing firms. This research has limitations. The main limitation refers to the methodological choices in terms of sampling based only ISI Web of Science database. Moreover, the search strings can also bring some bias to the sampling process.

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Chapter 79
The Industry 4.0 and the New Educational Trends: A Framework for Improving the Educational Activities

Marcio Pizzi de Oliveira, Annibal Scavarda, Ricardo Alberto Santa Flourez, Mario A. Ferrer Vasquez and Maristela Groba Andrés

Abstract The Industry 4.0 has provided new avenues for improving the music learning strategies. The present study seeks to propose a framework of action in the scope of the new educational trends, formulating propositions that allow the teaching customization in order to attend the different needs of the student.

Keywords Industry 4.0 · Education · Customization

79.1 Introduction

The cloud technology, the systems of recommendation, and the Internet of things changed the management of processes of artistic markets. The forms of consumption were restructured based on platforms and devices. Photographs, paintings, music, and other artistic artifacts can be stored and accessed worldwide, enabling a new form of experience based on immediate information retrieval. The forms of negotiation were also transformed, redefining roles in each market and empowering the artist as creator and also manager of his or her art.

Technology is constantly increasing ways for individuals to express creativity and other artistic skills. Several software and apps are launched everyday enabling people to take photographs, paints, and editing music. The customers of the digital age

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were introduced to the freedom of organization, development, and creation through software, apps, and platforms. These artistic experiences can implement new ways of thinking due to the facilities that are presented by those improvements.

Art turns to be an innovation in the field of business management. Flexibility, experience, and unusual strategies to improve decision-making are some of the features that attract researchers to this area. Instead of being an uncertain process, arts present methods for deconstructing and reframing business issues. Music, dance, and choreography can ‘provide methods for considering the rhythmic, tonal, harmonic, temporal, percussive, and kinesthetic elements of business problems’ [3].

Researchers are developing a great interest in artistic skills aiming to grasp the dynamics of change and organizational development [18]. The use of these skills in leadership situations [1, 2, 4, 20] and management [3, 6, 7, 12, 11, 15, 16, 17, 19] are the main targets of these studies.

The link between innovation and music can become a powerful tool for businesses researchers. There is a huge offer of software, apps, and platforms that emulate the musical creation, bringing the possibility to create songs and develop artistic skills even for those who are not initiated. These resources can be included in artistic initiatives for businesses companies. They manage to understand aesthetic methods that enable individuals to develop and understand the creativity of music craft, useful to frameworks for business management.

The present work presents a framework for business education based on remix music creation. This framework was built according to the association between the literature of artful events and the experience of music remixing classes at Federal Center for Technological Education of Rio de Janeiro. First, the paper presents the literature regarding business education and arts. Then, it presents the methodology of remixing classes. At the end, there is an analysis to build a framework for arts-based interventions based on remixing creation.

79.2 The Business Challenge of Creativity

Capacities and capabilities required in organizations include some operating characteristics not regularly classified as important. They are: the need to be reflective, to engage with change, to be comfortable with ambiguity, to have standards, to understand the key questions that need to be asked in any situation, to be conscientious about both people and what they want, and to ask about values and trust [12].

These criteria bring a new era of people management that value new demands and new capabilities from members of organizations. The increase of an open mind perspective concerned with these issues empowers studies in different fields. Creativity, for example, is inspiring researches associated not only to creative industry [16] regarding a working life characterized by time pressure and the demand to do more with less [19]. Creativity is increasingly seen as an attribute that needs to be embedded in every process or project [13].

Creativity needs a specific context of intangible resources to take place. Learning opportunities enabling expanded awareness, adaptability, resilience, resourcefulness, and play are imperative for management educators and businessmen to develop capacity for creativity, reflection, decision-making, and self-awareness [10]. The valorization of intangible and knowledge resources can prompt creativity and imagination to new business models [14].

Creativity has for a long time been associated with innovation and new ideas, but one of its main aspects is the capacity of developing judgments that put in risk of what was learnt before [5]. This can give to organizations the capacity to reframe operations and activities, not fearing to change paths. The exposure to creative and transformative learning through the arts can expand the ways of learning and development providing another way of seeing, thinking, feeling, doing, and being. It offers intrinsic benefits that help discover other ways of thinking than the taken-for-granted [11].

79.3 Arts-Based Interventions

According to Car et al. [6], the concept of artful making is consistent with the epistemological attempts to exceed rationalism as the dominant epistemological model regarding the processes of knowledge development. The authors presents a framework based on abstraction, a descriptive causal non-experimental method and theoretical accounts of innovation, art, management, and organization. The application of this framework can articulate and enhance management principles such as collaboration, trust, interdependence, play, preparation, and freedom that are used by artists and often neglected in modern management and organizations.

Gallos [8] presents a framework called artful teaching to explore the arts within educational strategies for management. The author argues that artful teaching is an innovative pedagogy for exploring human nature and modern organizational life; facilitating deep cognitive, socio-emotional, and behavioral growth and fostering creativity and the development of complex skills. The traditional features of education as planning and preparation are still important. However, trial and error, risk taking, and willingness to model learning can develop experience and experimentation.

Creativity, innovation, and uniqueness are qualities that are attributed to artists but missing in the business world, which explains the growth of cooperations between artists and businessmen [6]. Arts-based interventions (ABI) form a group of initiatives that represent these kinds of cooperations. They are based on visual arts, improvisational acting, reflective writing, drawing, music, poetry, film and provide de essence for new ideas that fit to the search for 'newness' [9].

Kerr [12] created the 'Artful Learning Wave Trajectory' which is a model of 'artful' experiences, linking artwork events like the points in a trajectory. The result is a network of 'artful experiences' mediated by the individual's perceptions that brings benefits to him or her and to the organization. The points are: capacity, artful

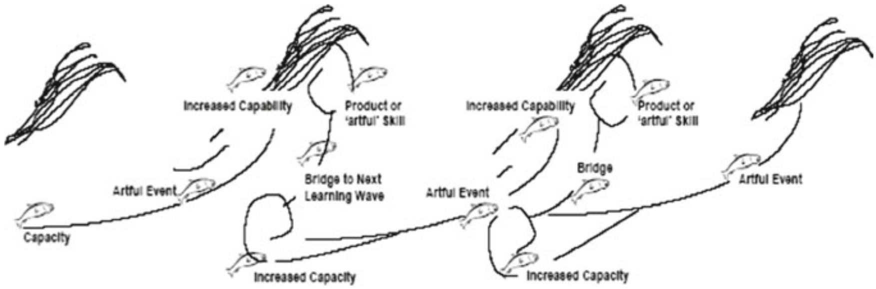


Fig. 79.1 Artful learning wave trajectory' model of Kerr [12]

event, increased 'artful' capability, and 'the application and action of the capability to have Product, through 'being artful' and becoming an 'artful being" [12], p. 12).

Capacity comprises elements of creativity and autopoietic response to conflicts that each human face to their 'being in the world'. Then, the person encounters an 'artful event', where he or she engages to an experience with the arts, and an experience through the arts, of 'being artful'. Through the 'art event', which is not just a metaphor, the experience leads to self-assessment that brings new understandings. Such 'meetings' can create relationships, 'and from relationships come qualities of connection, meaning and identity' [12], p. 12). See this model in Fig. 79.1.

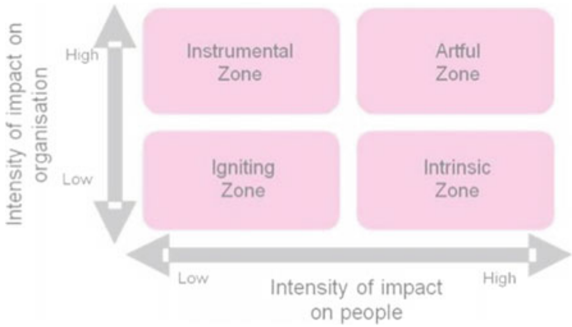
Using the work of Darso [7], Schiuma [17] identified four ABI zones: igniting, instrumental, intrinsic, artful, which measure the intensity of the impact on an organization and its members. The igniting zone is where the organizational interest is activated. The intrinsic zone relates to the engagement with people and the concentration of their emotions and energy in order to achieve specific organizational objectives. The instrumental zone aims to the pragmatic benefits which are achieved directly and/or indirectly by the use of a work of art or an artistic process. The artful zone is the result of a convergence of the 'art experiences' impact on people and on the organizational infrastructure.

When both intensities are low then the arts are used just as entertainment, but when both intensities are high the impact of art in business effects the organizational environment, training and personal development, and enables organizational bonding and transformation. Schiuma [17] proposes trajectory of Artful Organizational Development that moves from art being used as entertainment through being embedded in the organisational environment up to organizational transformation [17]. See this process in Fig. 79.2.

79.4 The 4.0 Remixing and the Educational Application

The researches regarding the association between education and technology have shown techniques that motivate synthesis through transdisciplinary projects, the

Fig. 79.2 Four ABI value zones of Schiuma [17]



mobilization of relational thinking through action, collaboration in different environments, decentralizing learning possibilities, the production of content as a pedagogical tool, problem solving and the ‘humanization’ of education through the student’s experience. These experiences contributed to the selection of the practices used on the framework and adaptations of the educational context of each class.

The remixing practices fit into this context due to the possibility of creating content using collaborative practices that belong to students’ life plan. The motivation of learning through exchanges between students can be both through the use of technologies recording, editing, and disseminating music as in creative practices with face-to-face actions. The relationships with the music creation and the demand for large reflections regarding the learned knowledge can enhance the students’ synthesis and relational thinking.

New technologies and 4.0 industry implementations bring new horizons to educational practice. The Internet of things, within the scope of Industry 4.0, enables technologies to assist students with data, tips, and solutions for their training. These technologies enable musicians to understand with real-time precision which notes are out of tune, which music intervals offer the most difficulty for singing, and what are the most frequent problems in rhythmic performance. All through detailed graphs and tables and easy to understand.

The Youmusician application, for example, allows a student to play an instrument in a step-by-step process. The microphone of the mobile phone becomes a sensor that informs if the chords and the rhythm are right. The application is just one example among a variety of instrument applications that enable performance and learning monitorization. Through the use of these resources, the teacher can implement strategies within the classroom that contemplate more complex actions that effectively require individualized follow-up.

Teaching the importance of phrasing, the correct use of dynamics, the ability to listen to the hole and the detail, the practice of identifying broad relationships between repertoires, artists and musical genres can develop a scope of an initiative with benefits for the management education. This scenario offers a range of possibilities that can bring a broader view enhancing essential skills for the management practice. Figure 79.3 shows the features of the artful teaching, the main outcomes of this

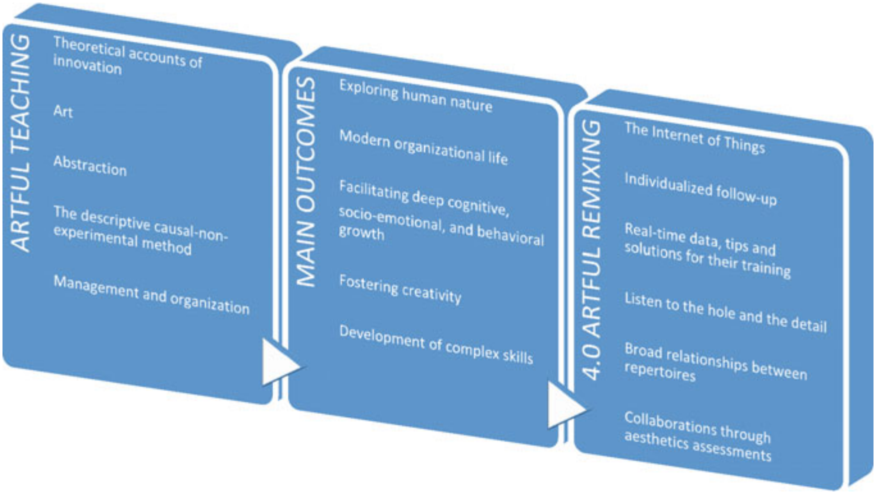


Fig. 79.3 Development of 4.0 Artful remixing

methodology, and potential tools of the remixing methodology that can develop similar effects due to music creation.

The management of teaching strategies can receive implementations as researchers offer new understandings; companies increase the technological possibilities and society changes. However, the structure of basic education presents institutional and infrastructure peculiarities that must be evaluated by the teacher. In the present research, these peculiarities motivated constant reflections throughout the process of formulating activities that went through adaptations, exclusions, and improvements.

79.5 The Remixing Framework of CEFET-RJ

The practices presented in this framework were developed in the period between April 12 and June 5 of 2018 at The Federal Center for Technological Education of Rio de Janeiro. They were part of the program of music education of the first year of high school. The students of three different classes participated of the practices.

The activities created for the present work present a short duration, following an average of 15 min per activity. Their organization in the context of classes does not follow the conventional patterns of complexity sequence or fixed subject orders. A class can present rhythm, listening, singing, and creation practices. Thus, the activities aim to provide alternatives for the student to create resources in order to carry out music projects and performances. It is also necessary for the student to create bridges between practices for through synthesis to obtain skills and knowledge that enables him to perform well.

The content of many activities developed in the research was provided by students. The repertoire, the applications used, and even the characteristics of the activities were permanently debated with the classes involved. In addition, the rules for the accomplishment of the works were not restricted in order to motivate the students to produce their own and creative contributions. The use of applications and software on students' computers, tablets, and cell phones also contributes to the individualization of teaching. The aspects related to the learning and operation of the applications and software were delegated to the students.

One of the guiding principles for the creation of the activities was the exploration of several manifestations of the phenomenon for the search of understandings about the process. The communication of musical aspects such as rhythm and sound tuning was expressed by conventional notation, unconventional notation, waveforms, presence gestures (of the colleague or of the student himself and non-presence body gestures (tutorials).

The teacher explicitly motivates the formulation of a critical and self-critical position due to music creation. The creative practices with remix applications offered several options of instruments and sonorities where the teacher constantly demanded the students' opinion and the proposition of solutions. In the collaborative practices, the students were constantly questioned about musical–theoretical aspects, musical and audiovisual production, communication, clarity, and cohesion.

Figure 79.4 shows an adaptation of the ABI zones' framework presented by Schiuma [17]. The igniting zone is related to entertainment as the remixing practices appeal to ludic music interaction, contemplation, and improvisation. The intrinsic zone creates a personal connection through the development of curiosity regarding other students ideas, the understanding of the importance of music to this community, and be free due to the music craft of remixation. The instrumental zone presents the explicit development of skills as rhythmic and listening precision, the understanding of the stages of composition, and the perception of the adaptations among music instruments. The artful zone can be achieve through the resilience on music composition, the ability to support the best idea instead his or her own, the engagement on the activities driven by the 'artistic spirit' and ignore the obligation aspect, and the understanding of the teamwork on music remix composition.

One of the main points of these activities is the fact that they are concrete actions inserted in the educational context. All of them belong to the daily life of the students, have already been experimented by them or presented by some media. Such activities have the potential to be part of the students' life project as a hobby or related to practices linked to fan communities. Thus, they are strongly present in the context of students' lives, which deserves special attention from music education professionals.

Fig. 79.4 ABI zones of 4.0 remixing framework

79.6 Conclusions

Researchers are more aware of the importance of artistic interference in management practices. But it is also true that technology and innovation have already brought the artistic experience closer to everyday life. The use of the new resources must be highlighted by studies that regard arts and management in order to introduce these new facilities in the scope of the mentioned practices.

The combination of music, business education, and innovation can settle new forms of art creation and business models. These elements are important to attend new demands of costumers and markets. However, they can be favorable not only to the creative industry but other kinds of activities that need alternatives of skills development. The ABI literature highlights several cases of the use of art in management, but there is a lack of arts and innovation studies. This may change with the awareness of new researchers about the topic.

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Chapter 80
Worker and Manager Judgements About Factors that Facilitate Knowledge Sharing: Insights from the Brazilian Glass Segment

Jorge Muniz Jr., Cleginaldo Pereira de Carvalho and Vagner Batista Ribeiro

Abstract *Purpose*: This study aims to assess factors of the tacit knowledge in the glass sector. Its focus is based on the managerial and worker perspectives about better knowledge sharing on the shop floor. *Design/Methodology/Approach*: The methodology applied was based on a comprehensive literature review about operation management, knowledge sharing and knowledge management assessment. A review of works relating these topics to the glass and foundry segments was also realized considering documents selected from the Web of Science (1997–2018). The field research work was conducted in the Brazilian glass sector, and the data collecting procedure used was a survey applied to 110 employees selected from the hot glass production line. An exploratory data analysis was performed to capture the employees' and managers' perceptions about the studied knowledge sharing factors. *Research Questions*: The study aims to answer the following research questions: What are the factors for a production system to align people, processes and knowledge? How to assess such factors? What is the importance of these factors in the production managers and workers' opinion? *Findings*: The results evidence that, in accordance with the employees' perceptions, the important factors for the KS are: conversation among the operators and study of work instruction. But it was evidenced that, in accordance with the managers' perceptions the important factors are: registration in the work instruction and study of work instruction. *Research Limitations/Implications*: This study was limited to the shop floor context and focused on the blue-collar workers' perception. The proposed approach can also be applied in other departments or organizations, even considering different cultures, worker groups or production sectors. *Practical Implications*: The findings support evidences to promote knowledge sharing through the shop floor context in the glass segment, which has a strong dependency on worker tacit knowledge. The work is also aligned

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with current research gaps identified on the literature. *Originality/Value*: This paper contributes to increase the understanding of KS to support managers' actions on practical implications and its implementation process.

Keywords Knowledge management · Knowledge sharing · Glass industry

80.1 Introduction

The knowledge sharing is a process of experiences exchanged among people with an expectation to obtain more knowledge, which in this work means collaboration and synergy of the blue-collar employees working together to reach the common targets. This research work is into the knowledge management (KM) and knowledge sharing (KS).

The KM is the systematic, formal and deliberate action into the mean of catching, keeping, sharing and reusing the tacit and explicit knowledge created and applied by the people during their routine tasks as well as in the improvement in their manufacturing processes, which generate measured results for the company and to the people.

KM is considered an emergent topic of study by organizations and the involved scientific community. KM has increased the number of researches addressing the various aspects, concepts, technologies, approaches and practices related to the development processes based on learning and knowledge [6, 10]. KM studies also consider the impacts in different levels of an organization, which can be evaluated regarding aspects such as technologies for knowledge creation, knowledge sharing, organizational culture, leadership, knowledge architecture and organizational learning [1].

The importance of an assessment process of the KM system is constantly increasing and for a learning-based growth strategy it stands out as a fundamental point for increasing the competitiveness of organizations [23]. It is also important to highlight the necessity of regular assessments, not only considering the capacity of the KM system, but also its reliability and performance.

The knowledge experienced by workers is very important for a dynamic development in foundry industry environments, contributing to high levels to the rapid development of technology. The studied glass segment has a strong dependency on worker tacit knowledge [2].

The purpose of this research is to assess factors of tacit knowledge in the glass sector, aiming to answer the research questions: "What are the factors for a production system to align people, processes and knowledge?", "How to assess such factors?" and "What is the importance of these factors in the production managers and workers' opinion?". The work is focused on the managerial and worker perspectives about better knowledge sharing on the shop floor. This scientific work presents concepts regarded as KM and KS got from a literature review with focus on the glass and foundry segments. It also presents results obtained from one first approach in a glass industry by a survey application. An exploratory data analysis was performed in order to capture the employees' perception about the studied knowledge sharing factors.

Section 80.2 presents the structure of this work, and Sect. 80.3 presents its theoretical basis with the main concepts related to KM and KS in glass and foundry segments as well as a KM assessment review. Section 80.4 describes the used research method, and subsequently, Sect. 80.5 presents the results and discussion, thus sustaining the purpose of this article and its conclusions, finally presented in Sect. 80.6.

80.2 Knowledge Management in the Glass Industry

Glass industry offers a broad and diverse range of products and intends to move toward diversification of business, focusing on research and development as well as innovation in response to the productivity [13]. Knowledge management (KM) and knowledge sharing (KS) practices have motivating studies at glass industries [2, 5, 16, 19] and other industrial foundry environments [8, 11, 22].

The glass and foundry industries have similar productive characteristics mainly in the processes of hot areas (casting of material). The knowledge of operators is important for a dynamic development of technology and good practices. The glass segment specifically has a strong dependency on worker tacit knowledge [2].

Studies in the recent literature consider the knowledge sharing influence on organizational [8] and operators'/workers' performance [22]. Other researches are conducted to identify factors of knowledge contribution in technology contexts [11, 16] and capture of lessons learned (past solutions and expert knowledge) during product design [4, 5, 7]. Researches in the segment are also to establish frameworks and practices to assist managers or to analyze its interaction on knowledge sharing [11].

In this work, the concept introduced by Nonaka [21] for the knowledge conversion process is considered. It acknowledges the importance of a tacit knowledge and focuses on the various processes of conversion of such knowledge into explicit and other tacit knowledge and vice versa. The four basic patterns of knowledge conversion, called SECI process, refer to: socialization (experiences exchanged between people), externalization (registration and formal availability of knowledge for other people), combination (content explicitly available generating new knowledge) and internalization (acquisition of knowledge by means already formalized and recorded).

80.3 Knowledge Management Assessment

The maturity in KM starts strongly based on technology, being for companies a mean to identify and manage data and information. Subsequently, it goes through stages of dissemination of KM by the company and exploration of the knowledge and the developed management system, where it is also necessary for the commitment of the top managers. However, the social or sociocultural aspect existent in organizations with knowledge-based environments is also strongly studied, not only considering KM as a process of generation and exchange of data or information, but also as a social process of learning. Personal involvement in a knowledge-based culture is stimulated by the social engagement of individuals, since socialization allows an openness to learning through continuous interaction that promotes the exchange of experiences with others and the direct observation of practices and skills of the experts in the group. This social influence has a direct impact on the development of a communication system, on the behavior and on the individual learning intention, providing a sharing and acquisition of tacit knowledge [10].

Considering the growth of knowledge economy, the evaluation of KM performance in recent years has become increasingly important, since it promotes strategic organizational learning and generates the capabilities required to meet customer expectations. It is necessary for organizations to be able to assess knowledge [9], and the actions of "measuring the value of KM" and "evaluating KM performance" are of great importance to managers and became also an important agenda among researchers and practitioners [3]. Even considering such importance, KM assessment remains as one of the least developed aspects of KM [12].

Knowledge management performance evaluation is often defined as actions, processes or systems for assessing, controlling and monitoring the status of implementation of KM [20]. The main objective of performance measurement is to improve KM effectiveness, efficiency and adaptability in order to add more value to the overall performance of an organization [12, 15]. The KM performance measurement also enables the organization to evaluate, control and improve its knowledge processes, which will ultimately lead to organizational improvements [24]. The evaluation approach aims to (1) review the implemented KM mechanisms and routines, as well as the achieved performance, and (2) predict the performance evolution of KM drivers and result in a future period in order to facilitate the strategic planning.

Lin et al. [14] considered the KM performance assessment, a model with the inclusion of four levels of evaluation, including the levels of knowledge creation, knowledge transfer, knowledge dissemination and knowledge accumulation, also considering factors of performance indication for each one of the four determined levels. Lee et al. [13] also suggested the knowledge management performance index (KMPI) considering the levels of knowledge creation and accumulation, but including the terms of knowledge sharing, knowledge utilization and knowledge internalization as components used to evaluate KM.

Wong et al. [24] reinforce a concept of KM performance measures, defined as performance variables, which are equivalent to metrics for key attributes and are considered important elements in KM evaluation, categorized into three main themes: knowledge resources, KM processes and the factors that affect KM. The categorization of KM measures is also related to qualitative evaluation, which assess the human aspects, such as culture, behavior, practice, perception and experience, or quantitative evaluation, which assess the tangible aspects, such as the number of knowledge workers and the number of research and development projects [12].

Different research approaches relating KM performance assessment are also observed in the literature review. Ingvaldsen [10] used the patterns of socialization, externalization, internalization and combination as the dimensions of the category or process of creation of knowledge. In addition, using a Bayesian belief network approach, a framework model for assessing the reliability of KM was proposed, which could help organizations to evaluate their ability to implement KM successfully by identifying key reliability variables. In Appendix A, it is possible to verify the main factors evaluated in KM and identified in the literature. According to Mohamed et al. [18], an analysis of knowledge may include the determination of the knowledge gap, which represents the difference between the knowledge needed and the knowledge available for employment, including the necessary skills for the appropriate knowledge use. Nakano et al. [19] understand that it is important to assess factors related to production, work and knowledge in an integrated way, and Mitri [17] relates tacit assessment depending on intuition, judgment and feeling.

This work aims to assess the interviewees' perception about KM factors, to define which are important and relevant to the KM performance.

80.4 Research Method

The methodology applied was based on a comprehensive literature review about operation management, knowledge sharing and knowledge management assessment. A review of works relating these topics to the glass and foundry segments was also realized.

Guided by Nakano et al. [19], we grounded the literature background using the terms "knowledge management" and "knowledge sharing" with topics: (a) "glass" and (b) "foundry" on topics. We analyzed 15 papers selected by relevance from ISI Web of Science (period of 1997–2018).

The field research work was conducted in the Brazilian glass sector, and the data collecting procedure used was a survey applied to 110 employees selected from the hot glass production line in a non-probabilistic sample. An exploratory data analysis was performed to capture the employees' perception about the studied knowledge sharing factors obtained from one first approach in a glass company. The data is finally evaluated in a qualitative way. Figure 80.1 presents the methodological sequence adopted in this work.

The applied questionnaire considered two questions developed to capture the workers' perception about the importance for Nonaka's factors of knowledge conversion (SECI). For this purpose, three factors were compared in pairs. The first question aimed to compare the act of "conversation between operators" (socialization) and the "registration in the work instruction" (externalization). The purpose of the second question was to compare the act of "registration in the work instruction" (externalization) and the "study of work instruction" (internalization). For effects of our analysis, the pattern of conversion is not studied.

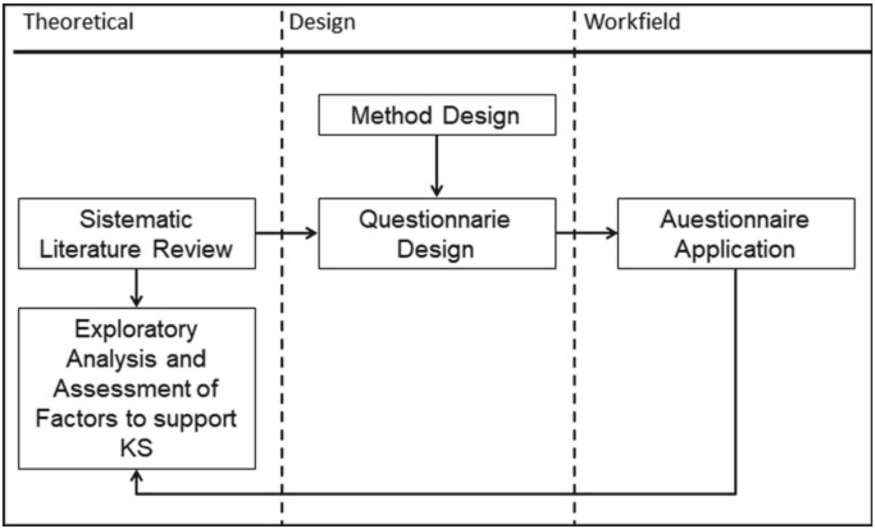

Fig. 80.1 Methodological sequence (search: authors)

80.5 Results and Discussion

As the results of this research work, Fig. 80.2 presents the percentages of the employees obtained from their perceptions regarded as different factors and considering the question: What is more important to establish the KS among shop floor workers?

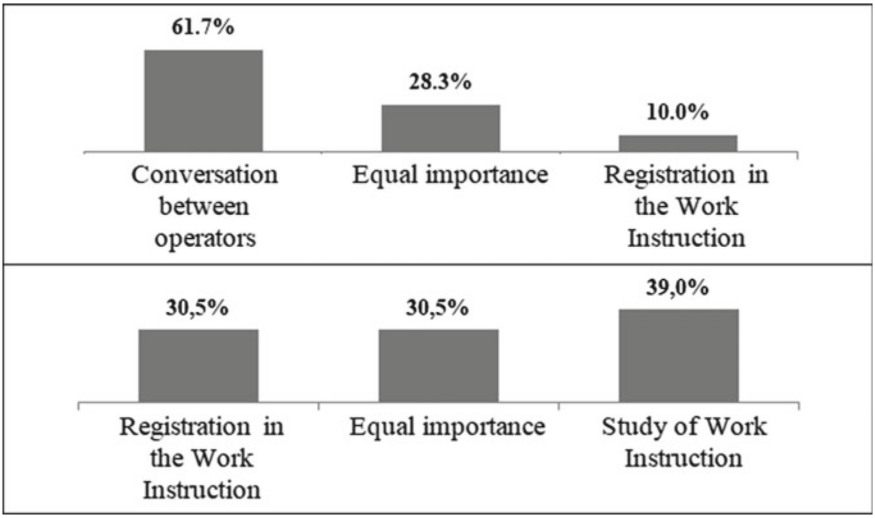

Fig. 80.2 Employees' perception for factor comparison (search: authors)

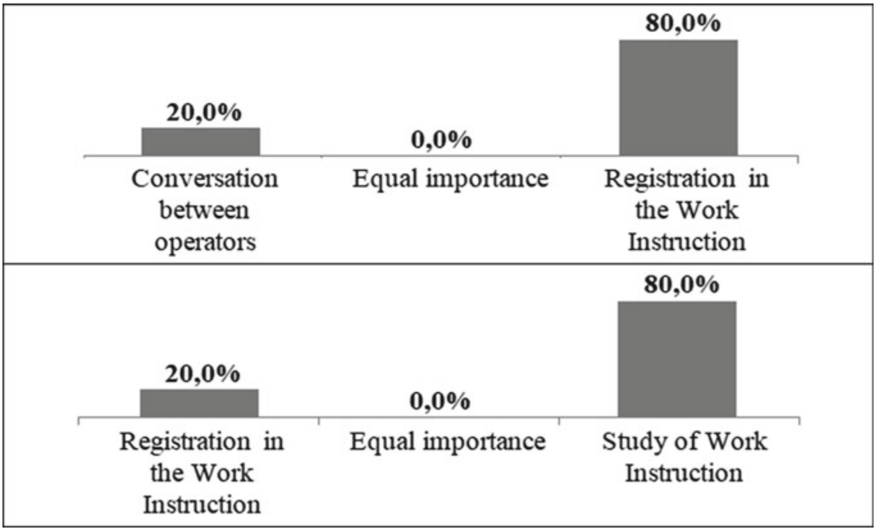

Fig. 80.3 Managers' perception for factor comparison (search: authors)

The results presented in Fig. 80.2 show that, in accordance with the employees' perceptions, the "conversation among the operators" and the "study of work instruction," for the majority of them, are more important than "registration in the work instruction" when these dimensions of knowledge conversion are compared in pairs.

For the same research question, Fig. 80.3 presents the percentages regarded as the managers' perceptions.

Considering the results of Fig. 80.3, in accordance with the managers' perceptions, the "registration in the work instruction" is considered more important when comparing with "conversation among the operators," but it is not highly relevant when compared with "study of work instruction," which is considered 80% more important.

80.6 Conclusion

The deep study about KS has gained importance in the academic field, but studies focused on the glass sector are still rare.

This study was conducted to analyze how the KS is perceived by the operators having as the field a Brazilian glass enterprise.

A survey had its content designed by the researchers, and it was applied and, as the results, was observed that: "Conversation among the operators" and "study of the work instruction" were more important factors of knowledge conversion for the KS success in the employees' perceptions. "Registration in the work instruction" and "study of work instruction" were more important in the managers' perceptions.

The pattern of socialization (conversation among the operators) was identified in a more relevant level of importance, but deeply studies are required in order to better understand the relation and influence of other factors on it, as well as to evaluate its influence on the production performance.

As the limitation of this work, it pointed the few numbers of companies interviewed in order to support a most robust conclusion.

In order to assure the precision of the results obtained from this research, it is recommended to amplify the number of glass companies and the application of multivariable data analysis method as, for example, analytic hierarchy process (AHP).

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Chapter 81
Patent Analysis and Field Theory: A Study of the Wind Power Sector

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Abstract This paper aims to analyze the strategic action field involving companies which stand out in patent filing in the wind energy sector. Based on the information on patents and the market, the field was classified, identifying the actors, the process of mobilization for the emergence of the field and governmental participation.

Keywords Wind energy · Field theory · Patent analysis

81.1 Introduction

The technological development of the wind energy sector led to an increase in the use of this energy source, justifying the need to carry out research to improve sector's performance and the search for innovations in this area. Success, from the point of view of innovation and business, depends to a large extent on aspects such as the structure of the workforce, corporate strategy, alliances with other companies or with universities and, above all, the organization of the company [1].

Another way of explaining the search for technological resources prominence is the structure of the field in which the companies of the sector are inserted. Fligstein and McAdam [2] suggested the strategic action field, which states that it is a company's ability to take the perspective of other actors in the field that induces collaboration between the parties, i.e., the strategic actions of some actors (firms) [3].

In this context, actors' role in the field is to induce the behavior of other actors, increasing competition between parties in terms of financial, social, cultural, technological, legal, organizational and symbolic resources.

Given this theoretical standpoint, and considering the wind energy generation sector as a strategic field of action and the need to understand the structure and

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actors of the field in terms of technological resources (patents), the research has the following research question: How does the theory of strategic fields of action can explain the results of the patent analysis of the wind energy generation sector? To answer the research question, this paper aims to analyze the strategic field of action that involves companies that excel in patent filing in the wind energy generation sector.

81.2 Field Theory

Field theory is used in economics studies in the contemporary economic-organizational sociology. According to Swedberg [4], there are two fundamental approaches that apply the fields concept in different ways. Bordieu [3] considers the fields to be a network of objective relations between positions. The theory of strategic action fields, recently envisioned by Fligstein and McAdam [2], who affirm that it is enough to understand how field actors themselves interpret their positions, intersubjectively determining who are the incumbent and the challenging actors [5].

From the perspective of the strategic action fields, markets can be considered with a social space composed by a set of firms that interact among themselves and based on a set of institutions that reflect the history of the society in which they are rooted on and a determined distribution of power among the actors [6].

Fligstein and McAdam [2] present three ideal fields states of the: (a) emerging fields, (b) stable fields or (c) fields in crisis. (a) are poorly institutionalized spaces, in which the meanings, identities and ways of the organization are fluid and under dispute. The authors propose that these social spaces arise throughout the processes of mobilization, where they elaborate new lines of action and plan their first contours. Additionally, the emerging field has some level of facilitation from state fields; (b) in this field, the determined arrangements become institutionalized and are given by the actors. Challengers agree with the fields' logic, but they adhere to a cautious stance, partially adopting the institutions, and although they are reproduced in a systematic way, they are constantly subjects of incremental changes; (c) most of the times when the strategic action fields are in a crisis state, this is due to exogenous conflicts that produce moments of contention, which may or may not result in ruptures with the prevailing structures.

81.3 Wind Energy Sector

Global experience shows that the use of wind energy has been motivated and encouraged by political, economic and environmental issues. The need for diversification of the energy matrix, together with a need for cleaner energy generation, gives wind-generated energy an important development opportunity [7].

The growth of the wind energy market until 2008 was driven by Europe, in countries such as Denmark and, later on, in Germany and Spain that achieved increases of its installed capacity. More recently, Italy, France and Portugal have also made significant increases in capacity. However, since 2008, new capacity expansions have occurred more intensively in the USA and China [8].

Among the countries with the largest installed capacity in 2013 are six with more than 10,000 MW of installed capacity: China (91,412 MW), USA (61,091 MW), Germany (34,250 MW), Spain (22,959 MW) MW), India (20,150 MW) and the UK (10,531 MW), which account for approximately 75% of the installed capacity worldwide.

By the end of 2013, the number of countries with more than 1,000 MW of installed capacity was 24: including 16 in Europe; four in Asia Pacific (China, India, Japan and Australia); three in North America (Canada, Mexico, USA) and one in Latin America (Brazil).

Most wind turbine manufacturers are concentrated in six countries (the USA, Denmark, Germany, Spain, India and China), with components supplied from a wide range of countries.

Denmark, the pioneer country, held approximately half of the global market in 2005 [9]. In addition to Denmark, manufacturing companies from Spain and Germany make Europe a major exporter of wind technology. In 2010, net exports were EUR 5.7 billion [10]. The USA and India are also among the countries that export the technology.

81.4 Patent Analysis

According to Amadei and Torkomian [11], the patent is an industrial title of the invention or a utility model. A prize awarded by the state as a reward to the inventor. Patent registration guarantees to the inventors a degree of security in the negotiations between them and the party interested in buying certain technology so that it can be applied in an industrial sector.

Patents are deposited in the institutes responsible for their protection; it is estimated that 70% of the information contained in patent documents are not available from any other source of information [12]. For legal reasons, patents are systematically registered by government agencies. The documents are processed, classified and organized providing a source of information on industrial innovations.

Patent analysis is the use of statistical methods to convert patent information into useful knowledge, and it can be applied at different levels, i.e., country, industry, enterprise and in the technological field [13].

There are several analyses that can be carried out through patents, especially with the use of advanced data mining tools. The first-level analysis and second-level analysis are the two tools used in this research. They are briefly explained in the following paragraphs.

The first-level analysis corresponds to the first results that are sought in a prospective analysis, looking to answer three main questions: when, where and who. The "when" refers to when the technology is patented, how is the historical trend, that is, the patented behavior of this technology over time. The "where" refers to the countries that dominate it, i.e., the patent deposit countries. Finally, the "who" seeks to identify the people or companies holding the patents.

The second-level analysis involves the results found in the first analysis, combined with other parameters to deepen the understanding of the technological development of the object of the study. For this study, only the first-level analysis was performed.

81.5 Research Method

To reach the objectives of this research, it was divided into three stages: theoretical background, patent analysis and analysis of the strategic action field. The stage 1—bibliographic references were consulted on the topics of this paper: strategic action field theory, technological mapping and the wind energy generation sector; the stage 2—the patent analysis was carried out focusing on the generation of wind energy. To do so, the World Intellectual Property Organization (WIPO) database was selected, since it brings together the databases of the world's leading patent offices, and holds data deposited via the Patent Cooperation Treaty (PCT).

To carry out this search, it was necessary to define the search terms—the keywords for searching in the database were defined, namely, "wind power" or "wind energy". The nomenclatures used in the search were selected from stage 1; data processing—Excel software and its PivotTable tool were used to organize the data and later on to perform the analysis; and the first-level analysis—the first result sought in a prospective analysis is to answer three main questions: when, where and who [14].

The stage 3—an analysis of the wind energy generation market was carried out as, considering it as a strategic action field.

81.6 Patent Analysis

For the first-level analysis, the number of patents deposited in wind technology shows a trend of exponential growth in the period going from 2003 to 2012, as can be seen in Fig. 81.1. It was observed that the data for 2011 and 2012 were incomplete, since the time interval between the filing date, publication date and data entry at the WIPO base generates uncertainty in the results of the last two years of the study, but the trend line suggests growth toward a standard.

In total, the data show eleven countries with patent wind technology deposited, excluding patents filed in the Patent Cooperation Treaty (PCT), the European Patent Office (EPO), the Eurasian Patent Organization (EAPO) and in the African Regional Organization for Intellectual Property (ARIPO). Overall, the United States (USA)

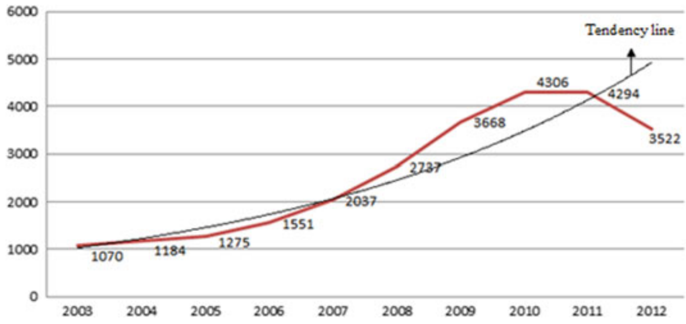

Fig. 81.1 Number of patents deposited per year

lead with 8,686 patents deposited in the study period, followed by China with 4,990 patents, Republic of Korea (2,107), Japan (1,420) and Canada (1,118), Russian Federation (340), South Africa (50), Mexico (46), Singapore (22), Spain (17) and Israel (15) patents.

Overall, the General Electric Company—GE leads with 575 patents deposited in the study period, followed by Mitsubishi (560), Wobben Aloys (341), Siemens AG (253), Vestas Wind Systems (248), Hitachi LTD. (139), Samsung (111), Hyundai Industries (74), Repower Systems AG (72) and NTN Corp. (69).

With additional information such as country of origin and total quantity of patents deposited by each company, Table 81.1 presents the top ten depositors with the largest number of patents on wind energy in the period from 2003 to 2012, followed by number of patents deposited in the period, the percentage of patents related to wind technology and their country of origin.

The US company GE and Japan's Mitsubishi have a low percentage of patents related to the technology studied when compared to other patents deposited by them.

Table 81.1 Leading wind energy technology depositors

Primary applicant	No. of patents	Representativeness in the company portfolio (%)	Country
General Electric Company	575	1.29	USA
Mitsubishi	560	0.43	Japan
Wobben Aloys	341	27.19	Germany
Siemens AG	253	0.31	Germany
Vestas Wind Systems A/S	248	11.16	Denmark
Hitachi LTD.	139	0.09	Japan
Samsung	111	0.04	Republic of Korea
Hyundai Heavy Industries	74	0.15	Republic of Korea
Repower Systems AG	72	12.44	Germany
NTN Corp.	69	0.54	Japan

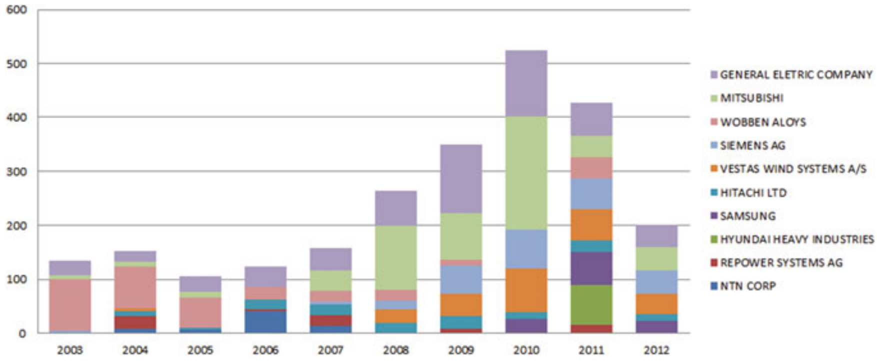

Fig. 81.2 Historical evolution of the main patent depositors in wind energy technology

On the other hand, the German companies Wobben Aloys and Repower Systems and the Danish Vestas Wind Systems have the highest representativity within their portfolio of patents when compared to the other companies.

When the geographical origin of the leading depositors is observed, there is a strong predominance of Asian countries (three Japanese and two South Korean depositors). Germany also stands out with three depositors and the other two leaders are the USA and Denmark.

When analyzing the insertion of the main depositors in wind energy technology during the ten years of the study, as shown in Fig. 81.2, it is observed that some organizations have deposited patents in the area studied throughout the period as GE and Mitsubishi, while others have gotten more involved with the theme in the last five years, such as Vestas Wind Systems and Siemens.

It is interesting to note that the German company Wobben Aloys, although with 27% of its patent activity focused on wind technologies, concentrated few efforts between the years 2008 and 2012.

81.6.1 Strategic Action Field Analysis

According to Candido and Toyama [6], the starting point for the analysis of markets as a strategic action field is to identify the state in which this space is located. Whether markets are emerging, stable, in crisis or in some intermediate state is not a trivial task, and each case has its specificities.

From the data of the technological resources provided by the patents' analysis and data of the wind energy generation sector, it was possible to observe that the field is classified as emerging, presenting characteristics of competition in technological and financial resources.

Technological dynamics is a fundamental aspect for understanding the emergence of new markets. It seems quite obvious that the emergence of new products and services, as an outcome of innovative technologies, is powerful vectors for structuring new markets. Entrepreneurs who succeed in transforming these innovations into products and services tend to enjoy periods of monopoly advantage, which in some cases are guaranteed by the state through patents protection [2].

The distribution of resources among the firms involved decisively influences the form of structuring, and a greater asymmetry of power among the agents involved generally implies more hierarchical forms of organization [6].

Based on this to identify the actors of the field, we looked for the ones who detained the process of generation of science and technology, i.e., more patents. Thus, considering the ten largest world patent depositors in the period studied, one can identify as dominant actors: GE, Mitsubishi and Wobben Aloys. The incumbent companies: Siemens, Vestas Wind Systems, Hitachi LTD., Samsung, Hyundai Heavy Industries, Repower Systems and NTN Corp.

Despite the field leaders, GE and Mitsubishi, these companies have diversified market operations, as seen in the analysis of the representativeness of wind energy patent deposits in relation to their portfolio of inventions. On the other hand, Wobben Aloys dedicates greater efforts in its technological resources for wind energy generation, being a leader also in the market with equipment installed all over the world.

Mechanisms for shaping the threat/crisis process consist in the collective assignment of threats or opportunities, organizational appropriation, innovative action (engaging in innovative actions for advocating stakeholder support, when one actor has innovative actions, the other actors follow suit, to keep competitive).

81.6.1.1 Mobilization Process

It can be observed that the emergence of the field was based on the functional characteristics of other markets that are considered "to work well." This is evidenced by the performance of the field leaders in distinct markets and prior to the commercial generation of wind energy.

The environmental movements in the world were also influential factors in the creation of the studied field. According to Behrends [15], in the World Summit on Sustainable Development held in 2002, an agreement was made in relation to the energy generated, with a suggestion to increase the use of renewable sources.

81.6.1.2 Facilitation of State Fields

States play a key role in stabilizing markets. Regarding internal market governance units, governments interfere in markets to create specific rules and impose other, more general definitions [6].

The economic policy of wind energy has played an important role in the development of the industry and contributed to its current success. As the industry and the wind energy technology have become better established, many countries started to include them in their policies incentives to increase the installed capacity of this renewable source.

Thus, it becomes necessary to establish incentives and support mechanisms for the deployment of wind energy. At present, government support and incentives for renewable energy producers may vary from country to country. According to the International Energy Agency—IEA [16], common incentive mechanisms include fixed rates, premiums, production tax credits, quotas (with or without green certificates), capital transfers and loan guarantees. Most of these mechanisms seek to establish a return per megawatt-hour of electricity that is competitive with other sources of energy to attract private investment.

It is important to emphasize that government policies must have the flexibility to adjust the subsidy level, that is, to make the cost of wind energy similar to that of conventional technologies. However, it is common for these adjustments to apply only to new installations.

Critical barriers can prevent or delay implementation, tending to change as the market develops the technology. Politicians must take a proactive stance, by being quick to adjust priorities. Additionally, support mechanisms should aim to reduce project risks, while encouraging technology to reduce costs (IEA 2011).

Dutra [7] and GWEC [8] put together in their publications an overview of the incentives for wind energy in several countries. In this paper, we focused on the Brazilian wind energy incentive policies and the ones of the countries with the highest installed capacity in the world: China, USA, Germany. A summary of these policies is shown in Table 81.2.

Public funding by governmental or semi-governmental agencies has been instrumental in the development of major wind energy projects in the world. Parties are exploring alternative forms of funding, such as project obligations. European experience shows that many different regulatory regimes work with the general price level compatible with current energy installation costs in order to cover the relatively long development and construction process.

81.7 Conclusion

The research integrated the field theory and wind energy themes, through patent analysis of wind energy generation, contributing to the analysis of the market as a strategic action field. Based on the results of the analysis of the field in relation to the technological resource, the dominant and incumbent actors were classified and identified, as well as the process of mobilization for the emergence of the field and the facilitation of state fields in this market, based on the technological resource.

In this way, the field studied can be classified as emerging in terms of technological resources, leading companies are the GE, Mitsubishi and Wobben Aloys. The incumbent companies: Siemens, Vestas Wind Systems, Hitachi LTD., Samsung, Hyundai Heavy Industries, Repower Systems and NTN Corp. The emergence of the

Table 81.2 Main policies fostering wind energy

Country/incentive aspect		Political incentives
China	Legislation	All new projects must first be included in the Project Development Plan announced by the National Energy Agency (NEA) and get approval before starting the construction stages
	Fiscal	Standard Portfolio Renewable Energy—application of a tax rate according to wind quality and solar resource of the region
USA	Financing in R&D	Wind Program—research focused on increasing the production and reliability of components such as gearboxes, blades, generators and towers
	Fiscal	(PTC) Production Tax Credit—provides a credit based on the production of electricity by wind sources, reducing the income tax and fostering investments in new wind farms (LBNL 2010) (ITC) Investment Tax Credit—credit provided for the installation of wind farms, allowing 30% of the investment to be repaid by means of a discount on income tax
	Compulsory renewable energy purchase programs	(RPS) Renewable Portfolio Standards—Law that compels energy producers to have a percentage of their energy coming from renewable sources
	Incentives for the voluntary purchase of wind power generation	Green Pricing—the consumer pays a fixed bonus on the electricity rate in order to finance the additional cost of production by renewable energy source
Germany	R&D	Research, development and demonstration programs (RD&D)
	Law of Energy by Renewable Sources (Erneuerbare-Energien-Gesetz—EEG)	Fees feed-in—paid to operators of plants from renewable sources and ensuring access to the grid for this production. Implementation of a national equalization scheme. Each transmitter in the grid sends the same percentage of energy from renewable sources as the total electricity it transmits to the distributors connected to its network

field was driven by social movements and state incentives, which made companies operating in other fields part of the emerging field of wind power generation.

As a contribution to the academy, this article brings an analysis that has been little studied in the literature and relatively recent theories. Thus, it is expected that this research will be expanded to further study the field and neighboring fields, possibly allowing to make relationships among the results in terms of fields' structure and behavior.

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Chapter 82
Investigation of the Productive Process in the Saline Industry: Case Study Based on Economic Viability

Dellano Jatobá Bezerra Tinoco and Samira Yusef de Araújo Falani

Abstract This paper will investigate how the production process is organized in a Salina. Based on a case study, the economic viability of the alteration of the current process will be analyzed and an alternative system will be proposed for the company studied, using net present value method.

Keywords Productive process · Economic viability · Operations management

82.1 Introduction

There are notable changes, especially in manufacturing, due to the globalization process, the threat of new competitors, the constant search for quality and the reduction of production costs to increase profit and strengthen the competitive position of companies. The means to establish this strengthening vary according to the characteristics of each company, the segment in which they operate, as well as the products they market [1].

The productive capacity of a company is given by the maximum possible production to be obtained under normal working conditions, and in a certain period [2] it is understood that the productivity of a company is directly related to its capacity and should be correctly measured, analyzed, and improved.

The present paper aims to show the economic feasibility in relation to the alteration of the productive process, including flowchart, machines, and equipment, thus providing the reduction of costs with the resources currently used adapting to the new production process proposed in this study. For the study to be carried out, it was necessary to collect data from a company that produces sea salt, located in Galinhos, Rio Grande do Norte, using the net present value (NPV) as a support tool for the analysis.

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82.2 Economic Viability

Economic projects are generally evaluated using four alternative popular methods: the net present value (NPV), internal rate of return (IRR), payback period (PP), and modified internal rate of return (MIRR). But in this paper, we will show the theory about the NPV, IRR, and PP, but we will apply NPV.

82.2.1 Net Present Value (NPV)

The concept of NPV like is an important financial index that plays a key role in decision making of long-term investment projects. A positive, higher NPV indicates that the net profits are higher, so the investment may have favorable economic performance, or the investment is considered as economically feasible [3].

82.2.2 Internal Rate of Return (IRR)

Basavaraj et al. [3] also show us that the IRR refers to the average earned capacity of an investment/project during its economic life. It equals the discount rate when NPV is set to zero. In general, the IRR should be greater than the discount rate for a project for economic feasibility.

82.2.3 Payback Period (PP)

Payback is the time when the net present value equals zero, so it is the exact time to know when the investment is recovered. In situations where the discounted return period is greater than the time horizon defined by the company to recover its investment, the project should be rejected, even if it has a net present value and a favorable internal rate of return, Samanez [4].

Boliari [5] presented formulas and pros and cons of methods in Tables 82.1 and 82.2, respectively.

Table 82.1 Formula of the methods

The method	Formulation
Net present value (NPV)	$\mathrm{NPV} = \sum_{t=0}^{N} 0 \frac{\mathrm{CF}^t}{(1+R)^t}$
Internal rate of return (IRR)	$\sum_{t=0}^{N} 0 \frac{\mathrm{CF}_t}{(1+\mathrm{IRR})^t} = 0$
Payback period (discounted) (PP)	$\mathrm{Payback} = A + (B/C)$

Table 82.2 Pros and cons of methods

The method	Pros and cons
Net present value (NPV)	NPV's reinvestment rate is correct, and there are no multiple solution possibilities. Well understood by industry and the choice of academics
Internal rate of return (IRR)	IRR assumes project specific IRR as the reinvestment rate creating overestimation. IRR may produce multiple solutions, confusing the user
Payback period (discounted) (PP)	Ignores the time value of money and cash flows generated beyond the recovery period, causing gross underestimation of the future cash flows. It has arbitrarily set thresholds

82.3 Saline Industry

Sodium chloride, or salt, is one of the most abundant substances in nature and offers more than 14,000 applications in their most frequent forms, most of them in the chemical industry. Salt is produced in the industry of chlorine, caustic soda, hydrochloric acid, glass, aluminum, plastics, textiles, rubber, hydrogen and cellulose, among other items, besides being used in food and beverages.

According to the National Department of Mineral Production—DNPM, Mineral Summary of 2017 [6], world production of all types of salt for the year 2016 was estimated at around 255 million tons, representing a decrease of about 6% in relation to the previous year. China accounted for 22.74% of output and continued to lead, followed by the USA (16.46%). In Brazil, salt production was estimated at 7.5 million tons, of these 6 million tons were salt by solar evaporation.

In Brazil, the main producing states are Rio Grande do Norte (RN)—in the so-called Pólo Costa Branca—and Rio de Janeiro, in the so-called Lakes Region. And, according to SIESAL—Union of Salt Extraction Industries the State of RN, the state produces about 5 million tons of salt per year, which represents more than 95% of the national production of sea salt.

As salt-producing companies move a huge structure in favor of their product, such as hectares of productive land, large numbers of employees, a large number of machinery, among others, the management of their productive processes linked to economic viability projects, fostering optimization of processes, can support and standardize tools that support and manage their production chain in order to promote an environment in which collaborative decision making is easier, and minimize the risk of loss in processes in terms of business impacts. Thus, it is necessary to make sure that human resources are focused on control and efficiency, prove the value of economic viability to the respective stakeholders, and prove that success does not happen only today, but is more likely with future management initiatives, among many other benefits.

82.4 Methodology

The present research is considered of exploratory character, since its main objective is to develop, clarify concepts and ideas. According to Zikmund [7], exploratory studies are usually useful for diagnosing situations, exploring alternatives, or discovering new ideas.

Characterized as to your nature, as applied, as it aims to generate knowledge for a particular application, thus obtaining a solution to the problem raised. With a quantitative approach, where it seeks the analysis of the data to achieve a viable result, and procedures with case studies, where the problem was identified, analyzed, and solved.

82.5 Company Characterization

The company studied was founded in 1996, and in 2003 became the largest private company in the saline industry worldwide, and today, it is part of one of the most important groups in the world. Its production unit is located in Rio Grande do Norte, employs around 160 employees, and produces around 500,000 tons of salt per year.

The company studied produces the following types of salt: industrial salt, coarse salt, ground salt, and crushed salt (with or without added iodine, industrial, and human consumption). Salt Livestock: Iodized ground salt (animal consumption).

To obtain the product, the production of the salt begins in a "sea arm," where salt water is collected and pumped to the evaporator tanks. Evaporation is a natural process, caused by the sun and wind, gradually increasing the concentration of the salts present in the water, where the extremely concentrated water is transferred, by gravity, to the tanks to the point where the brine is almost saturated of sodium chloride.

From this phase, the crystallization of the salt begins, precipitating the salt and almost total evaporation of the water. The crystallized salt is harvested through a combine harvester and transferred to the trucks, where it will be transported to the area where the funnel is located. At that point, the trucks are waiting, in turn, to discharge the crystallized salt into the funnel. Immediately, after passing through the funnel, the salt enters the washer by means of a conveyor belt for the washing operation. When leaving the washer, the product passes again through a conveyor belt, where the insulation is manually performed until the drying yard where it is stored.

The salt after the washing process, the salt "curing" that is the rest of this in the storage yard takes place for approximately 45 days so that its chemical elements normalize for the processing and addition of iodine. In this way, the salt is packed and is ready for consumption.

Annually, the company manages about 50 projects in all sectors without a formal methodology of economic viability projects. Some projects develop only with subjective arguments of old employees, without at least using economic viability techniques. All the information flow of their projects is registered in excel and by email. Given this scenario, the company focuses its efforts on cost reduction, which causes it to develop improvement projects more frequently, formalizing the need to evaluate and justify for the top management of the company the need for the company's evolution in projects such as this paper will demonstrate.

82.6 Data Collection

Data collection began by mapping the flowchart and surveying the structure involved in the production process in question, the salt harvest. Thus, we have in Figs. 82.1 and 82.2, the flowchart and equipment, respectively, involved in the current productive process of the company studied.

In Figs. 82.3 and 82.4, follows the description of the flow chart and the equipment, respectively, involved in the productive process proposed for the company studied. Read in Fig. 82.3 mechanical shovel—MS.

In the second table, we have the data collected in the current productive system used by the company studied. So, called as "without project" the current productive process of the company and denominated "with project" the productive process proposed (Table 82.3).

Table 82.4 shows the data collected in the proposed production system.

In Table 82.5, we have the calculation of the net present value—NPV, for a period of 5 years, considering an annual readjustment of 1.6%.

In Tables 82.6 and 82.7, we have the cumulative sum of NPV in the subsequent 5 years.

In Table 82.8, we have the total of the 5 years of the NPV with and without the project and its respective difference.

Fig. 82.1 Flowchart of the productive process of the salt harvest

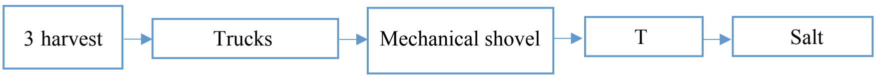

Fig. 82.2 Equipment of the productive process of the salt harvest

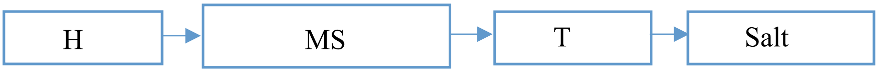

Fig. 82.3 Proposed flowchart of the productive process of the salt harvest

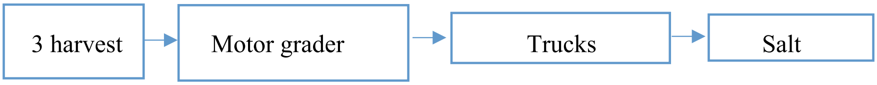

Fig. 82.4 Equipment proposed to the new production process of the salt harvest

Table 82.3 Data of the productive process without project

Without project	Data	R$/day	R$/month	R$/year
Tons annual	587.500	–	–	–
Internal transportation	–	2.175,93	65.277,78	587.500,00
External transportation	–	3.699,07	110.972,22	998.750,00
Rent MS extra	1	672,00	20.160,00	181.440,00
Rent motor grader	0	0,00	0,00	0,00
Tractor	Employee salary	35,15	1.054,40	13.050,00
Fuel	Equipments	1.111,04	33.331,20	299.980,80
Extra hour	–	224,47	6.734,00	60.606,00
Total	–	7.917,65	237.529,60	2.141.326,80

Table 82.4 Data of the productive process with project

With project	Data	R$/day	R$/month	R$/year
Tons annual	587.500			
Internal transportation	–	0,00	0,00	0,00
External transportation	–	3.699,07	110.972,22	998.750,00
Rent MS extra	1	480,00	14.400,00	129.600,00
Rent motor grader	1	800,00	24.000,00	216.000,00
Tractor	Employee salary	0,00	0,00	0,00
Fuel	Equipments	843,20	25.296,00	227.664,00
Extra hour	–	0,00	0,00	0,00
Total		5.822,27	174.668,22	1.572.014,00

82.7 Analysis of Data

Firstly, the current productive process of the studied company was analyzed critically and observed especially its bottlenecks. Given the mapped production process and the resources mapped to support this operation, it was necessary to simulate some

Table 82.5 Calculation of the NPV of the productive process with and without design

	Without project			With project	
	Current cost	R$ 237.529,60		Current cost	R$ 174.668,22
	Average annual readjustment			1.6%	
	Month	NPV		Month	NPV
0	Apr/18	R$ 237.529,60	0	Apr/18	R$ 174.668,22
1	May/18	R$ 233.788,98	1	May/18	R$ 171.917,54
2	Jun/18	R$ 230.107,26	2	Jun/18	R$ 169.210,18
3	Jul/18	R$ 226.483,52	3	Jul/18	R$ 166.545,45
4	Aug/18	R$ 222.916,85	4	Aug/18	R$ 163.922,69
5	Sep/18	R$ 219.406,35	5	Sep/18	R$ 161.341,23
6	Oct/18	R$ 215.951,13	6	Oct/18	R$ 158.800,42
7	Nov/18	R$ 212.550,33	7	Nov/18	R$ 156.299,63
8	Dec/18	R$ 209.203,08	8	Dec/18	R$ 153.838,22
9	Jan/19	R$ 205.908,54	9	Jan/19	R$ 151.415,57
10	Feb/19	R$ 202.665,89	10	Feb/19	R$ 149.031,07
11	Mar/19	R$ 199.474,30	11	Mar/19	R$ 146.684,12
12	Apr/19	R$ 196.332,97	12	Apr/19	R$ 144.374,14
13	May/19	R$ 193.241,11	13	May/19	R$ 142.100,53
14	Jun/19	R$ 190.197,95	14	Jun/19	R$ 139.862,73
15	Jul/19	R$ 187.202,70	15	Jul/19	R$ 137.660,16
16	Aug/19	R$ 184.254,63	16	Aug/19	R$ 135.492,29
17	Sep/19	R$ 181.352,98	17	Sep/19	R$ 133.358,55
18	Oct/19	R$ 178.497,03	18	Oct/19	R$ 131.258,42
19	Nov/19	R$ 175.686,05	19	Nov/19	R$ 129.191,35
20	Dec/19	R$ 172.919,34	20	Dec/19	R$ 127.156,84
21	Jan/20	R$ 170.196,20	21	Jan/20	R$ 125.154,37
22	Feb/20	R$ 167.515,95	22	Feb/20	R$ 123.183,44
23	Mar/20	R$ 164.877,90	23	Mar/20	R$ 121.243,54
24	Apr/20	R$ 162.281,40	24	Apr/20	R$ 119.334,20
25	May/20	R$ 159.725,79	25	May/20	R$ 117.454,92
26	Jun/20	R$ 157.210,42	26	Jun/20	R$ 115.605,23
27	Jul/20	R$ 154.734,67	27	Jul/20	R$ 113.784,68
28	Aug/20	R$ 152.297,90	28	Aug/20	R$ 111.992,79
29	Sep/20	R$ 149.899,51	29	Sep/20	R$ 110.229,13
30	Oct/20	R$ 147.538,89	30	Oct/20	R$ 108.493,24

(continued)

Table 82.5 (continued)

	Without project			With project	
	Current cost	R$ 237.529,60		Current cost	R$ 174.668,22
	Average annual readjustment			1.6%	
	Month	NPV		Month	NPV
31	Nov/20	R$ 145.215,44	31	Nov/20	R$ 106.784,68
32	Dec/20	R$ 142.928,58	32	Dec/20	R$ 105.103,03
33	Jan/21	R$ 140.677,74	33	Jan/21	R$ 103.447,87
34	Feb/21	R$ 138.462,34	34	Feb/21	R$ 101.818,77
35	Mar/21	R$ 136.281,83	35	Mar/21	R$ 100.215,32
36	Apr/21	R$ 134.135,66	36	Apr/21	R$ 98.637,13
37	May/21	R$ 132.023,29	37	May/21	R$ 97.083,79
38	Jun/21	R$ 129.944,18	38	Jun/21	R$ 95.554,91
39	Jul/21	R$ 127.897,82	39	Jul/21	R$ 94.050,11
40	Aug/21	R$ 125.883,68	40	Aug/21	R$ 92.569,00
41	Sep/21	R$ 123.901,26	41	Sep/21	R$ 91.111,22
42	Oct/21	R$ 121.950,06	42	Oct/21	R$ 89.676,40
43	Nov/21	R$ 120.029,58	43	Nov/21	R$ 88.264,17
44	Dec/21	R$ 118.139,35	44	dec/21	R$ 86.874,19
45	Jan/22	R$ 116.278,89	45	Jan/22	R$ 85.506,09
46	Fev/22	R$ 114.447,73	46	Fev/22	R$ 84.159,54
47	Mar/22	R$ 112.645,40	47	Mar/22	R$ 82.834,19
48	Apr/22	R$ 110.871,46	48	Apr/22	R$ 81.529,71
49	May/22	R$ 109.125,45	49	May/22	R$ 80.245,78
50	Jun/22	R$ 107.406,94	50	Jun/22	R$ 78.982,07
51	Jul/22	R$ 105.715,49	51	Jul/22	R$ 77.738,26
52	Aug/22	R$ 104.050,68	52	Aug/22	R$ 76.514,03
53	Sep/22	R$ 102.412,09	53	Sep/22	R$ 75.309,09
54	Oct/22	R$ 100.799,30	54	Oct/22	R$ 74.123,12
55	Nov/22	R$ 99.211,91	55	Nov/22	R$ 72.955,82
56	Dec/22	R$ 97.649,52	56	Dec/22	R$ 71.806,91
57	Jan/23	R$ 96.111,73	57	Jan/23	R$ 70.676,10
58	Feb/23	R$ 94.598,16	58	Feb/23	R$ 69.563,09
59	Mar/23	R$ 93.108,42	59	Mar/23	R$ 68.467,60

Table 82.6 Sum of the NPV of the productive process without the project

Year 0	Year 1	Year 2	Year 3	Year 4
R$ 2.615.985,84	R$ 2.162.274,84	R$ 1.787.254,50	R$ 1.477.276,89	R$ 1.221.061,13

Table 82.7 Sum of the NPV of the productive process with the project

Year 0	Year 1	Year 2	Year 3	Year 4
R$ 1.923.674,34	R$ 1.590.036,36	R$ 1.314.263,85	R$ 1.086.320,73	R$ 897.911,58

Table 82.8 Total sum of NPV of the productive process without and with the project

	Total NPV	Difference 5 years
Without project	R$ 9.263.853,20	R$ 2.451.646,34
With project	R$ 6.812.206,85	

scenarios from the point of view of the optimization of the productive process and in parallel, the optimization of the financial cost of the operation.

Considering the above and comparing Figs. 82.1 and 82.2 (flowchart and resources of the current productive process of the studied company) with Figs. 82.3 and 82.4 (flowchart and resources of the proposed production process), we already have a macro-view of the quantity reduction of operations and resources of the operation studied.

To justify the previous paragraph, we quantified the costs of the current operation in Table 82.3 and the costs with change of operation in Table 82.4. These data were analyzed from the point of view of the NPV in Table 82.5 and synthesized for a period of five years in Tables 82.6 and 82.7.

We finished the data analysis with Table 82.8, showing the financial difference of R$ 2,451,646.34 that we have between the current operation and the proposed transaction change.

82.8 Conclusions

The current economic viability is mainly equated with financial viability, where profitability is the goal.

In this study, it was noted the importance of economically evaluating alternatives to change the productive process of the company studied. It was considering the economic valuation method net present value to subsidize managers to accept the process change and thus reduce their costs with the operation. This made it possible to better base decision making on the economically viable investment alternative.

Although the study addresses only the net present value method, this deficiency was recognized in the existing literature and subsidized the study company to accept the change from its current productive process to that proposed in this paper.

Not only does the financial vision of the project become necessary, but also the view from the point of view of the optimization of production. This will be another article to be developed showing that the change of the productive process is feasible financially as well as from the point of view of the optimization of the productive process in gain of time, resources, and efficiency.

Thus, our analysis from the perspective of the future shows that the productive process of the studied company can be subsidized by other methods of economic feasibility to reinforce the financial result proposed in this paper, as shown in the methods IRR and PP in the theoretical reference.

We conclude, therefore, that it is necessary to develop or expand current methods to better consider other aspects when assessing the economic feasibility of changing the productive process of the company in question. This would help to find solutions to make top management decisions less vulnerable and better placed to face large-scale change processes.

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Chapter 83
Strategic Actions in Information Technology Investment: A Valuation of Amazon Using Real Options

Thaís Borges, Gabriela Caselli and Gláucia Fernandes

Abstract Managers of information technology investments need to take into account risks in their decision making. This paper develops a framework of strategic actions to the Amazon based on real options theory. We identify the components of value and provide the basis for valuing Amazon investments in terms of real option value.

Keywords IT investment · Uncertainty · Strategic actions · Amazon

83.1 Introduction

Every day new technologies are being created changing the way companies do business. That brings new tools and knowledge, opening new opportunities to companies to develop and expand. In order to maintain competitive advantages, corporations are highly investing in researches on information technology (IT), seeking to develop projects that could put them ahead of the competitors. According to Benaroch and Kauffman [1], however, a considerable proportion of IT projects are undertaken without a proper analysis of the associated investments.

Although IT help boost firm performance, issues of risk and uncertainty due to technical, organizational and environmental factors continue to frustrate efforts to produce meaningful cost–benefit analysis [2]. IT investments are often evaluated using standard discounted cash flow (DCF) techniques which fail to treat the uncertainties that characterize most IT projects. An approach that overcomes these shortcomings is the real options theory (ROT). An option is the right, but not the obligation, to buy or sell the underlying asset [3]. This approach helps managers to structure the project as a sequence of managerial decisions over time. In contrast with traditional NPV method, this method recognizes the ability of managers to delay, suspend, or abandon a project once it has started.

Amazon is probably the most relevant company that expanded its business by investing in IT. In the last year, Amazon stock showed an incredible growth by raising

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its value by 200%. Many investors do not believe that the current stock price reflects Amazon's value and that it is overrated. This article analyzes by using ROT whether Amazon investments have managerial options that could account for this difference in the company's valuation perspective. In fact, since the value of a company is the sum of the values of its projects, we analyze which options associated with IT projects may be the reason for the high stock value of Amazon (Brealey, Myers, Allen and Mohanty).

This article is organized as follows. After this introduction, Sect. 83.2 presents a literature review of real options and their use in IT companies. Section 83.3 presents the Amazon case, using traditional methods to evaluate the company. Section 83.4 introduces real options to be applied in the Amazon case as a way to add value to the company. The conclusions are presented in Sect. 83.5.

83.2 Literature Review

An option is the right to do something not having the obligation to execute it gaining benefits from future scenarios [4]. Options are essential for investments that have high uncertainty and many opportunities and risks [5]. According to Dixit and Pindyck [6], to make managerial decisions, it is important to analyze the risks and opportunities of a project using three factors. First, every investment is partially or completely irreversible, which means that the investment cannot be totally recovered. Second, every project is uncertain about the future and what is going to happen. It is possible to make projections but those are always based on probabilities. The last characteristic is about the project timing, it is possible to postpone it or not.

The option theory started with the study of Black and Scholes [17] applied to financial options. Later, the concept passed to be used in real investment projects, receiving the name of real option. An option can be a call or a put. A call is the option to buy, and a put is the option to sell, a security in a certain date in the future at a certain strike price by paying a premium for this right. In real option, a call is compared to an expansion option and a put to an abandonment option. In this case, the net present value is equivalent to the stock price in the future, the uncertainty of the success of the projects is the same as the variance of the stock price, the investment required to acquire the project would be the exercise price of the option, the time to decide to invest would be the expiration date, and the time value of the money can be compared to the risk-free rate of return [7].

In sum, the real options theory is an attempt to premeditate and treat the risks associated to a project, quantifying them based on how they can change the future of the project [8]. The real options can be divided as growth options, postponement options, and abandonment options. The first group can be branched following three different strategies as: scale up, switch up and scope up options [9].

- *Scale up*: it is an opportunity to expand the business, especially good when competitors are not a treat. It can enable the company to invest in something new and develop it efficiently with lower prices. If the new project succeeds, the company will have the option to expand the operations with superior expertise and pioneer know-how [9].

- *Switch up*: this option can be understood as a decision to change the business strategy. An example is when a company develops a superior know-how at something, stops their original business, and starts to sell their consulting services to other companies, escaping from a competitive scenario [9]. Another example is when a firm needs to switch products to meet the market needs [10].
- *Scope up*: this option refers to the opportunity that a company has to expand an investment made in a sector taking it to another one. The manager chooses to use the experience acquired in one industry to widen their core business [9].
- *Postponement*: it is the option in which the firm decides to wait to launch a project. Depending on the market conditions, the manager has the flexibility to decide whether is better to defer or not a project, limiting its losses, and waiting for a better opportunity to increase its potential returns [10]. These opportunities can be related to the competitor's position at the moment or if the clients are really to receive and adapt to a new technology.
- *Abandonment*: similar to the postponement option, this option looks at the flexibility of a project to be abandoned, studying its value preservation flexibility, a way to insurance the option or to sell its intellectual property in case of abandonment, taking in consideration the project's value during the options life [11]. According to Kim and Sanders [9], the decision to abandon a project must consider a set of factors as net losses and the competitor's movements that usually reflect the market trend.

Real options theory is broadly studied in the IT sector as it takes into consideration the managerial flexibility that is essential in IT projects [12]. IT projects are inherently risk-sensitive. These types of projects are the ones getting most investments, have a high failure rate, and impact the whole organizational structure. Santos [18] studies how real options theory can hedge the risks in IT investments. Taudes [19] used options to analyze the expansion option of a software platform. The real options theory also started to be used by companies to reduce the risks of IT project decisions by using the ROA to evaluate projects considering that they can be modified as new relevant information comes out [9].

Ignore that a company has the flexibility to deal with uncertainty in the project, therefore, could undermine the whole valuation of the company [6]. In the following sections, we will present some types of real options that could be used by Amazon's managers to manage the company risks.

83.3 The Amazon Case

83.3.1 The Company Overview

Founded in 1995, Amazon started as a new model of e-commerce focused on selling books. Nowadays, this firm became one of the biggest online retail companies and keeps developing new technologies to reinforce its core business and expand different sectors. A recent example of this expansion strategy is the acquisition of the whole foods on August of 2017 and the acquisition of PillPack on July of 2018, diversifying and enlarging its operations to the food and pharmaceutical sectors, respectively. In 2017, Amazon's market share represented 16.22% of the e-commerce retail market, making Amazon leader on the sector, according to Statista [13].

Amazon divides its segments in two: product and service revenue. According to Amazon's financial statement from 2017, product revenue accrues from product sale produced by Amazon, its shipping and digital media content. Service revenue represents the sales of third-party products and its shipping fees, the AWS revenue, digital contents, advertising services, and other minor services.

83.3.2 Financial Analysis

The financial statements from Amazon's Web site report the company's results for the period running from 2013 to 2017 and financial situation in the past years [14]. These values are presented in Table 83.1.

As it can be seen in Table 83.1, Amazon's revenue shows an outstanding result. Each year the revenue raised at least 20% and maintained an average of nearly 28%. If the company keeps this level of growth in the following years, it would be an exponential tendency. This growth results from a reinvesting strategy to increase the company's market value.

Table 83.1 Historical financial data from Amazon

	Year							
	2010 (%)	2011 (%)	2012 (%)	2013 (%)	2014 (%)	2015 (%)	2016 (%)	2017 (%)
Revenue growth	39.6	40.6	27.1	21.9	19.5	20.2	27.1	30.8
Gross margin	22.3	22.4	24.8	27.2	29.5	33.0	35.1	37.1
EBITDA	4.2	20	1.9	2.0	1.5	3.3	4.4	3.8
ROE	20	11	8	8	2	17	21	14.8

Source Web site from Amazon

Table 83.2 Amazon's competitor ratios

	Amazon.com Inc. (%)	eBay Inc. (%)	Walmart Inc. (%)	Target Corp. (%)	Average (%)
Revenue growth	30.80	6.55	2.98	3.43	10.15
Gross margin	37.07	77	25	29	38.21
EBITDA	3.80	24	4.0	6.0	8.36
ROE	15	28	19	31	29

Source Retrieved from Nasdaq [21]

At the same time, Amazon has significant expenses, producing a gross margin average below 30%. The EBITDA (Earnings before Interest, Taxes, Depreciation and Amortization) margin is also low, but this is guided by the company strategy that assumes that profit is a long-term goal, and the focus is on growth. The company also shows satisfactory ratios, having a history of little debts. As the ROE (Return on Equity) shows, the company has been creating value in the past years and overall has a good ROE.

In the USA, its major competitors in the online retail segment are the e-commerce eBay, Walmart, and Target, those last two which have physical and online stores. Besides these companies, Amazon also competes with Netflix, Apple, and Google on the media segment, which, however, is not its core business.

Table 83.2 shows the principal ratios of these companies.

Amazon's revenue growth is almost five times bigger than eBay's, it is three times higher than the group average, and its gross margin is only lower than eBay's. This value could be explained by Amazon's own production of products while eBay is only a reseller, what makes Amazon's costs higher.

The company's EBITDA shows that, among its competitors, Amazon is the less efficient on generating profit since its margin is only 3.80%, while eBay's is 24%. Amazon's ROE reflects the intensive investment approach, included Whole Foods' acquisition. Due to Amazon's operating expenses, the NOPAD margin is low compared to the average, presenting this ROE. EBay's margin is bigger than Amazon's, but it still shows an even lower ROE.

83.3.3 Valuation

To estimate Amazon's market value, we use the traditional DCF method once it is the foundation of our further valuation by the real options method. Based on the company's history and observed results, we were able to make assumptions for future scenarios to the firm for the next five years. The main premises used in the DCF are presented below:

- Revenue: The central moving average method was used to predict future revenues. According to the tendency function, the future revenue was calculated taking into consideration the seasonality indexes of each quarter;
- Costs of Goods Sold (CGS) and Operating Expenses: Believing that the CGS margin will continue to decrease on an average rate of 3.51% and the operating expense will continue to increase on an average rate of 4.34% annually, as it did on the past years, these two rates were used to project the next CGS and operating expenses margins;
- Tax Rate: The last Amazon's financial statement (2017) states that the American tax law changes the tax rate to 21% and it will be assumed this rate for the future years.
- Depreciation and CAPEX (capital expenditure): We assumed that the fixed assets would follow the revenue growth and that it would depreciate each year as on the past. Then, we corrected the value by the expected inflation for the next years. The Capex is the difference between the fixed assets each year; therefore, we used the fixed assets projection to calculate Capex;
- Change in Net Working Capital (NWC): Since the company presents a good liquidity, we assume that there will not be any change in the rate of the NWC, which is 0%;
- Growth Rate (g): We follow the projection of the American Consumer Price Index (CPI) for the next years of 2.5% [15];
- Risk-Free Rate: The US T-Bill of 3 months from 02 Jan 18 of 2.33% was used as the risk-free rate [15];
- Market Premium: We use the country default spreads and risk premiums of 5.08% from the USA [15];
- Beta: Beta was calculated using the last 3 years monthly stock price compared with the SP 500 values, which shows the biggest 500 companies in the United States Stock Exchange. The value found was 1.48;
- Discount Rate: we use the WACC (weighted average capital cost), which is calculated as $\mathrm{WACC} = E/V * \mathrm{Re} + D/V * \mathrm{Rd} * (1 - \mathrm{Tc})$. In this case, E is the market value of the firm's equity, D is the market value of the firm's debt, V is the sum of E and D, which is also equal to the total market value of the firm's financing (equity and debt), Re is the cost of equity, Rd is the cost of debt, and Tc is the corporate tax rate. The WACC found for Amazon was 6.14% annually.

Table 83.3 shows the valuation results for Amazon. The projection with these assumptions expects a stock value of USD $ 1,320.83.

Figure 83.1 shows the sensitivity of Amazon's valuation to these parameters. The variable of CGS had the most effect on the output of earnings per share (EPS), the stock value. Varying this parameter, according to this distribution, can change the value of the stock from USD 195.73 to USD 1,557.35. After that, the operating expenses had most impact, then WACC, revenue growth, and the stable growth.

A highlighting aspect of this graph is that the revenue growth is one of the parameters with the least impact. To this fact, we can infer that no matter how much the

Table 83.3 Results from Amazon's valuation (values in USD million)

	2017	2018	2019	2020	2021	2022
Revenue	177,866.00	201,413.85	229,043.98	256,749.81	284,379.94	312,010.07
(–) Cost	162,282.00	181,795.99	2047,93.63	227,724.92	250,562.71	273,482.64
CGS	111,934.00	122,306.01	134,204.39	145,160.12	155,140.62	164,242.12
Op. exp	50,348.00	59,489.98	70,589.24	82,564.80	95,422.09	109,240.52
(–) Depreciation	11,478.00	13,322.06	15,528.33	17,841.85	20,255.94	227,79.59
EBIT	4,106.00	6,295.81	8,722.03	11,183.05	13,561.29	157,47.84
(–) Tax expense	769.00	1,322.12	1,831.63	2,348.44	2847.87	3,307.05
NOPAT	3,337.00	4,973.69	6,890.40	8,834.61	10,713.42	12,440.79
(+) Depreciation	11,478.00	13,322.06	15,528.33	17,841.85	20,255.94	22,779.59
(–) Change in NWC	349.00	1,832.35	568.80	570.36	568.80	568.80
(–) CAPEX	11,955.00	6,467.48	7,590.70	7,611.49	7,590.70	7,590.70
Company FC	2,511.00	9,995.92	14,259.24	18,494.60	22,809.87	27,060.89

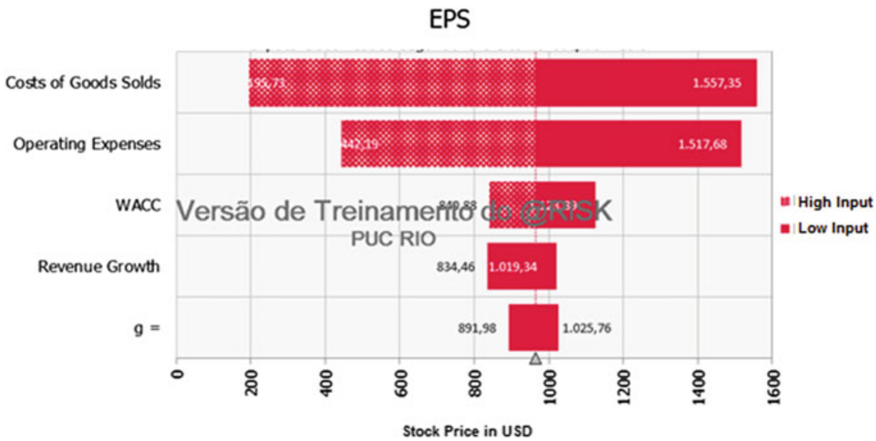

Fig. 83.1 Sensitive analysis of the Amazon's stock price

revenue grows, the real impact to the stock price are the earnings from the company that are mainly affected by the costs and expenses, hence the operating efficiency.

83.4 Real Options Applied to Amazon

In this section, we use the real options theory to evaluate an Amazon's project, analyzing the options of expansion and abandonment and how those can add value to the stock price.

Amazon's most recent expansion plan is the Amazon Go store, a new kind of convenience store totally cashierless. By using computer vision technology, the clients use their smartphone app to enter the store, they pick up any item, and it will be automatically charged on their Amazon's account. There are already four Amazon Go stores and Amazon plans to open more 3 thousand stores over the next three years, transforming the project into one of the biggest chains in USA. If the initiative is successful, Amazon has the opportunity to increase their activity in traditional retail, increase revenues, penetrate into a new sector as big player, and create potential locations for AMZN to build a pharmacy.

Since the beginning of the company, Amazon had always developed a growth strategy and has a history of outstanding investment in different projects. In consequence, the company has a lot of opportunities and risks around it. The risks of this project are associated most of all with the high competitiveness level of convenience store's market, with uncertainties related to the new technology applied the facial recognition and the acceptance of consumers. Also, the investment to create a high-tech store can be more expensive than it is expected.

According to a study from Morgan Stanley, on average, an Amazon Go store would have 2,000 Ft square. It is estimated that the cost to open one store of 2,000 square foot could reach USD 800,000, and the revenue would be USD 1,212,000.00 [16]. However, the first Amazon Go store required USD 1 million on hardware only [20].

Assuming an operating expenses margin lower than the average, because it will not have cashiers, we estimated that it would be 9%. The depreciation assumes a useful life of 10 years for the technology. Net present value uses the same parameters from the Amazon DCF Valuation and the WACC is 6.14%, achieving the present value of the cash flow of one Amazon Go store, USD 841,251.15. However, since the estimated initial investment was USD 800,000 the net present value was USD 41,251.15.

Through the binomial method and the Cox, Ross and Rubinstein Model (CRR), the Binomial Tree was built for one Amazon Go store. The project volatility calculated was 16.30%, and the market risk-free rate used was 2.33% [15]. The expansion option had a value of USD 1,559.84 million. Therefore, the option of expansion would add a value of USD 3.22 to the stock price resulting in stock price of 1,320.05. On the other hand, the abandonment option had a value of USD 94.99 million, adding a value of USD 0.20 to the stock price resulting in stock price of USD 1,320.03. The final value of the project is USD 1,655.67 million, and it would add USD 3.42 to the stock price resulting in a stock price of USD 1,324.25 for Amazon.

83.5 Conclusion

In this work, the Amazon's case was studied. The company and one of its most recent projects Amazon were evaluated using the DCF method and the real options theory as a complementary valuation.

The first valuation method used was the discounted cash flow, and it concluded a stock value of USD 1,320.83. After analyzing the real stock value at the end of the studied period, we concluded that the stock value would have to be compared to the stock price at the time the 2017 financial report was released. At the time the financial report was released, the market would have the same information as this work used to price the stock. This analysis showed that the DCF Method priced the stock under the markets value.

The real options theory was used to analyze Amazon Go most recent project to open 3,000 stores. The result was that the expansion option's value resulted in USD 1,559.83 million and the option to abandon in USD 94.99 million. Hence, the final value of the project taking in consideration the option to expand and abandon was USD 1,655.67 million. This value gave a plus of USD 3.42 to the stock price resulting in a final price of USD 1,324.25 for Amazon.

The value of Amazon with the studied options did not reach the observed stock price in February 2018, and this led to other assumptions. Although Amazon Go's Technology could have other opportunities to add to the company by analyzing other options, the main value it could add to the company would be consumer's behavior information. Besides that, Amazon has other technology projects with real options that were not studied in this paper that could aggregate value to the final stock price.

By analyzing Amazon Go project using real options theory, this work can be used as a real example of the CRR and BDH methods and also can help managers evaluate the decision's flexibility in their projects by taking into consideration the real options theory. Future researches could consider tax policies and exchange rates in their valuation. Moreover, further studies could evaluate if Amazon will be able to keep its growth rate and if it will succeed in all those market that it is migrating.

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Part VIII
Resilience and Risk in Operations

Chapter 84
Monte Carlo Simulation Applied to Risk Management in Logistics' Procurement for Defense Projects

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Abstract Monte Carlo simulation is a common approach to analyze risk in project management. This paper demonstrates how this methodology could be applied to improve governance on the public sector, mainly by means of corporate risk analysis. Real cases of logistics' procurement for defense projects were used to demonstrate this possibility.

Keyword Logistics · Risk management · Monte Carlo simulation

84.1 Introduction

When the number of projects managed by the Brazilian Air Force (FAB) increases, the quantity of procurement processes increases as well. Besides, the amount of time involved in these procurement processes has also increased in recent years, causing a slowdown from the formalization of a need (object request) to the receipt of this acquisition. This slowdown causes a negative impact on the public administration and, consequently, an increase on the uncertainty throughout the process of public procurement [2].

In this context, achieving organizational agility and control is very important in the processes of stock replenishment for logistical support, since any delay would imply, for example, in a lack of items to the Aeronautics Material Park and Logistical Groups, which would consequently lead to an unavailability of aircrafts, equipment and could thus compromise the fulfillment of the Brazilian Air Force (FAB) mission.

Corporate risk management faces a lack of specific approaches and tools that enable its implementation, since the standards and models of governance processes do not give the same focus to the management of corporate risks that the risk management applied to projects management provides [9].

For this reason, some questions arise about the possibility of using the Monte Carlo simulation in the government bidding processes, since this simulation has

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already been used as a tool for the quantitative risk analysis involving deadlines in the project management area. Similarly, bidding processes, according to Brazilian Law 8.666/93 [4], have their steps well defined with deadlines that are likely to be estimated.

Then, would it be possible to apply a methodology for quantitative risk analysis, in order to improve the perception of risk involving deadlines during a process of acquiring items focused on logistical support? How to draw up an approach to forecasting deadlines and measuring risks involving procurement processes, focused on the logistical support of defense projects, by means of the Monte Carlo simulation?

For this purpose, it was selected three modalities of bidding (ineligibility for tender, electronic reverse auction, and request for quotes) for the simulation. The results obtained in the applicability of the Monte Carlo simulation, through the @RISK software, were compared with the real procurement data for logistical support items, managed by one of the main logistics acquisition centers of the COMAER. Data collect involved procurement processes that occurred between 2015 and 2017.

84.2 Literature Review

The theoretical framework that provides a grounding base to this article is related to impacts of procurement in governance and risk management, Monte Carlo simulation and public procurements by means of bidding processes.

84.2.1 Risk Management

Risk is linked to the exposure to change. It is the probability that some future event or set of events will occur. It differs from uncertainty, which because it is related to a set of known variables about an event. Colloquially, it could be said that the risk is a known uncertainty and that uncertainty is an unknown risk. Therefore, the risk analysis involves the identification of adverse potential changes and the expected impact as a result in the organization [8].

Risk refers to a threat which, if it becomes a reality, may adversely impact a project, either in terms of cost, term, quality, or another dimension [19]. A risk is characterized by its likelihood of occurrence and its impact on the objectives of the project. Risk, from a project management perspective, is an event or an uncertain condition that, if it occurs, influences at least one project goal [16].

Many risks can be classified in different contexts. In an external context, it includes all the external environmental parameters and factors that influence how it manages risk and how it tries to achieve its objectives. Internal context includes all the internal environmental parameters and factors like internal stakeholders, approach to governance, and among others that can be reduced with the adoption of mitigating measures [7, 11, 12].

84.2.2 Monte Carlo Simulation

Simulation is the representation of a real system, by means of relevant information about the system so that it is possible to analyze its behavior of it, understanding what would happen to certain changes to minimize cost and time without the need of modifying for the construction or modification of the actual system [3].

According to Prado [15], simulation is a technique that makes it possible to imitate the functioning of a real system through the use of the computer, by means of simulation software, thus having several applications in the present day on several different areas, ranging from a toll, the functioning of a bank, a port, the production in a manufacture up to the movement of papers in an office.

Monte Carlo simulation specifically uses random number generation to assign values to the system variables you want to investigate. Nowadays, random numbers can be generated from a several computational methods, like a spreadsheet or a specific random number generating software.

Simulation is then replicated many times, until there is safety over the characteristic behavior of the decision-making variable on which to decide [14].

It is an efficient tool in the generation of estimates and therefore is highly recommended for the evaluation of uncertainty, because it can provide a series of valuable information, generated from various combinations of events established as input variables in the simulation, and their respective results within a project [1].

84.2.3 Public Procurements by Means of Bidding Processes

Brazilian Law n° 8.666, of June 21, 1993, regulates the art. 37, section XXI, of the Federal Constitution and establishes rules for bidding and procurement of public administration and other matters related to administrative works, services, including advertising, purchasing, sales, and leases under the authority of Federal, State, Federal District and Municipalities. All contracts with third parties will necessarily be preceded by bidding, except for the assumptions provided in this law.

The acquisition process has a strategic role for the any institution organization to reach its goals. Purchases directly interfere with the quality and capacity of delivering essential products or services, which will meet the demand of those who enjoy profit the public service [6].

Depending on how the procurement process was conducted in the private sector, acquisition of raw materials, supplies and components can generate cost reduction and considerable improvements in profits. The public corporations have the same goal, although they don't look for profit as a goal, the proper public expenditure management is fundamental to the reach of the public interest [18].

The bidding process is intended to ensure compliance with the constitutional principle of isonomy or equality of rights (impossibility of unequal treatment) and to select the most advantageous proposal for the administration, that is, the one that best meets in an objective way the service interest [10, 21].

Brazilian Law No. 8.666/93 also states that every bidding process must follow certain procedures according to the contract object, which are termed as bidding modalities. Bidding modality is the specific way of conducting the bidding procedure, from criteria defined in law, being the estimated value for hiring the main factor for choosing the bidding modality, except when it comes to electronic bidding, which does not isis not limited to by values [20].

Making a contract with third parties in the public administration must necessarily be preceded by bidding, except for the chances of dismissal and non-requirement of bidding (Brazil 2006). Exceptional situations these, which must be fundamentally justified, have seen the limits imposed for such discretion to the public administrator, which may be penalized in the forms of the Brazilian Law [13].

84.3 Methodological Assumptions

This research initiated by collecting data in one of the main acquisition centers of the COMAER, which was responsible, until the year 2017, for the logistical activities of demand, purchase, receipt, distribution of material, and hiring of services necessary to the logistical support of several FAB's projects.

Three different bidding modalities were selected, and a future scenario simulation was carried out for each one, a future scenario simulation was carried out related to the deadline for the process to be completed. It was assumed a beginning and an end for analysis of the bidding process, which was from the phase of elaboration of requirements (shopping list) until the phase of the contracting.

Subsequently, the results were compared with the data of the processes already completed, considering the same class of material acquired, to verify the behavior of the simulation regarding the probability of the process time, as well as to identify and classify the risks of this same process.

84.3.1 Selecting Items for Analysis

From data obtained in the procurements department, it was simulated the procurement of an item by means of the following modalities: ineligibility for tender, electronic reverse auction and request for quotations, according to Brazilian Law n° 8.666/93 [4] and Law n° 10.520/02 [5].

For each analyzed bidding modalities, it analised was evaluated with the help of the managers responsible for the procurements, by means of an unstructured interview, all the phases prescribed by law for the realization process. Additionally, in order to enter the uncertainties of each phase of the processes, it was obtained with these managers an estimate, based on their experiences, optimistic, pessimistic and a more probable, for each phase of the process, in order to feed the simulation.

84.3.2 Using of the Software @RISK

The computational simulation, by means to the software @RISK, was developed following three steps, executed separately, for each of the bidding modalities.

The @RISK software used is available on the Web site's URL http://www.palisade-br.com/risk/website, in its student version, which is a cheaper version, with a subscription of one year, but maintains the same features of the versions Standard, Professional, and Industrial.

In addition, the @RISK software includes a top rank analysis for spreadsheet that is a tool for performing quantitative risk assessments that evaluate the relationships between process parameters to compare the relative importance of variables, allowing to test the sensitivity/risk associated with uncertainty/variable.

Step 1: Definition of Uncertainty

Initially, it was necessary to define where there was uncertainty throughout each process step. In the analyzed cases, there was considered uncertainty in all bidding process steps. Thus, in order to estimate these uncertainties and to have an estimate beyond the perception of managers, a distribution of PERT probability was carried out, using three weighted estimates based on the data, which will behave within a curve of odds.

According to Santos [17], the application of the Project Evaluation and Review Technique (PERT) is the most commonly used method in project timeline estimates, as it is a model based on mathematical analysis that uses the well-known expected value (or weighted average) to define the duration of the project.

$$\text{Expected Time} = \frac{P + 4R + O}{6} \tag{1}$$

where O = Optimist Time, R = Realistic Time and P = Pessimistic Time.

Step 2: Adding Output and Configure Simulation

Once you have defined the uncertainty throughout the process and entered the probability distribution scores for each activity, you must configure the simulation parameters in the @RISK software. A simulation was performed running 10,000 rotated iterations rotated, and then it was chosen that the possibility for the software would to add outputs.

Step 3: Adding Output and Configure Simulation

A simulation was performed for each of the three selected bidding modalities. For the electronic reverse auction mode (Table 84.1), it was possible to observe that the

Table 84.1 Definition of estimates for electronic reverse auction

Electronic reverse auction						
	Activity	Predecessor activity	Time (days)			PERT estimation
			Optimist	Realistic	Pessimistic	
1	Drafting requirements	–	4	6	8	6
2	Draft of the auction notice	1	8	10	15	11
3	SRP publication	2	5	7	8	7
4	ACI auction notice	3	3	5	7	5
5	Preliminary study	4	20	25	35	26
6	NEA COMGAP	5	3	5	20	7
7	OPAJ NEA COMGAP	6	2	3	6	3
8	Legal analysis of CJU	7	15	40	50	38
9	NEA CJU	8	3	7	15	8
10	ACI NEA CJU	9	3	5	7	5
11	COMGAP + NEA approval	10	20	25	35	26
12	Adequacy of the auction process	11	5	8	12	8
13	Publication of the auction notice	12	8	10	14	10
14	Electronic reverse auction	13	43	45	50	46
15	Statement of agreement	14	13	15	17	15
16	Agreement formalization	15	40	45	50	45
Total			195	261	349	265

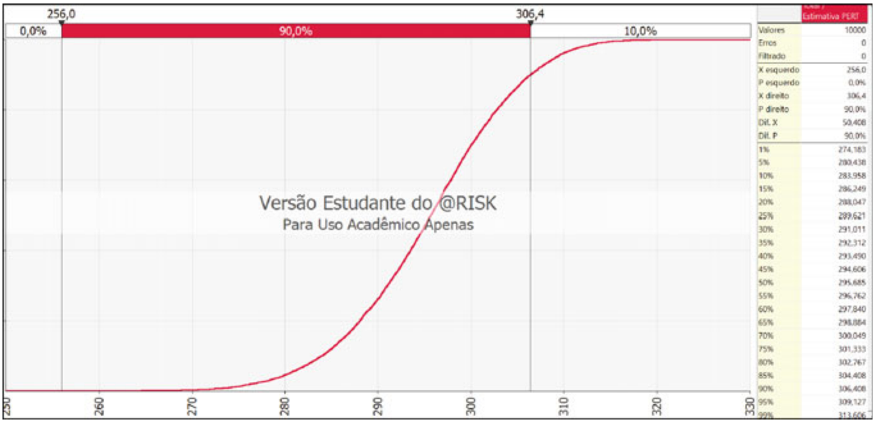

Fig. 84.1 Cumulative upward simulation score for electronic reverse auction

deadline considered most likely by the managers of 261 days was short, but very close, of the estimate based on the results of the PERT probability distribution, of 265 days.

Regarding to the simulation of Monte Carlo applied in each bidding modality, for the electronic reverse auction, it was obtained, with 90% probability of occurrence, an estimate of 306 days and standard deviation of 9 days (Fig. 84.1).

Concerning to the modality of ineligibility for tender, it was possible to observe an estimate based on the managers' experience of the 234 days and an estimate based on the results of the PERT probability distribution of 233 days. Regarding the Monte Carlo simulation, with a 90% probability of occurrence, the estimate obtained was 279 days with a standard deviation of 11 days.

For the request for quotes modality, the estimates obtained were 246 days based on the experience of the managers, of 253 days based in the results of the distribution of PERT probability and 303 days, with a standard deviation of 11 days, based in the simulation of Monte Carlo, with probability of 90% occurrence.

84.4 Numerical Comparison

Finding in order to respond to research issues and verify if it is possible to apply a methodology for quantitative risk analysis, typically used in simulation of future scenarios involving project schedule, on procurement processes for support logistics of defense projects, a sample of 21 procurements has been used, all of them already finished, separated like this: already completed, ten of the electronic reverse auction, seven of ineligibility for tender, and four of request for quotes, in order so as to compare the results obtained in the simulation with the real duration of the processes.

The 21 real processes used were chosen for convenience among the 60 processes that had items with direct applicability in defense projects as object of contract items with direct applicability in defense projects, which in case of delay in the completion of these processes, possibly would occur disorders and operational impact. The processes analyzed were initiated and completed between 2015 and 2017. Then, were excluded those who, according to the managers, were considered points outside the curve, exceptions to the normal management standards.

The results obtained are shown in Table 84.2, in which we can observe, concerning to the three modalities of procurement, the most probable duration estimate made by the managers, the PERT estimates and the Monte Carlo simulation, as well as the real duration of the 21 cases.

The estimated number of days of real cases was measured in the bidding process starting by the phase "Drafting requirements" until the phase "Agreement formalization." Related to the sequence of the actual cases, as listed in Table 84.2, were placed in order of the oldest case for the most recent case.

Comparison between estimates and actual duration of the real cases can be best viewed in Fig. 84.2. It is possible to observe a better approximation between the simulation of Monte Carlo, considering the standard deviation calculated, versus average cases, which corroborates what a literature says about an efficiency of the Monte Carlo simulation in representing a real system.

84.5 Conclusion

Related to the first phase of risk management, in the sense of risk identification to enable the following phases of analysis and mitigation, this study intended to be a first approach with the subject, applied to the procurement processes for the logistical support of defense projects.

With the purpose of investigating the forecast of deadlines that allow the measurement of risks and its intended mitigation, this research made use of the simulation of Monte Carlo, which is widely used in other areas, for the same purpose.

While Monte Carlo simulation is used for risk management in other areas, especially in project management, there it doesn't seem to be many studies addressing the application of this simulation to the effects of procurement processes in Corporate Governance.

According to the context in which the data was obtained, it was found that the Monte Carlo simulation, carried out by the software @RISK, behaved as an effective tool for advising the decision maker and, mainly, the managers of internal control about aspects of corporate risk management in public organization.

Furthermore, according to the present results, it seems to be possible to apply a methodology for quantitative analysis of risks, typically used in the simulation of future scenarios involving project schedule, in order to improve the perception of risk with deadlines during a process of acquiring items focused on logistical support of defense items.

Table 84.2 Comparing simulation results versus real cases

Modalities	Days—estimation			Actual duration of cases (in days)									
	Managers	PERT	Simulation of Monte Carlo	1	2	3	4	5	6	7	8	9	10
Electronic reverse auction	261	265	306 (±9)	322	308	316	221	316	234	279	364	274	194
Ineligibility for tender	234	233	279 (±11)	283	269	308	310	222	234	321			
Request for quotes	246	253	303 (±10)	354	272	297	298						

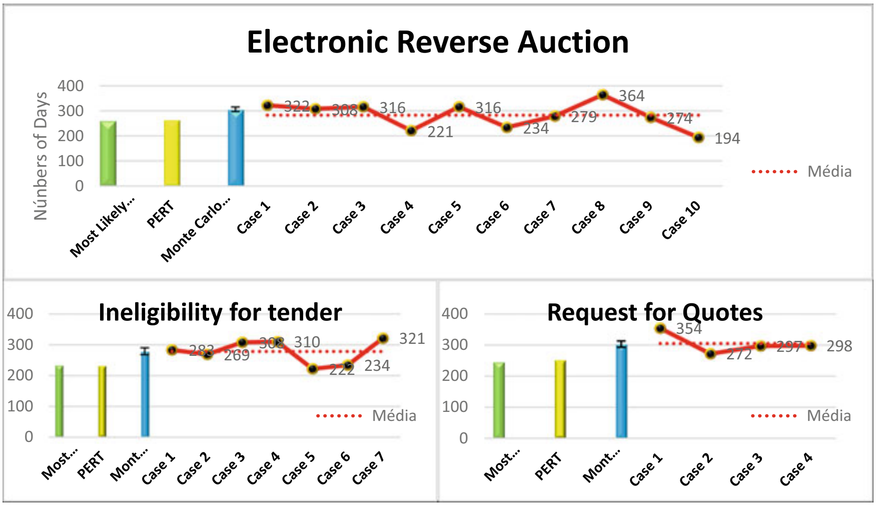

Fig. 84.2 Comparison between estimates and real-cases

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Chapter 85
Fires in Historic Buildings: Assessment of Evacuation of Persons by Computational Simulation

Ivana Righetto Moser and João Carlos Souza

Abstract The research aims to assess the performance of historical buildings, regarding the safe evacuation of people, through a computer simulation which uses human behaviour as a variable. The simulations verified the evacuation time and the maximum distance travelled in emergency situations, as well as indicated bottlenecks and building's critical points.

Keywords Computer simulation · Evacuation in historical buildings

85.1 Introduction

Studies on escape routes and emergency exits, with effective abandonment of the site, have been developed by researchers from several countries of the world, as Japan [12], Netherlands [4], and Brazil [2]. Human behaviour in situations of fire risk, or in other situations of risk, is widely studied by several areas such as psychology [6, 19] and traffic engineering [7, 8]. The behaviour at risk varies from person to person and the stress is very particular and few are related to individual's age or strength.

As historical buildings, of interest for preservation, were built in another period, when the current security requirements were not in place yet, these spaces should be adapted to make them safe. Considering historic buildings, great care must be taken regarding adaptations to prevent and protect these buildings from significant changes in their historical and cultural values [10].

Having said this was the objective of this research, the performance assessment of a historical interest building in the city of Florianópolis/Brasil, regarding the safe evacuation of people, through application of computer simulation, using the software PTV Viswalk. The same method was applied to the Historical Museum of Santa Catarina. The building of about 2,000 m^2 gathers just over 70 people simultaneously at the exhibition areas and the study pointed out that the building is safe in relation to the evacuation time in case of emergency.

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To understand the subject, pedestrian traffic surveys and the application of computational simulations are discussed and human behaviour in emergency evacuation, characterizing the peculiarities existing in historical buildings, besides the fire system's exits in listed buildings.

85.2 Literature Review

Architectural heritage is generally more prone to high fire risk due to structural and non-structural vulnerability of its constructive elements such as wood; potential source of fire due to the risk of old electrical installations, for example, and a generally significant density of occupants that, frequently, are odd to the architectural space (D'Orazio et al. 2016).

A current approach to conservation of historical heritage consists of observing environmental conditions, measuring trends, impacts, and risks to physical structures such as risk prevention [1]. According to Moser and Souza [11], the area of research that relates human behaviour and emergency exits to historical buildings is quite new in academia. Serpa [17] defines a fire safety building as one in which, when in a fire situation, it enables all occupants to have their safeguard guaranteed, without any injuries and that damages that happen to the property, do not exceed the place where the fire started. Fire safety can be defined as 'a series of measures and resources internal and external to the building, as well as the possible adjacent areas of risk, which make possible the control of a fire' [17]. Current fire safety standards are reviewed by Cunha [3] who says that there is a lack of studies in the area of architecture so that fire safety solutions come by the project, this being more flexible to the protection needs.

The emergency exits are part of the passive measures of the means of buildings escape, therefore must be designed at the design stage and be provided with fire-resistant materials [14]. They shall enable the escape of occupants by using safe escape routes free from the effects of fire and its consequences: heat, smoke and gases. They must, in cases of damage, take care of all occupants of that place, whether in the building or in its surroundings, including escape routes, emergency stairs, areas of refuge, emergency lifts protected from fire and gas, and must rely on independent power [16]. Similarly, Souza [18] concludes that routes, passages and doors must be sufficiently wide and in sufficient quantity, so that in case of an emergency, the exit of the occupants is fast and safe and, consequently, in a calm way.

The first scientific pedestrian traffic research began in the 1930s, through flow parameters, and then practical observation experiments were implemented. From the visual observations, it began to adopt the recording by images and, consequently, the study was improved, with improvement methods of filming that avoided distortions by perspectives, among others. It was obtained, therefore, more objective results and in major numbers [9]. Helbing et al. [8], for example, made observations through recordings and could characterize a regularity in the movement of pedestrians, in normal situations and evacuation.

The traffic flow of pedestrians is defined by “a mass of people which is moving simultaneously and indirectly along the mutual route” [9]. In this concept, according to the authors, factors such as different types of movement should be considered, psychological and physical mode different types of routes, among others.

In the evacuation dynamics, panic is defined by ‘Breakdown of ordered, cooperative behaviour of individuals due to anxious reactions to a certain event’ [7]. Similarly, Souza [18] characterizes panic as a psychological reaction in which an anxiety takes over the individual, which may exhibit acceptability behaviour to the disaster stimulus, leading, in the last case, to a loss of the senses.

From the analytical models and with the possibility of using the computational tool, new approaches were developed for the dynamic reproductions of the evacuation process and its study [9]. Computational evacuation models are widely used tools for assessing the safety of people in a building or agglomeration sites. Each model has unique characteristics and diverse simulation capabilities. The simulation softwares have specific characteristics and work with the philosophy of simulation through information of the buildings obtained from CAD program plans or geometric elements. Cunha [3] affirms that in the international scenario, computational simulation is already used as a tool for evaluating the design decisions of buildings of high standard or historical patrimony.

85.3 Method

A selected building was analysed for its physical and historical characteristics, regarding the events that occur in this building as well as its occupants. For this, the data collection was done through documentary research and observation in the historic building.

For the research we opted for PTV Viswalk module of the Vissim PTV software, which allows the use of the social force approach. This computer simulator uses as a parameter of characterization of the occupants the human behaviour, essential measure in the evaluation of the evacuation of people.

The scenarios of the simulations were run to verify the evacuation time in normal and emergency situation, as well as the maximum distances travelled for the building’s abandonment. In order to capture the density maps, the 2D visualization is used, and for visual analysis of bottleneck points, interaction between people and how they behave in the evacuation environment, 3D visualization is performed during simulation execution. The occupants of this building were positioned in each environment, according to what was observed in the data collection. The origin and destination of the pedestrians is then defined Compulsory paths may also be defined for pedestrians.

In this simulator the modelling of pedestrians can be chosen between approaches car following model by Professor Wiedemann, in which pedestrians are modelled as a type of vehicle and do not move freely, but rather along certain predetermined points, or the approach Social Forces Model, developed in 1995 by Professor Dirk Helbing, which allows pedestrians to walk independently of their destination, without a predefined network model of their trajectories. We opted for the Social Forces Model expanded model especially for use in software Viswalk [15].

The simulation parameters used are period of 10,000 s, which enable the execution of 10 consecutive simulations of 1,000 s each; the resolution of 10-time step(s) Sim. Sec., which defines that the pedestrian gives 10 steps per second of simulation; random seed 42 that provides the randomness of pedestrians to each simulation; and maximum simulation speed. The adopted method is the microscopic one and the software standardizes the shortest way for the simulations. The time intervals used were: from 0 s to 1000 s, from 1000.1 to 2000 s, and so on. For each rounded simulation, you choose the data you want to get in the ratings settings. External data is generated in PTV program files and imported into electronic spreadsheet.

85.4 Historical, Physical and Occupational Aspects of the Building

The main building of Colégio Catarinense, built in 1926, is a relevant example of school architecture in the state of Santa Catarina. Located in the centre of the city and has tipping in the municipal sphere. It has 12,104.19 m^2 of built area, divided into four floors consisting of primary school classrooms from 6th to 9th grade and high school, management rooms and administrative departments, library, laboratories, among others, as well as restaurant, auditorium and theatre. The building still houses the Man Museum of the Sambaqui, with an important archaeological collection of Brazil and the exterior [13].

The building has undergone several interventions over the years and the contemporary constructions attached to the main building have directly and indirectly influenced the evacuation of the listed building, therefore, are also included in this research.

The number of occupants of the building and how they are distributed in the spaces is of extreme importance for the study of safe evacuation. The occupants of each environment and time of highest concentration were observed, getting a total of 1,417 people in the school in the morning.

85.5 Computer Simulation

The computational simulation of the main building was made from the modelling of the building within the software. The occupants were considered and the routes defined in each scenario were studied. Some modifications were necessary in the layout, and however, these do not modify the school's characteristics.

At first, for computational simulation, the three-dimensional modelling was done using Revit software (version 2016) and exported to the IFC file (*.ifc extension) for reading in the Vissim PTV. However, when converting and reading the IFC file into the PTV program, the file has lost some drawing information. The unread information is the staircase, built with stairs tool in the Revit and sloped floors, which were built with the floor tool. The stairs after the conversion were represented by red blocks and the sloping floors did not appear because they were not converted.

The other tool of construction of the 3D-modelling was then used from the plans of the Auto CAD software. The importation of flat floors, walls and other obstacles gave rise to modelling built inside the software Vissim, since the plans and layout of the school are relatively simple, even in large proportions. However, the stairs were modelling using the commands of the PTV program, in addition to being informed of the necessary dimensions for the position of the levels of the building. The auditorium and theatre were not included in the modelling, due to the difficulties of building inclined floors within the software, as well as the mezzanines and the subsoil, to simplify the construction of the model, since they do not have occupants.

After the modelling, the insertion of the occupants in each virtual environment was made and the start and end point of the route of each volume of people was designated. The plants were added 1,417 pedestrians distributed in the classrooms, administrative rooms and other environments of the school where people were observed. Inserted pedestrians have the program's standard characteristics, both men and women. Only the occupants of the restaurant where it was observed that, among 50 people, half of this number is children, the type of pedestrian called "woman and child" was used.

Three different scenarios were studied for Colégio Catarinense (see Table 85.1). In the first scenario, the people distributed in the school have as destination the exits closest to them. This scenario aims to study the normal leaving using the escape routes provided in the fire and panic prevention project and the signs of implanted exit. For the normal walking speed, the desired speed of 1.2 m/s was adopted.

For scenario 2, the same volume of pedestrians leaves the building for the closest exit, nevertheless the desired speed of 1.53 m/s is adopted, which characterizes a faster walking speed as when in an emergency evacuation. Helbing et al. [8] affirms that simulations implemented at the desired speed of more than 1.5 m/s, which characterizes people in a hurry, for example, are irregularities in the movements of people with arching blockages at the exits and movements like avalanches when these arches break. For scenario 3, the abandonment of the building was designed to be carried out only by the exit 1 of the building and the path travelled passes the

Table 85.1 Configuration of the scenarios studied

Scenario	Description	Population	Desired speed (m/s)
Scenario 1	Closest exits	1,417	1.20
Scenario 2	Closest exits	1,417	1.53
Scenario 3	Exit 1	1,417	1.53

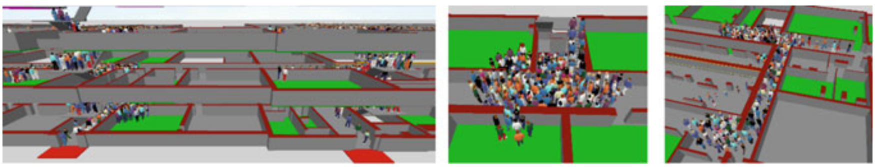
nearest exit of each pedestrian. In this scenario, the desired speed of 1.53 m/s was also adopted. With this third scenario, it is possible to verify the flows of people leaving the building, first using the escape route predicted in the project and implemented through the emergency signs, however, for some reason of obstruction or impediment of the exits, these should follow the exit 1 of the building.

In principle, all the characteristics of the layout in the internal areas that compose the evacuation paths of the building were represented; however, some adjustments were necessary in the layout of the rooms to enable the computational simulations, such as modification in the dimension of furniture and removal of desks of classrooms. Some avatars remained tied between or behind the desks, leading to errors in the simulations results, as these pedestrians remained in the network.

85.6 Results and Discussions

The visual analysis of the exit of the occupants of the Colégio Catarinense during the simulation shows that, in scenario 1, soon after the beginning of the evacuation, there is the presence of agglomerations in the circulations. In the first minute of the simulation, it is possible to see the staircases 2, 3 and 4, the most requested ones, in a number of people in their routes of escape, totally taken of pedestrians. These pedestrians present a lower speed than the one configured for the scenario and are very close to each other (see Fig. 85.1a). Consequently, there is a delay in the abandonment of rooms closer to the circulation areas along staircases 2, 3 and 4 dues to the mass of people forming near them, as can be seen in Fig. 85.1b. This cluster near the stair can be visualized in Fig. 85.1c, which shows the second floor, next to staircase 2 of the school, in the first minute of the evacuation. Along with regions of bottlenecks in the circulation, that is, where it has its reduced dimensions, we see the formation of bottlenecks.

In scenario 2, even with the increase in speed, crowding and interactions between people, similar to the previous scenario, are verified along staircases 2, 3 and 4. Arching is most visible next to classroom doors in the first few seconds of the simulations. In scenario 3, the same interactions between pedestrians, bottlenecks and agglomerations are visible, such as the simulation in scenario 1, since as they



(a) Staircase 2 and 3. *(b) Crowding.* *(c)Bottlenecks and crowding.*

Fig. 85.1 Simulation of evacuation with scenario 1 were driven through the nearest exits, each group of pedestrians does, in principle, the similar escape route to the previous scenario. However, the agglomeration and low displacement velocity due to the bottleneck near staircase 2 is further intensified by half to the end of the simulation, period in which all occupants of the building are towards exit 1. Figure 85.2 shows the simulation in time 247 s with 682 pedestrians in the network.

For density analysis, the density maps were checked every 30 s of evacuation, in scenarios 1, 2 and 3. In scenario 1, we read an agglomerate next to the circulations in the first minute of the evacuation, in the first and second floors. There is also a higher density of people in the network along staircases 2, 3 and 4 in the first few minutes of simulation and on staircases 2 and 3 until the end of evacuation time. Scenario 3 presents an agglomeration that is initially similar to that of scenario 1 and 2, however this intensifies with the passage of simulation time, since the agglomeration itself is an obstacle to the fluidity of the displacement in the ground floor, since this scenario has a single path to be made by all occupants of the building.

Figure 85.3 shows a critical moment where most of the ground floor in which people are, these are concentrated in a number equal to or greater than 5 pedestrians per m^2, areas in red, according to the colour scheme of density of Weidmann (1974 apud PTV 2018), at the moment 250 s of the evacuation, and there are in the network 670 occupants that still have not left the building.

With the simulations implemented in each scenario, it was possible to collect the information through the software and export to an electronic spreadsheet. The maximum total evacuation times of each simulation were verified, as shown in Fig. 85.4,

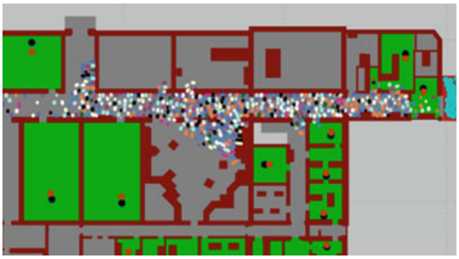


Fig. 85.2 View 2D of exit 1

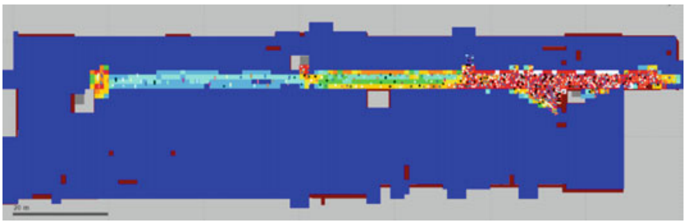
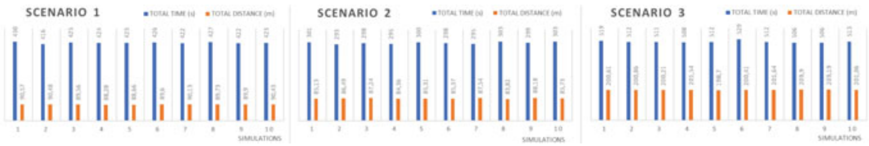


Fig. 85.3 Density map of scenario 3



(a) Scenario 1 *(b) Scenario 2* *(c) Scenario 3*

Fig. 85.4 Times and distances obtained in the simulations

and the average maximum times for evacuation of the school are calculated in each scenario. The mean maximum time was: 423.5 s or 7 min and 3 s for scenario 1; 298.5 s, or 4 min and 59 s, for scenario 2 and 512 s, or 8 min and 32 s in scenario 3. The total distances travelled were also collected for the evacuation of each simulation, (see Fig. 85.4), and the average total distances in each scenario were calculated. The mean total distance was: 89.82 m for scenario 1; and 85.55 m for scenario 2 and 200.96 m for scenario 3.

The simulations in the three different scenarios show that: the number of people who currently use the school in the morning period sets up a total and simultaneous exit of the building around 7 min by the nearest exits, that is, those provided by the project of fire and panic prevention in the school. For an emergency situation, the time found is 5 min, in the same exit configuration according to the escape route of the building. The number of stairs and exits are distributed along the 138 m length and four floors, which conform the school, allowing the evacuation of its occupants in a distributed way. However, 5 min is a time considered high for the evacuation of the school, since the stairs are not smokeproof enclosure type.

For an emergency situation, where each known and signalled escape route has the external exit impeded and the occupants are directed to a single exit, exit 1 promotes a considerable increase in the distance to be covered and also in the total time evacuation of this building. For this scenario, the time of about 8 min is considered to be high and worrying for occupant safety, since the interactions between people, agglomerations and the bottleneck provoked in the circulation along exit 1 and staircase 2 are accentuated and the time, well above the maximum time of abandonment considered safe.

In relation to the total distance travelled to evacuate the building, during the simulations of scenario 1, in which the occupants leave the building by the nearest exits, a route of approximately 90 m is made for the longest way. With higher velocity, the case of scenario 2, the average total distance of about 85 m is similar to the previous scenario. However, in scenario 3, where exit 1 is used by all occupants of the building, the longest way to evacuate the building increases considerably, compared to the nearest escape route, totalling more than 200 m to be travelled. This route is evaluated as extensive, since the occupant is inside a closed building and in an emergency situation, which can increase the situation of panic.

Given this, an assessment was made, along scenario 3, of evacuation over time. Figure 85.5 shows the graph of people evacuated per time elapsed in seconds. A

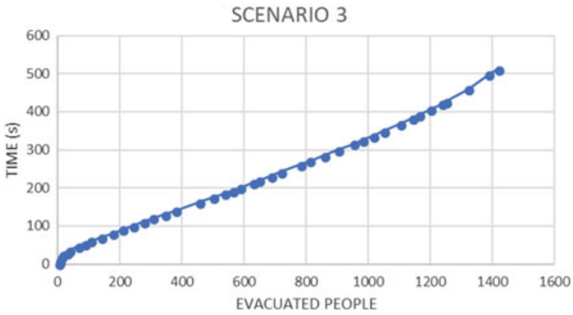


Fig. 85.5 Evacuation over time with scenario 3

quite linear evacuation is observed, even with the decrease of the people's velocity caused by clogging next to the exit.

85.7 Final Considerations

The study of the safe evacuation of people in a fire situation and in other emergencies has the main objective of saving lives. When in historical buildings, this search extrapolates for the attempt to preserve this heritage assets and its collection. The study on these themes contributes to the continuous search for knowledge applied to the fire's prevention and other technological disasters. This research had as objective the evaluation of the performance of historical interest buildings, regarding the safe evacuation of people, by means of computer simulation, using PTV Viswalk software.

It is understood that the adoption of an advanced computational performance-based approach, as done through the computational simulation study, promotes a better knowledge of the building and how people behave in these specific environments, in situations of abandonment. This tool promotes the best analysis of the building, since it is possible to visualize what happens in possible emergency situations. With the evacuation software, it is possible to recognize all the points that require more attention as narrowing that cause bottlenecks and, consequently, assists the safety professional as to what measures he will take at these critical points. Furthermore, the simulation brought the average maximum time that leads to the total evacuation of the building and also the distances that the occupant must go through to abandon the building.

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Chapter 86
Supply Chain Risk Management: The Evolution of Risk Source

Amanda Veit Braune Alvarez and Susana Carla Farias Pereira

Abstract This research aims to find out how SCRM publication has evolved and if risk sources have followed it. The applied methodology was systematic review. The findings indicate the increase of complexity in SC. In the same way, risk source changes as long as new disruptions and information are considered.

Keywords Supply chain risk management · Risk source · Systematic review

86.1 Introduction

Supply chain risk management has been gained relevance during the last decades. Organizations had realized that they have to improve not only the efficiency and effectiveness of internal processes, but also those that take place between companies [1]. In order to do so, it is necessary to manage the complex flows of materials, information and money considering the needs and objectives of all companies in the supply chain [2, 3]. Because of that, companies have included the management of their supply chains as a major component of competitive strategy [4]. This complexity can be directly related to risks. To exemplify how risks can impact on the performance of companies, Wagner and Bode [5] show two parallel issues: (i) the recent series of crises and catastrophes and (ii) the vulnerability of the modern supply chains. The first one covers natural disasters, terrorist acts and epidemics, also highlighted in other studies [6]. The second issue is sustained by the business environment competitive pressure and globalization.

As reported by Bode and Wagner [7], this complex environment has a negative impact on the companies' competitiveness, affecting the supply chain efficiency and unleashing supply chain disruptions, which, in turn, can cause a direct effect on their organizational operations. To minimize that, companies understood the need of identifying the risks which can affect their operations [8]. Overall, supply chain risk management is a relevant research area not just for the academia, but also for

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the companies due to the importance to control and mitigate the negative effects caused by risks [6]; as reported by Blos et al. [9], risk management and mitigation can capture finance aspects of decision-making as well. When identifying the risks, it is possible to find many risks sources. Jüttner et al. [10] considered three categories: environmental, network and organizational. On a more detailed classification, the risk sources are: environmental, supply, demand, manufacturing, logistics, information and financial [6].

Hence, this paper seeks to fill a literature gap: lack of studies considering risk sources and how they have been evolving [11]. Aiming to contribute, a systematic literature review was applied. In general, the number of scientific articles has increased exponentially over the last two decades.

In this context, this paper will present a systematic literature review that aims to explore supply chain risk management and how does risk source had evolved during the last years. This study had analyzed 67 documents from top ABS 2015 journals. According to this study, more than six different risk source classifications had been published since 2004. In addition to it, those classifications had evolved following supply chain complexity, increasing their specificities and chain comprehensiveness. As a contribution, this study could present the state-of-the-art risk sources and supply chain risk management relevance on top journals.

86.2 Methodology

Systematic review was applied to explore supply chain risk management. Steps defined by Tranfield et al. [12] were followed, as illustrated in Table 86.1.

Table 86.1 Systematic literature review stages

Stage I—planning the review	Stage II—conducting a review	Stage III—reporting and dissemination
Phase 0—identification for the need of a review	Phase 3—identification of research	Phase 8—the report and recommendations
Phase 1—preparation of a proposal for a review	Phase 4—selection of studies	
	Phase 5—study quality assessment	Phase—getting evidence into practice
Phase 2—development of a review protocol	Phase 6—data extraction and monitoring progress	
	Phase 7—data synthesis	

Source Tranfield et al. [12]

Table 86.2 Protocol for conducting a systematic literature review

Stage	Details	Goal
Scope review	Search in database as: Google Scholar, EBSCO, Emerald and Elsevier	Define research questions, constructs and keywords
Systematic review	Search in database: Scopus and Web of Science	Filtrate according to research question
Data analysis	Read the selected articles	Data analysis and synthesis

Table 86.3 Construct for systematic review

Constructs	Keywords	Codes	String
Risk management	Supply chain risk; risk management; risk source; risk drives; vulnerability; disruption; mitigation	Supply chain and risk	"Supply chain* + risk*"

86.2.1 Stage I—Planning the Review

At this step, the main point was to find out a research or/and practical gap. In order to do so, a research was carried out seeking for eventual gaps in supply chain risk management area. A lack of considering risk sources and how they have been evolving were found [11]. By this point, phase 0 was completed.

Proceeding to phase 1, finding out how supply chain risk sources have changed along the years was defined as a purpose. Based on it, specific objective and study review were delimited. Main objective of this research was to detect the main risks which affect supply chain management, looking into their evolutions and aspects. To achieve it, this study research question is: What are the main risks that affect supply chain management? Research protocol illustrated in Table 86.2 was followed.

To proceed to systematic review, research question constructs were described (Table 86.3).

86.2.2 Stage II—Conducting a Review

String presented in Table 86.3 was searched at selected database (Table 86.2) that was chosen aiming to identify SCRM most important papers. Scopus selection was the same made by Freitas et al. [13]. On the other hand, Markpin [14] had compared both databases, but found out more results at Scopus. In order to cover the greatest amount of result, both databases were considered. The first search showed up 1,846 documents (Scopus: 1,141; Web of Science: 723), from many different areas, years, sources and languages. Considering phase 4, the first selection needed to be done.

To do so, the most relevant journal in "Operations and Technology Management" area, according to the Association of Business School (ABS 2015), was chosen (Table 86.4). That choice was made based on Ghadge et al. [15], who consider ABS ranking "vastly referred and accepted in the academic world," and Rafols et al. [16], whereas this classification does not have much diverse set of subjects.

Thereafter, 257 documents were selected. The next step was made with the aid of Start Software that found out 107 duplicated documents, remaining 150 studies. Those remaining documents were analyzed based on abstracts and keywords, according to an inclusion and exclusion criterion (Table 86.5). While doing that, it was possible to note that not all of them represented this study subject focus, so another assortment was made. This time by whole article reading. For conclude phase 4, 67 articles were selected.

In order to study quality assessment (phase 5), selected articles should offer answers to the following questions [17]: (i) Do the articles context the same as the wanted ones in the search? (ii) Are these articles enough to consider that the study will embrace all theory? (iii) Do these articles have the necessary evidence so that the researcher can understand this theory? (iv) Do these articles have different sources? Can they be compared? (v) Considering these articles, is it possible to

Table 86.4 Journals selected

ABS 2015	Journal (ISSN)
4*	Journal of Operation Management (0272-6963)
4	International Journal of Operations and Production Management (0144-3577) and Production and Operations Management (1059-1478)
3	International Journal of Production Research (0020-7543), Journal of Supply Chain Management (1523-2409) and Supply Chain Management an International Journal (1359-8546)
2	Business Process Management Journal (1463-7154), International Journal of Physical Distribution & Logistics Management (0960-0035), Journal of Business Logistics (0735-3766) and Journal of Purchasing and Supply Management (1478-4092)
1	Benchmarking: An International Journal (1463-5771), International Journal of Logistic Management (0957-4093) and International Journal of Logistics: Research and Applications (1367-5567)

Table 86.5 Criteria and filter to select articles

Criteria	Inclusion	Exclusion
Focus	Study central theme about: supply chain management, supply chain risk, supply chain mitigation, risk sources or drives, vulnerability or disruption in chains	Central theme not about: supply chain management, supply chain risk, supply chain mitigation, risk sources or drives, vulnerability or disruption in chains
Access	Be written in English, Portuguese or Spanish	Not be written in English, Portuguese or Spanish. Do not have access to the download

generalize the conclusion and theory for other areas, studies and groups? (vi) Is the study relevant? All those questions had positive answers. The main factor to justify it is the way sources were selected.

As this review does not have selected specific year of publication, it was possible to embrace all theories and find articles from different sources, countries and years. After that assessment, data gathering and monitoring progress (phase 6) were done and also will be present in phases 7 (data synthesis) and 8 (report). These analyses were made by a bibliometric study.

86.2.3 Bibliometric Analysis

This analysis aimed to find more mutual document characteristics. The first one was made considering publication year. Assuming that on systematic review no publication year was filtered is possible to assume that this is a new research area, which is still growing. The presented database filter was made in August 2017, so 2017 publication was not totally considered. Next consideration was about each journal publication quantity. It is possible to believe that this subject is still gaining visibility on top journals, as it has many more publications at less rated ABS journals. The only way to verify this affirmation is analyzing each journal publication fluctuation along those years. Considering it, Table 86.6 reports how many articles have been published by each per year. It seems clear that the most ranked journal has longer gap in their publication periodicity. It may be caused by the stiffness and criteria of their publications. Publications first authors was analyzed as well. It shows that the UK is the country that has more publications in this area, followed by USA. Besides that fact, UK publications were made almost every year since 2004.

86.3 Conceptual Framework

86.3.1 Supply Chain Risk Management

Considering new business paradigm changing and the necessity to improve internal and external processes, companies understood that an efficient and effective supply chain can help them to achieve, develop and sustain competitive advantage in a business environment. Competition between companies requires them to apply new costs quality, agility and flexibility standards to meet the consumers' needs and expectations [18].

According to Christopher et al. [19] and Manuj and Mentzer [20], one topic that has gained importance over the last decades in the supply chain literature is risk management. Poorly controlled risks can lead companies to have bad results, for example: loss of reputation, lower product and process quality, inaccurate estima-

Table 86.6 Number of publications per year/journal

Year journal	04	05	06	07	08	09	10	11	12	13	14	15	16	17	Total by journal
JOM						1						1			2
IJOPM				1										1	2
POM				1					1						2
IJPR		1					1	1	1	1	2	3	3	3	16
JSCM															0
SCM IJ	1					1		2	1	2	1				8
BPMJ			1												1
IJPDLM	2				3			1	1	1		1	1	1	11
JBL											1				1
JPSM			1					1						2	4
BIJ										1				1	2
IJLM	1	1	1	1		1			1		2	3	2		13
IJLRA							1			1		1	1		4
Total by year	4	2	3	3	3	3	2	5	5	6	6	8	7	8	

tions. In the same way, König and Spinler [21] reckoned that 93% of the executives related risk as the top issue in supply chain management.

Considering those concepts, it is possible to affirm that companies' goals can only be easily achieved after the definition of which risks are involved in the business processes and how they will be managed by the firms [22]. However, management is getting challenged every time the environment gets more complex [15]. Overall, this complexity is an outcome of competitive pressure, which has been pushed up over the years by global operations. In addition to this, it is important to emphasize that the more complex the environment, the more difficult it will be to have a global competitive environment for the business organization [20].

According to Faisal et al. [2] and Mentzer et al. [3] when facing this scenario, companies started to manage their supply chain with the goal of attending their customers' demands, or in other words, this operational structure was understood as a way to get most of products, prices and markets. Regardless of the definition used before, it is important to understand that the SCRM worries about the operational and financial aspects of the decision-making. SCRM manages the supply chain risks to preserve the profitability and continuity for the chain, supported by the coordination and collaboration between partners [9].

Zhao et al. [23] corroborate with the importance of SCRM, arguing that turbulent and uncertain environments are growing in importance. On the other hand, Gaudenzi and Borghesi [22] argue that SCRM is a process which supports the SCM objectives, which will just be useful when "risk is understood as a multifaceted phenomenon."

To define SCRM, Jüttner et al. [10] indicate four constructs: (i) supply chain risk source; (ii) risk consequences; (iii) risk drives; and (iv) risk mitigating strategies. The relationship between the risk sources and the adverse supply chain risk consequences is moderated by two aspects: the supply chain itself and by the supply chain risk mitigation strategies. A better explanation is that risk sources have a direct influence on the adverse supply chain risk consequences, but these two factors can change that interaction result. The more supply chain construct aspects are inserted in this relation, the more adverse SCR consequences construct will be increased. On the other hand, the less the mitigating strategies are triggered, the more the adverse consequences will occur.

Along with this definition, regarding Wagner and Bode [5], SCRM strategies are related by two issues: (i) the crises and catastrophes, such as natural disasters, terrorist attacks and epidemics, and (ii) the vulnerability of the modern supply chains. The vulnerability cited in this definition refers to the globalized supply chain [24]. In the past, SC was domestic, with short distances or a restricted environment, but nowadays with global supply, the suppliers and buyers are placed anywhere in the world, which then changed the intra-firm business process to the inter-firm supply chain [5].

The changes mentioned above are the main reasons which caused the increase exposition to disruptions in the supply network and, consequently, caused the obstruction of the materials and information flows between the organizations [4], bringing in financial and demand losses, negative image and bad reputation for the companies involved [10].

Norrman and Jansson [25] add that another factor that contributes to the rising vulnerability into supply chain risks is the current business trends, for instance: reduction of supplier base, reduced buffers, increased demand for on-time deliveries in shorter time, shorter product life cycles and capacity limitation of key components.

An example of disruption occurred during 2011 in Tohoku in Japan, with an earthquake which affected the flow of the global automobile industry [24]. This event exemplifies how a disruption in one participant of the chain can affect all the networks. Chopra and Sodhi [26] point out about the difficulty in managing supply chain risks: They are commonly interconnected, carrying the possibility that when one risk is mitigated, another one is exacerbating, that way, qualifying the chain as "sensitive" [23].

86.3.2 Risk Source

As mentioned, risk in SCRM is a multi-dimensional construct, in which risk source is one of them. The definition of supply chain risk source is, according to [8], "any variables which cannot be predicted with certainty and from which disruptions can emerge." It is possible to find many classifications of risk sources in the literature, and in this section this classification will be addressed.

In the SCRM literature, risks can be classified from two to seven sources. Even when categorized into two groups, they can be different. The most embracing way is to consider internal and external risk sources [4]. Another broad way, classified by Svensson [27], is: atomistic (direct) and holistic (indirect) sources. For Holzmann et al. [28], risk sources are natural or a result of human activity. These classifications can be generic when studying risks and do not allow defining exactly the main source.

86.3.3 Risk Source Evolution

Considering the articles found, a literature review was done to supply chain risk, risk source and risk drives, disruptions and mitigation strategies as well. This was made because all these items are areas that support the supply chain risk management.

It was possible to notice that source definitions evolved during the last decade. Some of them were considered in the development of the ones which came up later on. This section will analyze the interaction between these definitions. Regarding the papers analyzed, they were selected by a systemic review and are considered a significant sample to analyze this theory.

When analyzed the year of publication of each source definition, the oldest one was published in 2000 [27] and the latest one in 2015 [6]. The first one [27] just distinguished the sources on atomistic and holistic. Considering that the authors started to write this article at least two years before the publications, this study was made by taking into account the 90's aspects of risk.

In 2001 [29], another two source studies were published: supply risks and demand risks. Even this source continued to appear in other coming studies; the description of those categories was getting more information and gaining complexity.

In 2003 [10], the environmental risk came into scene, together with network and organizational risk. In 2004 [25], the sources appeared as: external to the supply chain, internal and network-related. The external source in the description corresponds to the environmental one. Those two articles have been published, probably, in the same period.

Comparing with the one written in the 90s, those which were made in 2002/2003 already recognized more complexity in the chain. This relation shows that in the 90 s the risk was related just with the capacity (supply risk) and seasonal factors (demand risk).

Continuing in 2004, the risk sources were characterized into five sources: process, control, demand, supply and environmental [18]. These definitions were the same as Jüttner [8]. This analysis showed two interesting points: Both were based on Mason-Jones and Towill [30], and with just one year of difference on the publication date, they probably did not know that both of them were making the same proposal for sources. The other point is that the organizational source is now divided into two sources: process and control.

Four years after Christopher and Peck [18] publication, Wagner and Bode [5] published five risk source articles. This time, environmental source is separated into regulatory and catastrophic because newer events started to take place in the environment and new forms of red tape began to take effect. Process and control sources are now an infrastructure source. Nomenclature changes, and the definition gets even more detailed.

Finally, the latest articles which were analyzed were published in 2013 [4] and 2015 [6] considering: supply, demand, manufacturing, logistic, information, environmental risk and financial.

86.4 Conclusion

Considering the information, it is possible to conclude that in about 15 years the chains got more complex, and the events that could affect the supply or the demand side are not anymore caused just by seasonal or capacity disruptions. The environment, along this time, is not anymore understood just as something external to the supply chain like an economic, political or social event. This risk is now also caused by natural calamities and terrorist attacks.

The logistics side risk was first considered inside the supply and demand risks, and in the last studied analyzed is an important factor to look at. Just like information risk, that started to be taken into consideration too.

Probably, in 10 years' time the sources will be different, because the events and preoccupations will be some other ones.

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Chapter 87
Evaluation of Strategic Initiatives with MCDA for Issuing Natural Disaster Alerts

Glayse Ferreira Perroni da Silva and Mischel Carmen Neyra Belderrain

Abstract The chapter presents a multi-criteria decision model in order to support the evaluation and the definition of strategic initiatives by a Brazilian organization responsible for issuing natural disaster alerts. The model focused on values will allow the organization to establish priority programs and projects in line with its strategic objective.

Keywords Multi-criteria decision model · Strategic initiatives · Natural disaster alerts

87.1 Introduction

The implementation of alert systems is among the preparatory measures that enable organizations, communities, and individuals to respond quickly and effectively to natural disasters [4, 12, 13]. They can be defined as integrated systems to monitor, forecast, and assess disaster risks, which allow those exposed to adverse events to take timely and early action to reduce these risks [14].

As a consequence of the disasters that occurred in the second half of the last decade, especially the one that occurred in the mountainous region of Rio de Janeiro, in January 2011, it became essential to have a natural disaster alert system in Brazil. This system should put together scientific and technological competences in diverse areas of knowledge, especially meteorology, hydrology, geology, and natural disasters.

In this context, it was created the National Centre for Monitoring and Early Warning of Natural Disasters (Cemaden) whose mission is to monitor natural hazards in risky areas in Brazilian municipalities where disasters are likely to occur. Moreover, it conducts research and technological innovations that may improve their former warning system.

The Brazilian Federal Government's Program for Risk Management and Disaster Response, to which Cemaden is attached, has as its main objective to increase its

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capacity to warn about forthcoming natural disasters by improving its monitoring network. Therefore, it is extremely important for the agency to evaluate and select initiatives (translated into the form of priority programs and projects) that favor the improvement of its system of issuing alerts in order to achieve the strategic objective present in the federal government's multiannual plan 2016–2019.

Thus, this paper aims to structure a multi-criteria decision model that supports Cemaden's definition and evaluation of action plans (called initiatives), so that Cemaden achieves its objective. The value-focused thinking (VFT) method is used to identify the objectives related to the institutional values and to support the multi-criteria model. The multi-attribute value theory (MAVT) is used to measure the performance of the alternatives and to select the ones that better contribute to the achievement of the institution's strategic objective.

This paper is organized as follows: In Sects. 87.2 and 87.3, we present the theoretical foundations on which the study is based; in Sect. 87.4, we explain the methodology for the development of the work; in Sect. 87.5, which is subdivided into three parts, we explore the construction of the multi-criteria decision support model; and in Sect. 87.6, we present the final considerations.

87.2 Value-Focused Thinking—VFT

Keeney [9] defines VFT as the process by which one seeks to identify the values that a decision-maker should use as guides in the decision-making process. These values are translated as the way to identify decision opportunities, guide strategic thinking, and collect information.

Values are what really matters. They are the guiding force in the decision-making process in the VFT approach. Therefore, the work is guided toward the determination of values involved in the decision-making process and the generation of alternatives respectively [8].

The objectives represent a statement of what is needed to be achieved. They are also characterized by a decision-making context, an object, and a direction of preference. The VFT distinguishes 'fundamental objectives' from 'means objectives.' Fundamental objectives, in a decision-making context, are the ends that the decision-makers wish for. Means objectives represent the way to achieve these ends. For strategic decisions, fundamental objectives are defined as strategic objectives. Strategic objectives are those fundamental ones that guide organizational decisions and form the basis for more detailed fundamental objectives appropriate for specific decisions [10].

The process of structuring objectives results in a more precise and in-depth understanding of what is important in the decision-making context. If someone continues to structure a means-ends objectives network to lower levels, eventually he will get alternatives. So, with a means-ends objectives network, the specification natural stop point is alternatives or classes of alternatives.

87.3 Multi-attribute Value Theory—MAVT

Multi-criteria decision analysis (MCDA) is a methodology used to support decision making in the presence of multiple, and often conflicting, objectives. Such approach should not be seen as a tool for solving problems, but as a process [3].

MAVT is one of several MCDA methods available in the literature. This method employs value functions which assist decision-makers to numerically express their preferences for each mean-objective. The MAVT includes different aggregation models to aggregate the partial value functions and to calculate the overall performance of the alternatives. Among the existing models, the additive model is the simplest and also the most used one [2].

Unlike the MAUT, the MAVT does not seek for modeling the decision-maker's attitude regarding the risks. However, Ferreti [6] lists a number of advantages of the MAVT over other multi-criteria methods: It presents justifiable results, since it is based on fundamental axioms of rational analysis. It is able to handle a large number of alternatives without increasing the elicitation effort when compared to a smaller number of alternatives; and it allows that both quantitative and qualitative parameters be evaluated.

87.4 Methodology

The definition of the VFT means-ends objectives network is the first step of the intervention. It is based on documentary research and analysis of the relationship between the content of agency's internal documents (management reports, research plans, internal statute, etc.) and the content of federal government's multiannual plan 2016–2019.

In the sequence, the MCDA problem is structured based on the VFT network as suggested in Franco and Montibeller [7]. The relationship between fundamental and means objectives is the basis for the structure of the value tree (according to the top-down approach) and for the definition of the attributes. The lowest level objectives of the VFT network support the identification of decision alternatives (referred to as initiatives), which are later prioritized based on the decision-makers' judgment.

87.5 Application

The following subsections detail the step-by-step application of the methodology, as described in the previous section.

87.5.1 Step 1—Stakeholders Identification

As there was already a consensus among the participants on the need to define and to evaluate initiatives aimed at achieving the institution's strategic objective, the first step was to select the stakeholders who would participate in the construction of the decision model. Based on the dimension of power and interest [1], we selected the experts responsible for monitoring and for issuing alerts, because they were identified as the stakeholders with the greatest power and the greatest interest in the decision.

87.5.2 Step 2: Structuring the MCDA Problem

Figures 87.1 and 87.2 illustrate the VFT means-ends objectives network and the MCDA value tree, respectively. The relevant attributes for the decision making are listed at the lower level of the value tree. Attributes are a quantitative or qualitative measure of performance associated with a particular criterion [2]. In order to maintain the rigor of the method, according to [11], good attributes have to meet the following necessary properties: be unambiguous, comprehensive, direct, operational, and understandable.

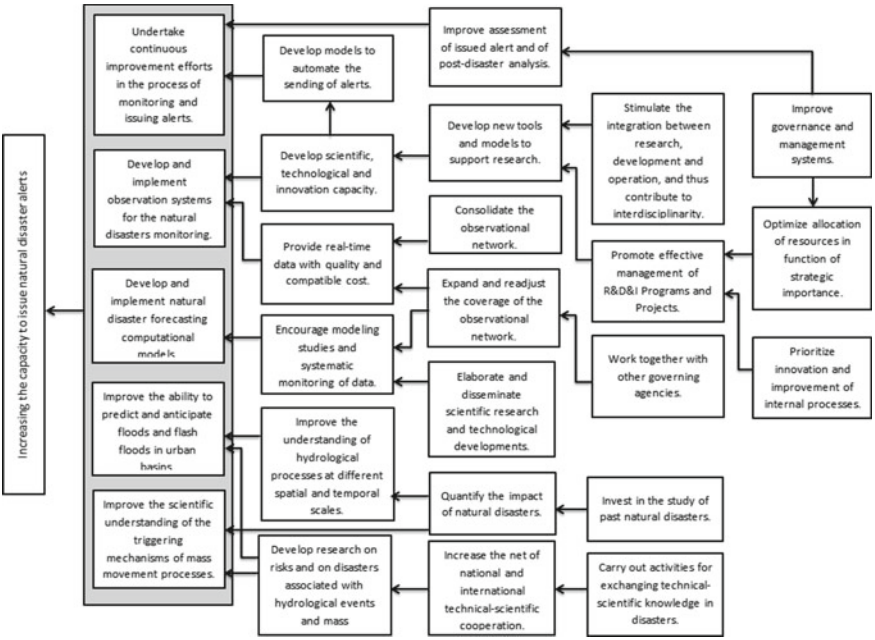

Fig. 87.1 A means-ends objectives network for Cemaden

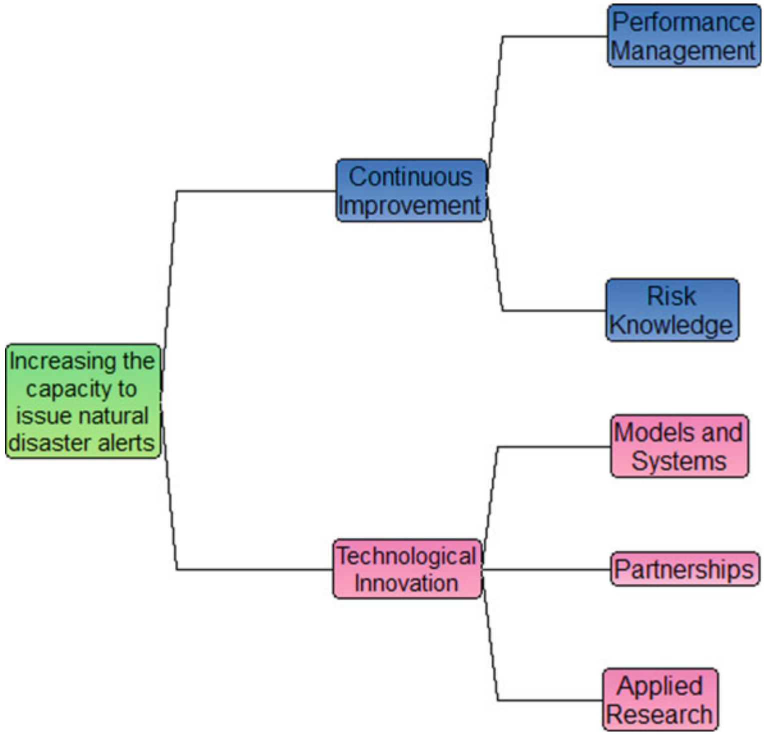

Fig. 87.2 MCDA value tree

The attributes presented are of a qualitative nature, with five levels of impact, preferably ordered according to the value judgments of the decision-makers (Table 87.1). The value function was obtained using the direct rating method. As suggested by [5], value zero was associated with the worst acceptable level (N_1—the

Table 87.1 Description of attribute impact levels

Impact level	Reference level	Value function	Description
N_5		100	Very high contribution
N_4	Good	80	High contribution
N_3		50	Medium contribution
N_2	Indifferent	30	Low contribution
N_1		0	Negligible contribution

alternative contributes negligibly) and value 100 was associated with the most feasible level (N_5—the contribution of the alternative is very high). Both levels serve as an anchor to assess the relative value of the other levels of impact, according to the judgment agreed by the decision-makers.

Finally, after some meetings with the group of decision-makers, we listed some initiatives (here considered as decision alternatives) that can contribute to the achievement of the Cemaden's strategic objective, which is to increase the capacity to issue natural disaster alerts: (1) promoting seminars and workshops with the scientific community and the Civil Defense; (2) implementing a project office dedicated to the management of research, development, and innovation programs and projects; (3) developing flood-forecasting tools using nowcasting; (4) implementing a mobile application with features of crowdsourcing in order to offer a channel of communication with society and operate as a data collector; (5) defining the performance indicators for alerts; (6) creating national networks for scientific and technological cooperation in disaster management; (7) operating the product of satellite precipitation estimates derived from NASA's Global Precipitation Measurement Mission.

87.5.3 Step 3—Alternatives Evaluation

Table 87.2 presents a local evaluation of the alternatives toward each sub-criterion, according to the value functions defined in Table 87.1.

Table 87.2 Local evaluation of the alternatives for the sub-criteria

Sub-criterion		Performance management	Risk knowledge	Models and systems	Partnerships	Applied research
Alternative 1	Level	N_4	N_4	N_1	N_3	N_2
	Score	80	80	0	50	30
Alternative 2	Level	N_1	N_1	N_5	N_1	N_5
	Score	0	0	100	0	100
Alternative 3	Level	N_1	N_5	N_5	N_1	N_3
	Score	0	100	100	0	50
Alternative 4	Level	N_4	N_5	N_5	N_1	N_2
	Score	80	100	100	0	30
Alternative 5	Level	N_5	N_1	N_3	N_1	N_4
	Score	100	0	50	0	80
Alternative 6	Level	N_2	N_4	N_1	N_5	N_4
	Score	30	80	0	100	80
Alternative 7	Level	N_1	N_5	N_4	N_1	N_1
	Score	0	100	80	0	0

Later, it was elicited the trade-off values of criteria and of sub-criteria and obtained the normalized weights, in order to allow a posterior aggregation of all the evaluation dimensions. The method used to determine the trade-off values was Swing Weights, based on the compensation concept [5] (Table 87.3).

In the phase of partial and global evaluation of the alternatives, it was used the V.I.S.A. software, a computer program for decision support developed by SIMUL8 (www.simul8.com). Figure 87.3a illustrates the performance of the potential actions in relation to the main objective. The global performance of the alternatives in the multi-criteria model was obtained from the aggregation of the partial performances, resulting in the score shown in Fig. 87.3b. Table 87.4 shows the alternatives sorted according to the overall evaluation obtained.

Finally, as the last stage of the evaluation phase of the alternatives, we performed the sensitivity analysis. Figure 87.4 shows the behavior of the global evaluation of the alternatives in function of the variation in the trade-off value of the criterion 'continuous improvement.' It can be seen that as the trade-off value of criterion increases,

Table 87.3 Trade-off values of criteria and of sub-criteria

Criterion	Sub-criterion	Assigned value	Normalized weight	Normalized weight (%)
Continuous improvement	Performance management	60 points	0,38	38
	Risk knowledge	100 points	0,62	62
Technological innovation	Models and systems	100 points	0,46	46
	Partnerships	40 points	0,18	18
	Applied research	80 points	0,36	36

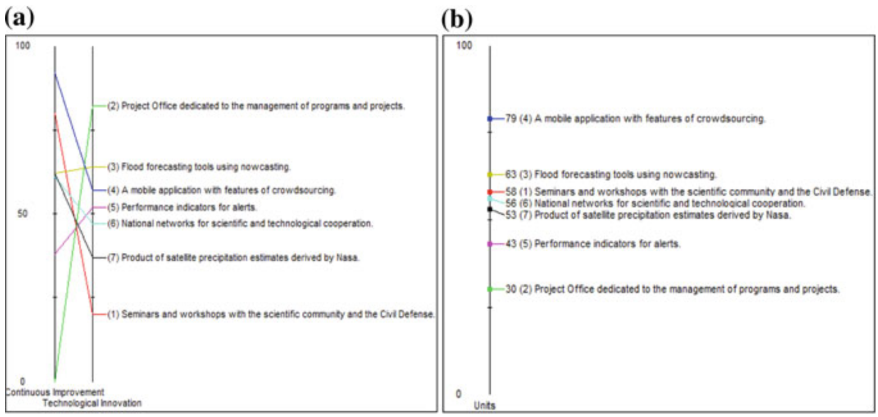

Fig. 87.3 Performance of the potential actions relative to the main objective (**a**) and global performance of the alternatives (**b**)

Table 87.4 Final ranking of the alternatives

Alternative (short)	Overall evaluation	Rank
4. A mobile application with features of crowdsourcing	79	1
3. Flood-forecasting tools using nowcasting	63	2
1. Seminars and workshops with the scientific community and the Civil Defense	58	3
6. National networks for scientific and technological cooperation	56	4
7. Product of satellite precipitation estimates derived from NASA	53	5
5. Performance indicators for alerts	43	6
2. Project office dedicated to the management of programs and projects	30	7

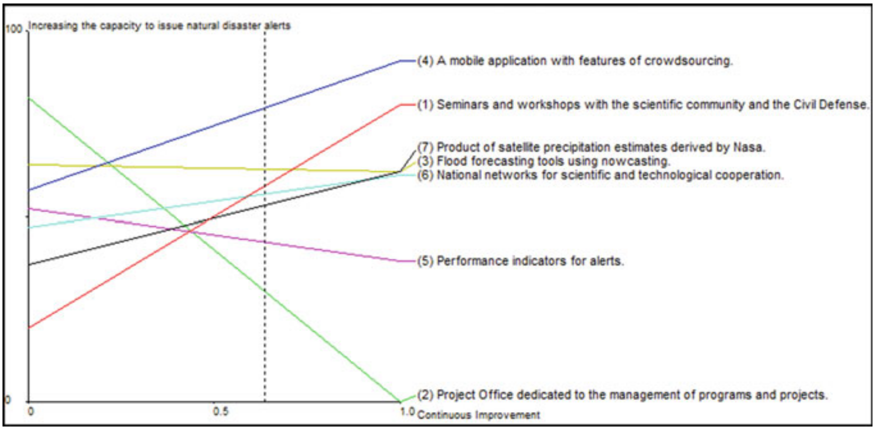

Fig. 87.4 A sensitivity analysis for the 'continuous improvement' criterion

the overall evaluation of alternatives 1, 4, and 7 improves significantly, whereas that of the Alternative 2 drops to zero when trade-off value of criterion reaches 1. This means that if 'continuous improvement' is the only criterion considered in the model, the overall evaluation of Alternative 2 will be zero. Variations around 10% above and below the trade-off current value of the criterion do not change its overall value, as the order of preference of the alternatives remains the same. Thus, it can be concluded that the model is robust in relation to the 'continuous improvement' parameter.

87.6 Final Considerations

This paper aimed to structure a multi-criteria decision model to support the definition and evaluation of strategic initiatives by a federal public institution responsible for monitoring and for issuing natural disaster alerts. The VFT method proved to be useful in defining the fundamental and means objectives, focusing on the values that guide the institution's operation. So, we constructed the multi-attribute value model and evaluated the performance of each initiative in relation to the institutional strategic objective, considering the decision-makers' preferences.

We believe that the overall score obtained by the strategic initiatives will be able to subsidize strategic decisions about prioritization of programs and projects in order to reach institutional objective present in the federal government's multiannual plan 2016–2019. In a limited public budget scenario, appropriate allocation of financial resources which will really bring results is vital for any institution.

Suggestions for future works are: inclusion of a criterion related to the budget in the model, since this may be a restriction for the implementation of the evaluated initiatives, participation of at least one manager in the process of model construction and using cognitive maps for the investigation of additional criteria, above all of quantitative nature.

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Chapter 88
The Human Factor in Project Risk Management and Resilience

Paulo Yazigi Sabbag

Abstract Resilience in adults is the ability to cope with severe adversity. The judgment of individuals is affected by the presence of risk. The human factor in project risk management needs to be considered in terms of the effectiveness of the processes involved. This article presents the ERS scale for resilience in adults.

Keywords Risk · Resilience · Management · Scale

88.1 Introduction

Even though project risk management is practiced professionally by countless organizations that complete tens or hundreds of projects a year, there remains doubt about the importance of this technique. An issue is the human factor in the face of risk.

The problem that will be examined here is how to ensure uniformity and effectiveness in the practice of project risk management. This article considers three theoretical domains: project risk, judgment bias and resilience in individuals. An ERS scale factor analysis will then be presented to measure resilience in adults to discuss the care that needs to be taken in the practice of project risk management.

88.2 Theoretical Domain

Among various types of operations, projects present the greatest risk and uncertainty. This is the reason why risk management methodologies have been developed and disseminated more for projects than routine operations, even though they can be applied to them as well.

To the PMI, the Project Management Institute, a project is "a temporary endeavor undertaken to create a unique product, service or result" [8, p. 4]. The PMI standard

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states that: “all projects pursue risks, because they are unique undertakings with various degrees of complexity which seek to provide benefits” [8, p. 397]. Since the definition of a project is an endeavor, its successful execution is less probable. Since it is temporary, there is less chance of achieving its objectives in the given time frame. Since it is unique, it involves the unknown and uncertainties.

The norm defines individual risk as “an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives” [8, p. 397]. The overall project risk represents the effect of uncertainty on the project as a whole: There is risk in the context that surrounds a project, in the organizational conditions where the project occurs and risks due to the situation of the project’s execution itself.

This standard [8, p. 395] establishes two objectives for project risk management: to decrease the likelihood and impacts of negative risk events, and to increase the likelihood and impact of positive events. To achieve these objectives, the norm envisions seven management processes associated with this “knowledge area,” with their respective objectives:

- **Plan Risk Management**: the process of deciding how to conduct risk management activities for a project;
- **Identify Risks**: the process of determining which individuals risks may affect the project and documenting their characteristics;
- **Perform Qualitative Risk Analysis**: the process of prioritizing risks for analysis or later action through the combined evaluation of their probability of occurrence and impact;
- **Perform Quantitative Risk Analysis**: the process of numerically analyzing the combined effects of identified individual risks and other sources of uncertainty on overall project objectives;
- **Plan Risk Responses**: the process of developing alternatives, selecting strategies and agreeing on actions to enhance opportunities and to reduce threats to project objectives;
- **Implement Risk Responses**: the process to execute agreed-upon plans to respond to risks, which may be anticipated responses (Plan A) or contingency responses (Plan B);
- **Monitor Risks**: the process of monitoring the implementation of the agreed-upon plans, tracking the identified risks, identifying and analyzing new risks, and evaluating risk process effectiveness throughout the project’s execution.

These management processes are not mandatory, and the project manager may select them on a case-by-case basis. The application of the PMI standard is methodical: Each process contains inputs, tools and outputs, and produces documents for management planning and control.

Created as a collection of best practices worldwide, the PMI standard presents established tools and techniques for each management process. To identify risks, it suggests brainstorming, root causes, SWOT analysis, and analysis of assumptions and existing documentation. For qualitative analysis, it suggests probability and impact assessment to select the most severe risks. To develop responses, it suggests using decision trees and the expected monetary value technique. For quantitative analysis, it suggests Monte Carlo simulation techniques.

In terms of weighing the consolidation of risk management techniques, it is still often observed that the result of their application is innocuous, that is missing the point: The best technique may be ineffective or inefficient if who is applying it does not possess the required skills. It is the human factor that qualifies the application of these techniques and tools. In this aspect, resilience may be the determining factor to consider.

The American Psychological Association [1] dictionary defines resilience as the "process and result of successfully adapting to difficult or challenging life experiences, especially through mental and behavioral flexibility and by adjusting to external and internal demands."

Others relate resilience to risks: Ong et al. define resilience as "a pattern of functioning indicative of positive adaptation in the context of risk or adversity" [6, p. 82]. Most of these definitions are related to a proactive ability to adapt.

High resilience signifies not just recovering from, but also coping with a situation without serious physical, psychic or social impacts. Resilient functioning includes not just attributes of the individual's personality, but also contextual attributes, such as coping strategies and social abilities.

When the subject is risk, there is evidence that perception, acceptance and tenacity in coping with risks are affected by the condition of the individuals involved in the processes. Tversky and Kahneman [11] point to various biases in terms of judgment. Situational acceptance is most associated with individual risk: Individuals tend to avoid risks when exposed to gains and take risks when exposed to losses. Salience is another bias: Disasters that attract greater media attention even though rarer are perceived as riskier. Ease of recall (availability heuristics) is another bias: Rare risks even though they are memorable tend to be underestimated, while everyday risks are overestimated. Selective attention is another: It is more likely that close, obvious risks will be managed, while inconceivable risks that are difficult to understand are underestimated. Lupton [5] adds cultural bias: Risks that are perceived as unacceptable by society cause more terror. The author also mentions the power of the group: Members of less powerful groups tend to worry about risks more than members of powerful groups [5]. Douglas [3] adds the sense of subjective immunity: People tend to underestimate risks that are supposedly under their control. Another bias that she cites is familiarity: Familiar risks increase self-confidence which can lead to the underestimation of risk.

All these biases are based on the subjectivity of the individual who is facing risk. The understanding of the phenomenon of resilience on the part of individuals enables us to deal with these biases, which helps us be more effective in managing risk. The PMBOK Guide refers to an emerging trend and practice in risk management known as "project resilience" [8], p. 399 which deals with emergent risks—those that can only be recognized when they occur: They can be dealt with by developing a project's resilience.

88.3 Discussion

The most used scale used to measure resilience in adults in English-speaking countries was created by Wagnild in 1993 [12], and it reveals five factors in resilience: perseverance; equanimity (calm, good humor and emotional control); life purpose; self-confidence; and existential isolation (sense of being alone). In Brazil, Pesce et al. [7] recognized the cultural influence of this scale when they validated it with young students and have found six factors equivalent to the original factors using different terms: the ability to resolve situations; values; independence; determination; self-confidence; and the ability to adapt. The CD-RISC scale [2], created to support change management, produces a single scale that considers: personal competence, confidence in instincts, a tolerance for negative effect, the positive acceptance of change, control and spiritual influences.

The ERS scale is based on a questionnaire that considers 11 theoretical factors [9]. After a pretest, the questionnaire was applied to a management specialization course for young professionals in 60 Brazilian cities. With 1503 valid observations, the scale was validated by using the IRT—item response theory. Of the 40 questions, nine were eliminated and a resilience score was created on a scale from 1 to 100. In the ERS scale, the resilience scale was classified into higher resilience for scores above 77 and lower resilience for scores less than 66. However, the existence of a unique score tells us little about the construct.

The exploratory factor analysis (with a rotated component matrix) discussed here reveals nine factors that make up resilience. Various "structural equations" were tested to gauge whether some of these factors determine others, without success. These tests indicate that resilience is a single construct and that the nine factors with their weights explain the phenomenon, as shown in Table 88.1, with original questions written and validated in Portuguese.

In choosing the nine factors, the commonalities extracted varied from 0.679 (Question 24) to 0.304 (Question 1). The factors numbered from 1 to 9 in the columns of Table 88.1 are elaborated below (the percentage that they contribute to the global resilience score appears between the parentheses):

1. **Self-efficacy and Self-confidence** (17.24%): Also known as "internal locus of control," self-efficacy means the deep belief that an individual governs his own lives, not destiny. This factor goes hand in hand with self-confidence, the belief in one's ability to face adversities.
2. **Problem solving** (12.75%): It involves resolutivity, which was also found by [2, 7].
3. **Temperance** (11.65%): It is equivalent to Wagnild's [12] regulating emotions with equanimity.
4. **Empathy** (11.65%): Only the ERS scale mentions this factor, which may be attributed to Brazilian culture. The ability to put yourself in place of another and feel sympathy, compassion and having the ability to comfort others.

Table 88.1 Explanatory factor analysis of the ERS scale for resilience in individuals

Variable: factor:	1	2	3	4	5	6	7	8	9
28. Trying to solve problems, I am confident in my strengths to compensate for my weaknesses	0.563								
8. I trust in my ability to discover how to solve arising problems	0.555								
9. I consider work as important and valuable, and this ensures my complete attention and effort	0.522								
27. My life results of choices and decisions that I make, and this is my freedom	0.507								
12. I have a clear view of what I want to achieve and a purpose and focus in life	0.495								
2. When I face a difficult situation, I am confident that everything will turn out well	0.481								0.332
13. I believe that I am very able to cope and respond well to challenges	0.437				0.391				
1. I consider challenges to be a good way to learn and improve	0.409								
7. People say that I do not interpret events and situations well		0.674							
14. People rarely seek my help to solve problems		0.578							
26. I tend to keep distance from colleagues at work to protect myself from the impact of changes		0.540						0.391	
31. My friends tell me that I break down and lose my way when faced with a serious problem		0.513	0.326						
21. I am almost unable to controlling my emotions helping to keep focus on activity		0.493	0.396						
19. When I discuss a “hot” topic with others, I am able to keep my emotions under control			0.794						

(continued)

Table 88.1 (continued)

Variable: factor:	1	2	3	4	5	6	7	8	9
18. I can control the way I feel when setbacks occur			0.743						
24. If a colleague is bothered by something, I have a good idea why				0.804					
23. By looking at people's faces, I can perceive the emotions that they are feeling				0.766					
25. When colleagues feel stress from change, I support them because I understand what they are going through				0.594				0.414	
4. I am open, creative and comfortable with paradoxes and ambiguities					0.694				
5. I feel that my participation makes a difference and promotes change					0.543				
3. I am the type of person who lives for trying to accomplish new things	0.387				0.438				
16. I recognize my interdependence with others and ask for help when I need it						0.725			
17. I am considered flexible and I keep bridges open with people because this is valuable						0.550			
15. I maintain strong social ties and I feel comfortable in various social situations					0.416	0.514			
10. I act when facing problems, even when I am not sure of the outcome							0.600		
30. I bear a lot of pressure at work and in my personal life							0.594		
6. I am used to facing stressful changes, trying to understand them and learn from them							0.581		
29. I try to plan, but I am open to feedback to reevaluate them						0.351		0.505	
20. I try to maintain a positive influence on changes that occur around me	0.371							0.414	
22. When a problem arises, I think of many possible solutions before trying to solve it									0.707
11. When my first solution does not work, I try some other solutions until I find one that works	0.306								0.439

5. **Proactiveness** (10.57%): The propensity to act or cope with new or though situations, including tolerance for ambiguities and pursuing social ties. This is also associated with purpose in life from an existential perspective.
6. **Social skills** (10.16%): The ability to articulate support when facing extraordinary situations, in opposition to the tendency to isolate oneself which is characteristic of those with reduced resilience.
7. **Tenacity** (9.73%): The vitality to persevere without giving up despite difficulties. This factor was also cited by Wagnild [12].
8. **Learned optimism** (8.20%): The ability to counter negative emotions and thoughts with positive emotions and thoughts, to balance them to avoid disbelief, despair and helplessness—a concept mentioned by Seligman [10].
9. **Mental flexibility** (8.05%): The ability to substitute tactics that do not work for others and letting go of tactics that have been shown to be ineffective.

Table 88.2 presents the tests for sphericity (homogeneity of variance) and the sample's adequacy. Table 88.3 presents the average sub-scores by factor, calculated considering the weights for each question in Table 88.1. The overall average of 72.5 corresponds to moderate resilience in the sample, which indicates that the phenomenon of resilience is not rare. Later research with 4,000 scale users revealed 30% with high resilience, 40% with moderate resilience and 30% with low resilience.

Table 88.2 KMO and Bartlett's test

Kaiser-Meyer-Olkin measure of sampling adequacy		0.846
Bartlett's test of sphericity	Approx. chi-square	5803.213
	Df	465
	Sig.	0.000

Table 88.3 Sub-scores by resilience factor

	Average:
F1_WEIGHT—self-efficacy and self-confidence	70.9
F2_WEIGHT—problem solving	76.9
F3_WEIGHT—temperance	63.7
F4_WEIGHT—empathy	70.6
F5_WEIGHT—proactiveness	75.6
F6_WEIGHT—social skills	80.0
F7_WEIGHT—tenacity	75.5
F8_WEIGHT—learned optimism	81.3
F9_WEIGHT—mental flexibility	58.4
Overall resilience score	**72.5**
Standard deviation	9.23

Note in Table 88.3 that "mental flexibility" and "temperance" are the factors with the lowest average scores in the sample, while "learned optimism" and "social skills" are the factors with the highest average scores in the sample.

Considering that people involved in project risk management present various degrees or scores in terms of resilience, along with the known judgment biases, there are risks related to the relative risk acceptance or aversion of the individuals involved, which reduces the efficiency of the planning and implementation of responses to risk. This is the human factor in action in the practice of project risk management.

The reduced ability in the practice of risk management processes partly explains its reduced effectiveness, but the resilience score of those involved needs to be considered. To reduce the deleterious effect of the variation of resilience among those involved, some caution should be taken to get the greatest effectiveness out of project risk management practices:

1. Given the variation in resilience scores and the perception/acceptance of risk, collective efforts dealing with risk management processes tend to be more consistent than individual efforts: They make it possible to identify more and more varied risks, determine a conservative evaluation of the most severe risks and, in turn, have to face planning larger groups of anticipated responses (A plans) and contingent responses (B plans).
2. If the team involved with risk management presents scores equal to the sample's averages, its reduced mental flexibility will incite it to restrict its scope to known risks that have greater chances of occurring. Care should be taken in identifying improbable, unthinkable and unimaginable risks. Reduced temperance in turn can harm the ability to face risky situations and crises. Caution recommends that discipline be maintained in the implementation of contingency plans (B plans) and warns of the possibility that their use may lead to crises, which will require moderate or elevated resilience to properly deal with these crises.
3. The qualitative analysis of risk is surrounded by bias and subjectivity, which again makes a collective effort preferable. The effect of pessimistic and skeptical moods tends to be mitigated by this. Caution should be taken to avoid groupthink which is defined by Janis [4] as a desperate search for consensus at any cost eliminating conflict in the most powerful areas of organizations.
4. The factors related to emotions—temperance, empathy and social skills—if they are elevated in the project team, indicate a humanizing approach to management which considers the emotional aspects affected by the project. Such a group may also present greater caution in terms of change management, in facing resistance to change and addressing the needs of those affected by crises.
5. Rather than classifying individuals as risk-lovers, risk-takers, risk-avoiders or being risk-averse, as many do ingenuously without any scientific basis, the evaluation of resilience scores based on validated scales makes it possible to recognize whether those involved in risk management are better equipped to face these risks, based on the assumption that this way judgment bias may be reduced.
6. The PMBOK Guide indicates that one of the emerging trends and practices in risk management is considering "Project resilience" [8, p. 399] when facing

emergent risks—those that can only be recognized after they occur: They can be faced by the development of project resilience. Project resilience, according to this norm, requires: contingency margins for schedules and budgets; flexible processes; a skilled team; frequent reviews when the first warning signs appear; and the collection of information. Curiously, the norm does not mention individual resilience as a relevant factor. It is evident that improving the resilience scores of those involved also increases the project's resilience.

7. For those who recognize and are aware of their resilience scores, the permanent practice of risk management tends to favor their learning and sustains and improves their resilience scores. This is due to the fact that any success obtained tends to increase self-confidence, learned optimism and proactiveness, and at the same time collective efforts tend to increase empathy, social skills and temperance.

88.4 Conclusion

The existence of a scale to measure resilience in adults can be relevant in complementing the goal of obtaining greater effectiveness in project risk management. Understanding resilience scores can be useful, but developing a comprehension of the nine factors and the sub-scores that comprise resilience can be even more useful.

Recognizing that those involved in project risk management present a variety of resilience scores reinforces the cautions suggested here and at the same time can contribute to the improvement of their resilience through disciplined and permanent effort.

Educating project managers about adult and project resilience has proved to be an initiative as valuable as educating them about risk management techniques.

Future studies can test the effectiveness of the suggested cautions and at the same time measure the real effectiveness of project risk management. Another issue for future study is evaluating the cohesion of a project management team, which may affect its performance in relation to managing risk. Correlating resilience scores with judgment biases in situations of risk is another promising possibility.

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Part IX
Service Operations and Servitization

Chapter 89
Public Service's Perceived Quality: A Literature Review

Paulo Rafael Minetto Maceta and Fernando Tobal Berssaneti

Abstract This study explores the use of perceived service quality concept in the public service. A literature review using a bibliometric approach was conducted in order to identify the trends, characteristics, main topics, and other relevant aspects about the public service's perceived quality in the academic literature.

Keywords Public service · Perceived quality · Literature review

89.1 Introduction

Quality is a multidimensional concept and contains different views in the academic literature, and the service quality is based on customers' judgments [21]. The perceived quality is determined by the comparison of the perceived service with the expected service [6].

The public services are very important since in both developed and developing countries are essential SERVICES and are a facilitating factor for nation's evolution in a competitive world and also have a deep influence on the quality of life of the citizens [2].

This thematic is relevant since que measurement of the satisfaction, and by consequence, the perceived quality, for private services are deeply different from that regarding public services [13]. An opportunity to develop high-quality services in public organizations can come from measuring their services´ quality perception [8].

This study analyzes the perceived quality in the public sector through a literature review using a bibliometric approach. The first part of the study shows a literature review, followed by the method description. Then the results are shown followed by the discussion and conclusion sections.

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89.2 Perceived Quality

Organizations have become more customer-centric, and the customer satisfaction is a well-studied topic that can be applied to virtually all kinds of products and services [27], and the higher the value perceived by customers, through the perceived quality, the greater the customer satisfaction [23]. It is important for organizations not only to understand the expectations and desires of their clients, but to focus efforts on reaching them [7].

The measurement of the customers' quality perception of the services is important to determine the clients' experience, which is essential for the improvement of processes, focusing on their efficiency, and effectiveness [25]. In order to measure the quality of a service, it is necessary to consider two factors: the technician factor, referring to the final quality of the generated result, and the functional factor, which is related to the perceived usefulness of the service to the client [10].

The quality of the services offered acts as an overall value of the quality judgment by the clients, and the quality of services can be understood as the added value to the customer [23], the process quality being, frequently, adopted as a driver of customer satisfaction [27], and service quality can become a competitive advantage for organizations [24].

Perceived quality is defined as the client's judgment about the excellence of an organization's service being different from the quality objective measured, which involves only objective aspects [23]. In order to measure the quality of a service, it is important to consider the quality perceived by several groups of clients, because the perceived quality could vary between these groups [15].

89.3 Public Sector and Public Services

According to Fryer et al. [11], the public sector consists of organizations that deliver government goods and services at the local and national levels, important to note that the boundaries between the public and private sectors are not well defined and there is a certain overlap of activities. Public organizations seek to satisfy the public representatives to whom their organization are serving and are responsible for producing measures that show the achievement of goals and objectives [4, 9].

A relevant aspect of the public sector, according to Arlbjørn et al. [3], is that the lack of a market mechanism generates the need for the political management of the organization's priorities and objectives, leading to multiple goals, that many times, they are difficult to be conciliated.

As in the private sector, the public administration, according to Pilkaitė and Chmieliauskas [16], is demanded by their stakeholders to generate performance and transparency, in order to make better decisions that are reasonable if compare the spending of money from taxes and the improvement of the effectiveness of services provided to citizens. This pressure caused the public sector to undergo a major change in the late 1980s, replacing a more bureaucratic model with the New Public Management (NPM), a movement to modernize the state apparatus, where citizens leave the role of taxpayer to assume the role of customer-citizen, making the focus of public management moves from the internal processes to results and outputs [17].

Björk et al. [5] show that the improvement of the public services' quality, as well as the maintenance or reduction of public spending and the validation of the internal processes in the public sector organizations, comes from the new focus due to NPM. In the same way, Rhodes et al. [19] explain that public organizations started focusing on results, paying attention to deliveries and outputs rather than inputs, to meet the needs of public service beneficiaries, who are now considered as clients.

With the new paradigm brought by the NPM to treat citizens as customer-citizens, there was an increase in the concern to measure and evaluate the deliveries of public services, which should not only be done by quantitative factors, but also by qualitative factors related to the quality of services [20].

Nielsen and Pedersen [14] present e-government (eGov) as the next major reform in the public sector after NPM. The eGov improves and delivers of public services [1] and their implementation provides an opportunity for the commitment of public agencies to transform the governance of public administration [22].

89.4 Methodology

Randolph [18] exhibited the goal of a literature review as a way to understand the academic literature of a research area, the qualitative and quantitative data's extraction, the integration and generalization of the findings and the trend's analysis.

The bibliometric review is a research´s field within the literature review techniques that analyze the bibliographic material quantitatively and is used to generate insights and provide a general overview about a field of academic research [12].

This study uses a bibliometric approach and focuses on two main databases: ISI Web of Science and Scopus. They were chosen because, according to Wang and Waltman [26], they are the two most important multidisciplinary bibliographic databases in academic literature. In both databases were used the same search string: ((“Perceiv* Qualit*” OR “Perceiv* Serv* Qualit*” OR “Perceptio* of qualit*” OR “Percept* of serv* qualit*” OR “Qualit* percept*”) AND (“public* sector*” OR “public* servic*” OR “public* manag*” or “public* organi*”)). The symbol “*” was used to allow in the search results of documents that contain correlated terms with the searched ones like plurals, gerunds, substantives, and verbs. Additionally, were used two filters: (1) restrict search for “Articles” and (b) restrict search for papers from 1980 (the beginning of the NPM) to 2018 (search's date). The search was made in July 2018.

As a result of this, literature search with the parameters described was obtained 139 papers in Scopus and 113 papers in ISI Web of Science. Then, all the papers were checked to eliminate the duplicate occurrence in both databases what result in the exclusion of 72 duplicated papers, resulting in an initial sample of 180 papers.

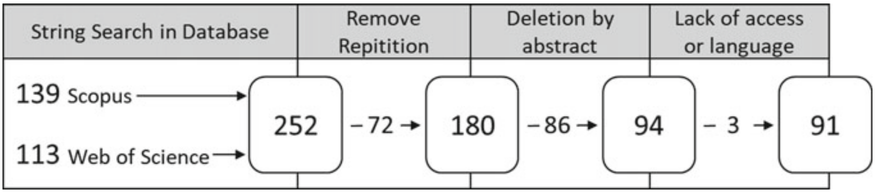

Fig. 89.1 Articles selection steps and sample size. Elaborated by the authors

As the second step of result's refining, all the abstracts of the documents were read to confirm the linkage between the article topic and the study theme: the perceived quality in the public services. During this step, 86 articles were excluded from the sample, resulting in an intermediate sample of 94 papers. The final step was the exclusion of three articles, two of them due to the author's lack of access to the papers and one of them due to be written in Dutch, a language that is not known by authors. This lead to a final article's list was composed of 91 studies. All the steps and the size of the exclusions, intermediate and final list could be found in Fig. 89.1.

All the 91 articles that are included in the final list were read and were raised data in two main categories: article data and study data. The article data included the year of publication, journal name, author's name, and country of affiliation of each author. The study data were composed of the geographical focus, methodological approach, and the public service type analyzed for each study, if the article compares the public and private sector and if the service analyzed was an e-government service. A bibliometric analysis in the keywords, abstracts, and the author's co-citation was also performed using the VOSviewer software version 1.6.8.

89.5 Results

Initially was analyzed the year of publication of the studies presented in the final list, which is shown in Fig. 89.2. All the papers were published in a 30 years' period, from 1988 to 2018, been 70.3% of the papers published in and after 2010. The articles were published in a total of 79 journals; the majority of them published only one article. The journals with the higher number of publications are the "Managing Service Quality", with four articles and the "International Journal of Sustainable Transportation" that has three published articles.

When the authors were analyzed, a total of 242 authors were found and, in the same manner as the journals, the majority had only one paper published. The authors with a bigger amount of articles published are Achilleas Kontogeorgos and Shahab Alam Malik that published three articles each. Another 13 authors published two articles. The authors had affiliations in 34 countries from which we can highlight the USA with 17 articles, Spain with 13 articles, and India and England with 10 articles each.

Fig. 89.2 Articles published by year. Elaborated by the authors

The analysis of the methodological approach showed that the articles used six preferred methods, the most used was the survey that was used by 72.5% of the articles. The other methods used were the secondary database analysis (12.1%), case study (5.5%), cross-sectional observational study (4.4%), focus group (3.3%), and theoretical study (2.2%). The studies had scopes that cover more than 40 countries and only two studies didn't focus on a specific country or region. The studies that had this geographical scope cover all the continents. Asia and Europe were the continents with more studies (31.6% each) followed by South and Central America (18.4%), Africa (10.5%), North America (5.3%), and Oceania (2.6%). Another division of the countries could be between developed countries (39.5%) and developing countries (60.5%).

Through a papers' public service focus, were found that 26 articles analyzed the health services, ten studied the transportation services, another ten papers focused in the education services, and nine publications targeted the bank services. Were found 15 articles that didn't specify a service or analyzed the public services as a whole, and other 21 studies that had focus on other specifics services like water, telecommunications, agriculture, tax administration, social security, electricity, television, sports, and animal care services among others. Only nine of the articles studied eGov services and 22 papers compared the public services with the private services, mainly in the health and education sectors.

A term co-occurrence map based on articles title and abstract are shown in Fig. 89.3, which shows that the most cited words in the papers' title and abstract form only one larger cluster with the words "service", "quality", "perception", "result", and "study." All other words don't fit in a cluster, being isolated each one in a cluster.

The keywords' analysis is presented in Fig. 89.4, which explicits the most cited keywords of the papers in two clusters. One is related to the healthcare service and another with the keywords related to the service quality and some correlates terms.

Figure 89.5 shows the density's analysis of author's co-citation has two main clusters. The one with the biggest density is focused on A. Parsu Parasuraman and Leonard L. Berry and includes other less density names as Richard L. Oliver, J.

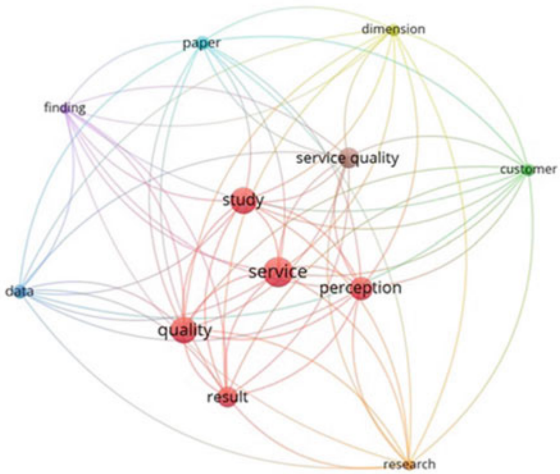

Fig. 89.3 Term co-occurrence map based on articles title and abstract. Elaborated by the authors

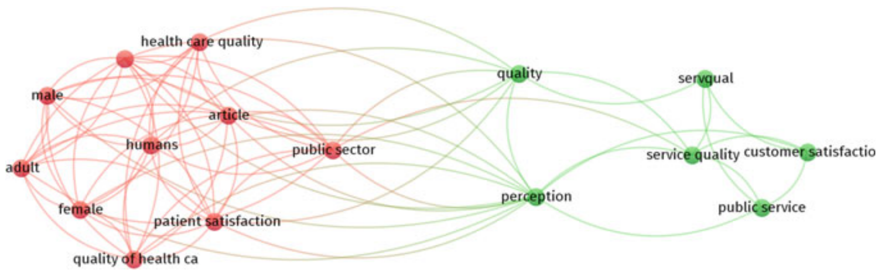

Fig. 89.4 Keywords co-occurrence map. Elaborated by the authors

Joseph Cronin, Steven A. Taylor and Christian Grönroos, the other clusters include Leonard L. Berry and Valarie A. Zeithaml.

89.6 Discussion

With the change from the perspective about the citizen becoming a customer-citizen that came with the NPM in the beginning of 1980s, the quality of the outputs of the public service becomes a goal of the public organizations, but the literature about the perception of quality, although started at 1988, has a bigger interest around the year 2000, but increased recently after 2010. It is notable that there is a large amount of papers publishing researches in the perceived quality of public services. Although the journal with the bigger quantity of publication is related with the quality management, there are journals of specific areas that are publishing that field research articles, as

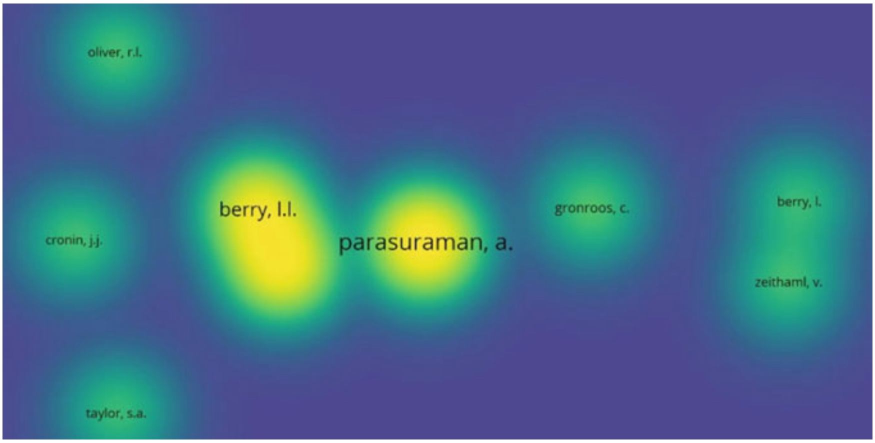

Fig. 89.5 Density's analysis of author's co-citation. Elaborated by the authors

health care and education services, and also there are articles published in journals from public sector management area.

Since the perceived quality is strongly linked with the customer, the methodological approach that is the most used is the survey. Others methods used to involve the use of data from secondary databases and the more qualitative approach. There are many authors publishing articles about the perceived quality of public services, but there isn't a concentration of studies for the same authors. One indicator of this is that only 6.2% of the author published more than one article. Those authors have affiliation in 34 countries. The fact that USA and England are two of the countries with the large amount of publications is expected since those are countries with a lot of research in the management and quality field. India and Spain are between the four countries with more publications are due the banking sector in India have many players from the public sector, and the public television service in Spain being an important player in the sector.

The studies focus on all the countries around the world what shows the importance of the quality of public services in all the continents. Comparing the developed and developing countries that were studied in the articles, it is easy to note that almost two-thirds of the publications focuses on the developing countries, what can be explained by the importance of the government service for the population from the developing countries be bigger than the importance of these kinds of service in the developed countries. Furthermore, it is easy to understand the prevalence of studies in the healthcare services because in many countries this kind of service is mainly provided by the government. The same occurs with the transportation and education service. The presence of the banking service between the more studied ones is due to many studies about the perceived quality in banking service in India. Although the importance of eGov is gaining in the academic community, it is only studied in less than 10% of the articles analyzed what is understandable due to the profile of the services analyzed.

An indication that there is no clear similarity in public and private services´ perceived quality can be deduced as only 22 articles (24.2% of the total sample) show a comparison between the perceived quality of public and private services. One hypothesis is that the same service from public and private sector is consumed by different consumers, in other words, the consumers that use the public service don´t use the private one.

The abstract's analysis indicates that there aren't clear clusters. The main cluster refers to generic terms from the perceived quality theme like "quality", "perception", and "result." All the other clusters contain only one word each, indicating that there is a convergence of the sub-areas of the perceived quality in the public service main theme. It is important to note the words "customer" that indicates how the public sector is acquiring the NPM moto of considering the citizen as a customer-citizen, and "dimension" that refers to the dimensions that the author uses to analyze the perceived quality of the services, in other words, the criteria are used to evaluate the quality of the service.

The keywords' analysis shows two distinct clusters, the bigger one involves many terms related to the healthcare services and the other one with the perceived quality. In the first one, we can find terms describing the categorization of the customers as "male", "female", and "adult", other words related to health care as "healthcare quality", "quality of health care", and "patient satisfaction." The second cluster refers to perceived quality terms as "SERVQUAL", "customer satisfaction", "perception", and "service quality." Is important to note that in both clusters there are terms referring to public service: as "public sector" in the first and "public service" in the second cluster.

The author's co-citation analysis, notwithstanding don't show it graphically, could be divided into four main groups. The first one involves Parasuraman, Berry, and Zeitnaml, the three authors that published the seminal article about the SERVQUAL methodology that initiates the perceived quality analysis in 1988. The second group includes Cronin and Taylor, the authors of the article about the SERVPERF, methodology that links the perceived quality with consumer satisfaction and purchase intention published in 1992. The third and fourth group contains only one author each, Oliver, that in the 1980s studied the cognitive model of the antecedents and consequences of satisfaction decisions a base for the SERVQUAL research, and Gronroos, a Finnish academic focused on service and relationship marketing.

89.7 Conclusions

The NPM changed the focus of the public service that begins to see the citizen as a customer-citizen, in this way, the measurement of the perceived quality of the public service is a natural way to develop the outputs of the government organizations. Although the interest about the perceived quality of public sector attracts more attention of the academic community in the last years, there aren't journals focused or authors focused on this thematic.

The analyzed literature covers over than 15 public services and more than 40 countries, including developed and developing countries what demonstrate that the perceived quality in the public service could be used in various situations to benefit the public service deliverer. The dimensions of the perceived quality emerge as one of the main topics in the abstract content map, what could indicate a new study focusing on the criteria or dimensions of the perceived quality analysis in the public sector.

In order to expand this study, the literature review analysis in perceived quality in the public services can be enlarged with future researches that could be developed using different and more deepen literature review techniques like content analysis.

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Chapter 90
Criteria Describing the Perceived Quality of the Public Services

Paulo Rafael Minetto Maceta and Fernando Tobal Berssaneti

Abstract The New Public Management introduces operations management´s concepts from private into the public sector, and one of these concepts is the perceived service quality, that evaluates the perception of the citizen–customer with the public service provided. This study analyzes the criteria used in the literature to measure the public service´s perceived quality.

Keywords Public service · Perceived quality · Literature review

90.1 Introduction

Organizations from private and public sectors seek improvements in order to survive and to remain competitive and increase the quality of their services is a good way to achieve this goal [1, 15] and could become a competitive advantage [23]. The academic literature has different definitions when analyzing the service quality concept since it is multidimensional and based on the customers evaluation [18].

To measure service quality, it is important to consider two factors: the technical one, related to the output quality and the functional one, resulting from the perception of the client of the usefulness of the service [8]. Due the importance of the service quality topic, the identification of the determinants that leads to service quality and the criteria that measure that determinants are a topic with a crescent interest in the academic literature, but there is no consensus as to what criteria should be measured [18].

The public sector has a more important relationship with the service quality, since the better the quality of the public services, the better will be the governance of the public organization what leads to achieve the regional development goals [2]. Although the big challenge is that the public organizations have to achieve the citizen´s requirements in the public service quality, the dimensions that measure the

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service quality in the public sector are scarce studied in the academic community [5] what leads to a gap in the literature.

This study focused in the criteria used to analyze the public service quality and adopt a literature review approach to catalog the criteria that the academic studies utilize to measure the perceived quality of the public sector from the perspective of the customers. The study begins with a brief review of the literature, followed by the methodological approach and the presentation of the results. Then the discussion and conclusion of the study are presented.

90.2 Perceived Quality in the Public Sector

The measurement of the service quality perception of the customer is important to determine the clients' experience, which are essential for the improvement of processes, focusing on their efficiency and effectiveness. The service quality is similar to the value added to the customer [22], and it will become a process that enables the customers' satisfaction [27].

The public sector is formed of various public organizations that produce goods and services to the citizens, and it can even overlap some parts of the private sector [10]. But the public sector do not have the same market mechanism from the private sector leading the public organizations to have political management with multiple objectives making it difficult to measure their goals [3].

The public sector underwent a major change in the late 1980s, replacing a more bureaucratic model with the so-called New Public Management (NPM), a movement to modernize the state apparatus, where the citizen leaves the role of the taxpayer or a citizen to assume the role of the customer [16].

Another change that the NPM brought to the public sector was that it started to adopt some management techniques and tools from the private sector, that is, the sector that has more experience dealing with customers and the public sector was starting to deal with the clients [28]. One of these techniques that the public sector adopted was service quality management [15]. The public sector also suffers an increasing pressure to have more quality in its services [1].

The objectives of public administration are presented by Duarte and Reis [7] as: (1) maximizing innovation; (2) maximizing geographic impact (economies of scale); (3) maximizing the connection between partners and skills (network effect); (4) maximizing the number of direct beneficiaries; (5) maximizing the number of indirect beneficiaries; (6) maximizing technical skills; (7) maximizing economic efficiency (economic sustainability); and (8) maximizing synergies between actions (project integration).

The complexity of measuring performance in the public sector can lead to simplified models of performance measurement that may lead public organizations to erroneous conclusions about their performance and lead public organizations to behaviors that do not improve service quality [19].

The measure of the perceived quality of the public service is difficult because the public organizations cannot just meet the expressed needs from the customers, they need to meet the unexpressed needs and, also, allocate public resources giving transparency and explaining their decision to the public [11].

The electronic government, or e-government (eGov), is the adoption of the electronic methods to deliver the public services to the citizens and is seen by the academic literature as the next evolutionary step in the public administration [14], and it will lead the public organizations that adopt the eGov to improve their service quality [2, 21].

90.3 Methodology

In order to obtain the criteria used to measure the perceived quality of public service from the academic literature, a literature review approach was performed in two main database, namely ISI Web of Science and Scopus that is the two of the most important bibliographic database in multidisciplinary academic literature [26]. The literature review was divided into three phases, which is illustrated in Fig. 90.1.

In the first phase were performed a search in the databases using the following search string: ((“Perceiv* Qualit*” OR “Perceiv* Serv* Qualit*” OR “Perceptio* of qualit*” OR “Percept* of serv* qualit*” OR “Qualit* percept*”) AND (“public* sector*” OR “public* servic*” OR “public* manag*” or “public* organi*”)). The symbol “*” was used to capture articles that contain correlate terms. Were used, besides the search string, two filters in the database: (1) document type: “Articles” and (2) data: from 1980 to 2018. In this first phase a sample of 139 articles from Scopus and 113 papers from ISI Web of Science were obtained.

The second phase consists in the refining of the articles’ sample built in phase 1. The first analysis performed was the exclusion of articles that were duplicate between the results of the two databases, which occur with 72 articles. Then, the entire abstracts from the 180 remaining papers were read to select those that are aligned with the theme perceived quality in the public service. From this analysis occurs an exclusion of 86 articles. Another three articles could not be in the final sample due

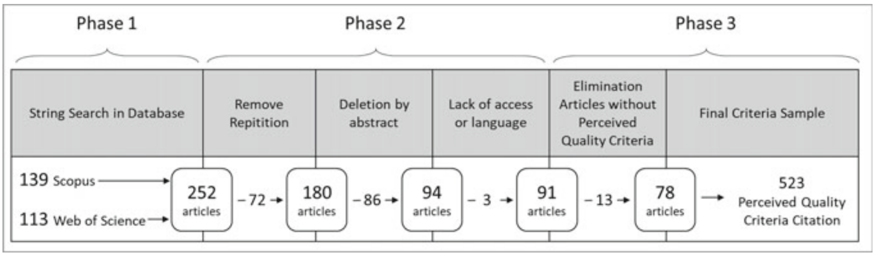

Fig. 90.1 Methodology steps and articles sample size. Elaborated by the authors

to the fact that the authors cannot find a source of the article or did not have the knowledge of the language of the paper.

To perform the third phase of the methodology, all the 91 articles were read by the authors that search in the article the criteria that the studies used to measure the perceived quality of the public service studied. Within this search's result, 13 articles didn´t show any criterion that measure the perceived quality, mainly because they used a theoretical approach in the study or they analyze the results of the perceived quality but not how it was measured.

After the three steps described, were obtained a final sample of 78 articles from which raised 523 citations of perceived quality in public service criteria.

90.4 Results

All the perceived qualities in public service criteria´s citations were organized into twelve criteria clusters, which were made grouping similar criteria´s citation into groups from similar sources of the service quality. The criteria cluster and the count of citations in each cluster could be seen in Table 90.1.

Some clusters like "Staff," "Facilities," "Equipment," and "Cost" are easily understandable and also have a tangible meaning. The "Availability of Service Delivery" contains criteria that measure if the service is at the customer's disposal when the

Table 90.1 Citation count by criteria cluster. Elaborated by the authors

(continued)

Table 90.1 (continued)

Criteria cluster	Citation	
	Count	%
Staff	110	21.0
Availability of service delivery	61	11.7
Communication and information	52	9.9
Reliance in the service	50	9.6
Access to the service	47	9.0
Facilities	46	8.8
Time of service execution	42	8.0
Security	34	6.5
Service quality and customer satisfaction	34	6.5
Equipment	24	4.6
Cost	14	2.7
Social and environmental	9	1.7

customer wants to use the service. The criteria from the cluster “Time of Service Execution” measure the time of the service, and it could measure the time the customers need to wait and also the duration of the service to be executed. Related with this cluster, there is the “Access to the Service” cluster that reunites criteria that analyze how ease is to the customer to access the service that could be physically or electronically.

The “Communication and Information” criteria cluster groups the criteria related to how the organization gives information about the service and also criteria that measure the quality of the information.

The cluster “Reliance in the Service” contains criteria measuring how the customers rely on the service and the organization that delivers the service and also how is the integrity of the database of the organization that is delivering the service. In other way, the “Security” cluster has criteria that measure how safe the customer feel using the service and also how the organization treat the privacy of the customer and their data provided to the service organization.

The “Service Quality and Customer Satisfaction” cluster groups some more generic criteria that measure how the customer perceived the general quality of the service execution and also the satisfaction of the customer with the service delivery.

Finally, the cluster “Social and Environmental” clusters the criteria that measure the perception of the customers with the externalities of the service to the society and how the service impacts the environment that it’s included.

After that, the perceived quality criteria’s citation from each cluster was subgrouped to have a better understanding of which dimension of each criteria cluster was measured by the citations. This subgrouping could be found for each cluster in Table 90.2, and the exceptions were the criteria cluster “Cost,” that could not be subgrouped since the citations were all very similar with criteria like “costs,” “reasonable cost,” “tax” or “tips,” and the cluster “Social and Environmental,” that could not also be subgrouped due to the criteria be in a small number and very different between them, like “Fairness,” “Transparency,” “Dignity,” “Pollution,” “Government Objectives Alignment,” and “Social Responsibility.”

90.5 Discussion

From the result section, we could perceive that the “Staff” is the criteria cluster that has a bigger amount of citations. It is due to the intangibility of services which leads to the simultaneity of the delivery and consumption elevating the importance of the staff in the process [12] and also due to a service quality has a strong dependency of the process [4] that is executed by the staff. Also, Diamond-Smith et al. [6] explained that in the public sector, the past interaction of the customer with the staff influences the perceived quality of the service in the present.

Another interesting insight is that the appearance criterion appears in four different clusters like “Staff,” “Facilities,” “Equipment,” and “Communication and Informa-

Table 90.2 Criteria citation count inside the clusters. Elaborated by the authors

Criteria	Citation	
	Count	% within clusters
"Staff" cluster		
Knowledge	23	20.9
Courtesy	15	13.6
Attention	14	12.7
Appearance	11	10
Empathy	11	10
Willingness to help	10	9.1
Others	9	8.2
Competency/ability	6	5.5
Quality	6	5.5
Respectful	5	4.5
"Availability of service delivery" cluster		
Availability/readiness	35	57.4
Responsiveness	11	18
Overloaded	6	9.8
Frequency of service delivery	3	4.9
Others	3	4.9
Range of services available	3	4.9
"Communication and Information" cluster		
Quality	15	28.8
Content	8	15.4
Communication	7	13.5
Availability of information	5	9.6
Clarity	5	9.6
Others criteria	5	9.6
Appearance	4	7.7
Reliability of information	3	5.8
"Reliance in the service" cluster		
Reliability	18	36
Assurance	9	18
Error-free records	7	14
Confidence	6	12
Trust	6	12
Guarantee	2	4
Responsibility	2	4

(continued)

Table 90.2 (continued)

Criteria	Citation	
	Count	% within clusters
"Access to the service" cluster		
Opening hours	16	34
Location of service delivery	14	29.8
Existence of website or technological solutions	7	14.9
Easy access to facilities	5	10.6
Accessibility of facilities	4	8.5
Parking Area	1	2.1
"Facilities" cluster		
Quality	14	30.4
Comfort	13	28.3
Cleanness	10	21.7
Appearance	8	17.4
Layout	1	2.2
"Time of service execution" cluster		
Punctuality	16	38.1
Waiting time	16	38.1
Duration of service	5	11.9
Ease of scheduling	5	11.9
"Security" cluster		
Security	19	55.9
Safety	7	20.6
Confidentiality	5	14.7
Privacy	3	8.8
"Service quality and customer satisfaction criteria" cluster		
Ease of use	9	26.5
Quality and performance of the service	9	26.5
Effective and usefulness of service	6	17.6
Customer service/continuity of services	4	11.8
Customer satisfaction	3	8.8
Others	3	8.8
"Equipment" cluster		
Quality	13	54.2
Appearance	4	16.7
Modernity	4	16.7
Comfort	3	12.5

tion" showing that the same construct could be measured in different ways, depending of the experience of the customers.

The criteria group "Ease of Use" is the most cited in the "Service Quality and Customer Satisfaction" cluster and it is explained by the fact that the public service is considered a "high contact service" which involves some customer actions [4], and, for the customer, as easy what they need to perform in the service, the better.

The satisfaction of the customer was only cited in three articles [13, 24, 25], and it could be explained due the fact that in the public sector, there is a limited or absent competition [9] and the customer satisfaction does not have a great impact as it has in the public sector.

The access to the service is important in the public sector, and have a bigger impact in the public health services, since many users of this kind service, according to Rivard et al. [17], have locomotion difficulties and prefers services that have easy access.

It is curious to note that the "Social and Environmental" cluster is the one with less criteria citation since the main objective of the public sector organization, according to Agus et al. [1], is to provide social benefits, and it could indicate that, although it is the public sector objective, the customers do not have this concern.

90.6 Conclusions

The measurement of the perceived quality of public services is increasing its importance in the academic literature. It occurs due to the importance of delivering a good public service to achieve the citizens' needs and requirements. The majority of the papers that analyzes the perceived quality in the public sector show the criteria that they use to measure the customer perception with the service quality.

Since the study was developed around 78 articles that cited 523 times the perceived quality criteria in public service it could be considered representative as an extract of the literature.

The staff that delivers the public service is the subject of measurement with the most quantity of citation in the literature, and this indicates the importance of the relation between the staff and the customer during the service execution. The facilities and equipment also play an important role in the interaction during the service execution and affects service quality perception.

Although it was expected that the social and environmental criteria were important in the perceived quality, the number of citations are low, what represents that the citizens could be disinterested in this aspect.

In order to expand this study, the perceived quality criteria could be analyzed by year of article publication to understand if the importance of each criteria cluster varies in the literature during the year. Another analysis could be done by the country of the study and also analyze the criteria by the kind of public service studied in the articles.

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Chapter 91
An Analysis of the Music Market Model Through the Lens of the Service-Dominant Logic

Annibal Scavarda, Marcio Pizzi de Oliveira, Augusto da Cunha Reis and André Luís Korzenowski

Abstract The Service-Dominant Logic has disrupted the product-centric model, offering a new conception for service ecosystems. This approach can be applied to the music market in order to understand the recent changes in value creation. The current study analyzes the music supply chain based on Service-Dominant Logic.

Keywords Service-Dominant Logic · Music supply chain · Service ecosystems

91.1 Introduction

The Service-Dominant Logic (SDL) develops a critique of product-centric logic that includes tangible (goods) and intangible (output) services [28]. In product-centered logic, services are characterized by attributes that goods do not have—intangibility, heterogeneity, inseparability, and perishability [31]. However, the SDL approach reconfigures this structure by positioning the service, in the singular, as the basis of all exchanges, and the product as a vehicle for the provision of that service. The consumer has a central role in the market integrating the value creation system with the application of knowledge and skills. Thus, the consumer is always a co-creator of value in a mutually beneficial relationship with companies.

However, what happens when the physical environment stops being the standard of a market and the consumers starts to apply his or her skills directly to the creation of value? Ordanini and Parasuraman [23] studied this phenomenon within the music market through a conceptual model to analyze the creation of value in ecosystems of services. In the ecosystem of recorded music, the digital medium replaced the physical medium and the several actors of the market began to interact directly

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with consumers. These began to apply knowledge and skills directly without the intermediation of traditional actors such as major record companies. This event has brought about transformations in all dimensions of value creation that permeate the recorded music market, allowing a macro-level analysis [23].

The digital era offered the world new technologies that enabled a new experience to the customer through the application of knowledge and skills. The social media emerged as an instrument of communication of wide and immediate interaction. The upcoming of resources such as file sharing, the creation of solutions via crowdsourcing, the development of collaborative encyclopedias, and other examples of collective intelligence has emerged. However, since the advent of the model of Ordanini and Parasuraman, several changes emerged. What is the importance of these phenomena in the scope of value creation ecosystems? What is their relevance for consumers? And for companies?

The present research performs a content analysis with the intention of revealing understandings about these doubts that permeate the recorded music market. Furthermore, this paper uses the model of Ordanini and Parasuraman [23] to perform a macro-analysis considering the recent changes regarding the recorded music market. The research begins with the presentation of SDL and the transformation of thinking about services and value creation. Then, it presents the model of Ordanini and Parasuraman [23]. Finally, the paper creates an analysis of this model taking into account the four dimensions categorized by the authors: medium, meaning, use, and network.

91.2 The Value Creation Process

In the last 50 years, marketing literature has incorporated other entities beyond the companies in the process of value creation. The environments related to customers began to be considered in the process, but the SDL approach, the active role of the actors regarding the creation of value started to be considered [28].

The literature of value creation has been committed to the studies that guide their look outside companies [6]. The focus of value creation has been shifting from the company to the customer [24], where value is created in a process driven by him or her skills and not by the resources of the company [7]. Value is always uniquely and phenomenologically determined by the beneficiary [28].

Since the SDL exchange base is the services and not the goods (which were the center of the previous logic), value creation is now driven by value in use rather than by value in exchange. The goods became tools for obtaining services. In order to the proper management of the process, it is necessary to apply knowledge and skills in a beneficial way, which motivates the creation of value [28]. Within this process, value is always a co-creation between the company and the customer [28]. However, despite the value being co-created through the collaboration of companies, employees, consumers, shareholders, government agencies and other entities, it is always determined by the beneficiary: the customer [28].

Within the phenomenological perspective, Holbrook [9] defines value as “an interactive relativistic preference experience” [9]. This implies that consumer experience is marked by subjective preferences insofar as it interacts with the product and evaluates it in three senses: comparative, situational, and personal. This conception converges with the Aristotelian conception of value in which it is subjectively experienced [5].

This assessment of the origin of value influences the positioning of companies in relation to value creation. Firms can only offer value propositions [29] that can be improved from understandings about the customer value chain [8]. In short, the consumer is the creator of value and the company is a facilitator of value [6].

In the context of the music market, the change from the physical to the digital has transformed the value in use and created new demands. When the major record companies dominated the production of the medium and the conception of value in use, music lovers remained limited in the process of creating value. The change to the digital medium and the technological enhancement of devices transformed the relations regarding value in use. The possibility of expanding the music collection indefinitely and of listening to music almost everywhere has led to changes in users’ consumption practices. Thus, the musical experience has become complex and broad, creating value in many directions.

91.3 The Conceptual Model of Ordanini and Parasuraman [23]

The main motivation for the development of the conceptual model for the creation of value in service ecosystems was the realization of a macro-level analysis tool with the potential to be applied in other ecosystems. The construction of the model was based on a longitudinal and historical long-term proposal that according to Maglio and Spohrer [16] is essential to create precise understandings about the dynamics of value creation in service ecosystems.

In order to observe the viability of the model, the authors chose the ecosystem of the recorded music market. In this ecosystem, there was a profound rupture due to the musical content, previously embodied in a physical medium, to become digital and therefore replicable and distributed widely on the Internet. The question presented by the authors was: What happens when the physical artifacts that are the main vehicle for value creation in a service ecosystem are no longer needed, allowing (or requiring) the actors to apply their competencies directly?

Ordanini and Parasuraman [23] created the conceptual model to evaluate the creation of value in service ecosystems. The service ecosystems are “structures of social and economic actors interacting through technology institutions and languages to engage in service provision and value creation” [30]. The authors chose the music market to apply the model, defined as the structure responsible for the discovery and development of artists that includes the marketing, distribution, and licensing of recorded music produced by these artists. Thus, the authors seek to assess value creation in a changing ecosystem.

The passage from the physical to the digital model caused transformations in the way of making exchanges. The major record companies presented the monopoly of the knowledge of the productive processes developed in vertical supply chains that consumed all the exchanges of value. Subsequently, the creation of the digital format was disseminated, which allowed several actors to make independent exchanges. Thus, value exchanges changed from indirect to direct. Previously, the actors transferred knowledge and skills by embedding them into direct objects. Afterward, they managed to apply their skills directly through service interaction [29]. By the light of the dominant logic of the service, we can identify that the actors start to co-create valuable offers with the generation of networks of interactions among the users.

The proposed model has four dimensions that are interrelated. They are medium (what is in exchange for value?), meaning (why the exchange happens?), use (where value is realized?), and network (how the interactions between the actors are organized?). This paper develops a content analysis based on papers that focus on changes in the recorded music market regarding the four dimensions of the model.

91.4 The Analysis Through the Dimensions of the Ordanini and Parasuraman Model [23]

91.4.1 Medium

The shift from the physical to the digital allowed the music to spread across the Internet, eliminating the exclusivity of record labels for managing the sale. This process changed the format of musical consumption, transforming the experience previously conditioned to the physical environment. The consumer developed a different perception of value in use due to the possibility of expanding the collection indefinitely and to listen to music at various times and places. The value in exchange became disfigured by the abundance of ways of acquisition (legal and illegal) of the medium.

The framework developed by Ordanini and Parasuraman [23] did not consider a service that became a new pattern of the current music market: the streaming model. With this model, the notion of the music purchase per unit is replaced by a monthly fee which allows access to the whole music collection. The streaming model represents the music industry's greatest prospective source of revenue and is well established among consumers [27].

However, the popularity of this service is not related exclusively with the freedom to listen to several kinds of music. The resources available on the streaming platforms attracted users creating a strong connection with the music audience. As the tools presented on Spotify music platform were updated, core data was continuously generated to progressively improve the platform's precision in terms of value offering [26]. The ability to create playlists, share, text, and discuss enable platforms to struggle for improving features. The battle for the supremacy regarding music streaming market requires the companies to invest in the quality of the service offerings [22].

However, besides the decay of the download model there are evidences of its importance for the music market. With the emergence of 5G in the telecom infrastructure, the download music model can be a relevant asset [13]. The use of licensed streaming Web sites and licensed Web sites can have a positive relationship with the purchase of digital music, suggesting a stimulating effect of music streaming on digital music sales [1]. In addition to that, online streaming services can positively impact music record sales [12].

91.4.2 Meaning

With the advent of digital music platforms, the ability to listen to a large musical archive in several devices expanded the listening experience. These aspects gain such relevance that they became a regular standard for consumers of the digital age. According to Ordanini and Parasuraman [23], what is heard is less important than "how" it is heard. Software, Web sites, and applications can combine multi-action music creating opportunities for consumers. Thus, the musical meaning was sliced into a range of experiences very different from those offered before.

Ordanini and Parasuraman [23] identified that the musical meaning of the digital age is increasingly being shaped by breadth rather than depth, ubiquity rather than restriction, and social interactions rather than solitude. However, these statements do not present important aspects of the experience as proactive and creative skills. New forms of meaning bring consumers closer to the music curation and artistic craft making them feel at the center of the music scene.

With the introduction of Napster and the first download software, the musical experience transcended the listening skills achieving other capabilities as organizing, tagging, and texting. The resources presented by the reproduction device iPod and the music platform iTunes allowed the organization of music in folders and creation of playlists. However, the recommendation systems are the most studied resource of customization among all the features available on digital platforms. The music information retrieval can bring real-time suggestions to customers increasing loyalty and maintenance of membership.

The content assessment systems can identify the background music to user-generated videos [14] and the music genre through visual–acoustic features [18]. The context assessment systems can develop music recommendation through social network analysis [11], wearable sensors [3], and neural networks models [32]. The relevance of music recommendations leads to the contestation of the statement presented by Ordanini and Parasuraman [23]. If the "how" is more important than what is heard there were no need to improve the systems of recommendation. Thus, the music market is moving forward to both directions of "how" and "what" with specific strategies to each one of the questions.

As long as the music technology evolves, new improvements allow the consumer to develop a more unique and personal experience. The new streaming live platforms use virtual reality to offer experiences closer to real life for disabled customers [19]. The live shows are able to use the automatic stage lighting system based on emotions to increase the realism of the performances [10]. The use of Music Paint Machine offers the opportunity for users to create a painting through music performance [20, 21]. The studies show that the value creation with music is being shaped to create real-time multimedia experiences. Thus, musical meaning is becoming hybrid, multifaceted, and immediate.

91.4.3 Usage

In the history of the music market, the purchase of records, cassette tapes, compact disks, and mp3 presented several examples of points of value creation. However, these points were attached to gatekeepers who were responsible for the negotiation of the exchange value. In the digital music era, the usage patterns (the instances where the beneficiary perceives the creation of use value) became a large number of possibilities with digital platforms and other forms of legal and illegal exchanges [23].

According to Ordanini and Parasuraman [23], the distinctions between traditional actors (artists, labels, distributors, and consumers) became blurred. The new configuration of the music market allowed the strengthening of digital platforms and sites that permit new listening and creative experiences. Wikstrom [34] brings examples of the singers Robyn, Imogen Heap, and Björk. These artists developed their own applications which present the instruments and sounds available on their songs to enable co-creation with users.

The music co-creation platforms as Indaba music enable users to create music with recordings available in the community due to the Creative Commons license [15]. The development of applications and co-creation platforms suggests that the music market can develop new segments based on prosumers and new partnerships between users and music artists. These instances of usage are unique due to the empowerment of previously dependent actors of the record company supply chain. The current applications and co-creation platforms can offer opportunities to create use value but also to become instances to bring exchange value due to the collaboration between artists and users.

91.4.4 Network

The transition to digital music has brought to the table the disintermediation process in the context of the music market. Artists began to directly contact their fans by dispensing with traditional intermediaries such as major labels. The disappearance of distributors and the strengthening of consumers as market players also contributed to the dismantling of the vertical structure of the music supply chain. The relationships are no more dyadic and sequential, but large networks and simultaneous.

The traditional digital companies are developing streaming platforms embedded in their systems. The creation of new music streaming services by Facebook and Google manage to increase the scope of these companies [2]. The streaming platforms are also building strategies to enhance the reach of their actions. Spotify acquired the application Shazam, a service that has a recognition engine to identify songs [4]. Deezer acquired the music platform SoundCloud, a service of music distribution for the independent music market [17]. The analysis of this context managed to realize that the companies are developing structures to centralize value creation points of sharing, searching, identifying, and uploading music.

The streaming platforms are developing applications that help to discover new talents. Spotify and Deezer developed services that allow artists, managers, and labels to submit unreleased music to be analyzed by the company's editorial team and be included on their popular curated playlists [33]. The launch of Apple Music and the efforts made by Spotify and Deezer to build high-fidelity applications for Samsung show that the association between music streaming and mobile phones is an important move for these companies [25]. The recent rise of the streaming platforms enables a new management approach. These aspects are reframing the supply chain of these companies which became similar to the traditional record company framework.

91.5 Conclusions

The framework of Ordanini and Parasuraman [23] contributed to the construction of a macro-level model for the SDL field and to the understanding of how the dimensions of an ecosystem can present changes of value creation in the long term. The authors used as a focal element the physical medium. The analysis proposed in the present work focused on the current developments of the music market. This initiative allows to identify transformations in the value creation in all dimensions of the authors' model.

According to the findings of the present paper, some of the statements brought by the aforementioned authors may have changed due to the reformulation of the service of the market. The evidences of the literature show that the reconfiguration and reorganization of the services and relationships may enable the resurgence of the physical medium. The features available on the music platforms became valuable to attract and maintain customers, and however, the taste and the musical preferences of the user are still important targets of the managers of these platforms. In addition to that, the structure of the streaming services is closer to the old record labels configuration, what may open the door to a new age of powerful music institutions.

These insights can be helpful for other researches in the field of recorded music as well as in other creative industries that concentrate their studies on the user experience. However, the model has limitations due to its conceptual nature, which requires studies to test its effectiveness with empirical findings. Furthermore, it was possible to apply the framework of Ordanini and Parasuraman [23] in a new situation which contributes to prove its density and effectiveness.

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Chapter 92
Lean Office and Digital Transformation: A Case Study in a Services Company

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Abstract The purpose of this article is to report the implementation of lean office and digital transformation in a services company. The research method was a qualitative approach, with literature review and case study. The comparative results between current and future Value stream maps showed consistent improvements in performance indicators.

Keywords Lean office · Digital transformation · Services company

92.1 Introduction

A lean enterprise represents the shop floor, office processes and administrative processes. Lean has traditionally focused on manufacturing or the shop floor; however, its basic principles are applicable to any part of an enterprise [1]. Applying lean concepts to the administration area of the enterprise, known as lean office, is vitally important to both support and aid lean manufacturing practitioners. Tapping and Shuker [2] argue that, when manufacturing a part, administrative functions make up '60–80% of all cost associated with meeting a customer demand'. Danielsson [3] cite studies report that 50–80% of the workforce in the Western world works in offices, and thus, the office environment is very important as a full-time employee spends approximately 40% of their waking hours at work.

There is an increasing interest of companies in the digital transformation of the office environment. But conducting a digital transformation in all business units and processes at the same time is challenging and costly, as there is a massive number of factors that influence this implementation, and a proper deployment usually implies several iterations. It is recommended to start with just a few users and a limited number of activities, and then expand the project in order to reach the defined scope [4].

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There are few studies dealing with the joint application of lean office and digital transformation, which reinforce the importance of this work, whose aim is to complement the scarcely available literature, describing the good results expected with the digital transformation in the operations department of a Brazilian Internet of Things solution provider.

92.2 Literature Review

92.2.1 Lean Office

92.2.1.1 Definitions

The lean thinking concept was proposed based on Toyota Motor Company's lean production system, known as the Toyota Production System (TPS), whose main target is elimination of waste resulting from overproduction, waiting time, excessive transportation, inappropriate processing, unnecessary inventory, unnecessary motion and defective products [5, 6]. The lean thinking paradigm is characterized by the five principles defined by Womack and Jones [7]: (1) value: good or service targeted at the end customer; (2) value stream: set of activities required to produce a good or service; (3) flow: uninterrupted execution of all activities comprising the value stream; (4) pull: existing demand to perform any activity in the value stream and; (5) perfection: the pursuit for continuous improvement. da Silva et al. [8] explain that lean thinking is supported on TPS [9, 10]. It concerns the elimination of waste in the production process that does not add value to the customer, besides reducing cost and improving productivity.

The application of lean thinking principles in the administrative areas is called lean office and it is considered an adaptive evolution of lean production, achieving the benefits of lean production [11]. The big difference between lean production and lean office is that while in lean production the work scenarios are very visible since they are processes with physical flows, in turn, in the lean office, the processes that add value to the product depend largely on information flows and employee knowledge [12]. According to Herkommer and Herkommer [13], lean office is a philosophy that seeks, in information processes, results similar to lean production.

Danielsson [3] identified two main perspectives in the context of lean office design:

The neo-tayloristic lean office, which applies a scientific management approach advocating a standardization of the office design, and implies among others that: (a) personal attributes are taken away from the individual workplaces or from the workplace as a whole and only working material directly linked to the work is allowed; (b) management marks clearly that it is the one who decides how the office will be designed and used by employees; and (c) a 'standardization' of the office design is pursued to the possible extent.

The team-based lean office, which focuses on problem solving and 'learning organizations' as methods to shorten lead times and free up time, and implies among others: (a) A new employee's role which means more power and responsibility on both the individual and team level [14]. It implies responsibility for the conduct of the individual work, but also the planning and development as well as the incorporation of the own work in the team's labour process; (b) A new role for the supervisor, who takes a step back and avoids micro-management of the work and instead takes an overall responsibility; (c) Relational coordination, i.e., the quality of work is dependent on relationships, which in turn is based on clear common goals [15]. A prerequisite for this is good relations between employees, but also between employees and managers, i.e., a social and human capital; and (d) Leadership is a key component for these types of learning organizations [16].

92.2.1.2 Benefits

Lean office was developed based on lean thinking concepts, initially applied only on factory floors, and later also in the administrative office environment [17]. The successful application in industrial production enabled the adaptation of the use of lean tools in the office environment, agilizing the management of information and materials, with the elimination of idle procedures which generated waste and thus creating more value to the flow of information and administrative processes. de Almeida et al. [18] cite Scalera et al. [19], which argues that the lean office approach allows reducing overproduction of print documents, cutting the time needed to provide services, restricting excessive movement of people between sections, improving the use of underused human resources, reducing the number of hierarchical levels, and minimizing document storage costs.

McKellen [20] reported the typical benefits of implementing lean office, which can be summarized by de Aguiar Gonçalves et al. [21] as: (a) effective communication through visual management: use of updated and organized murals, as well as electronic dissemination of information; (b) efficient use of space: elimination of physical file storage areas, as well as the use of online file storage; (c) reduction of crossing time: identification and elimination of delays between departments, as well as elimination of excess of approvals for purchases of office supplies and equipment; (d) reduction in the amount of processed paper: reduction and elimination of printing e-mails for future reference, as well as reducing the amount of copies; (e) formalizing document crossing systems: implementation of standard operating procedures; (f) reduction of meeting's time: early and efficient communication of necessary meetings, which begin and end on time; (g) elimination of internal computer notifications: verification of online data and external terminals; and (h) motivation of the people: use of empowerment.

92.2.1.3 Implementation

Monteiro et al. [22] reported the case of a public organization (an association of municipalities) dedicated to solid waste treatment in Oporto region, which started a lean office journey in 2010 triggered by a restructuring initiative in all the supporting departments. The main phases of the project were: (1) lean event and project presentation; (2) priorities identification; (3) pilot team identification; and (4) methodology application. The last phase included the following steps: (i) team organization; (ii) visible best practices; (iii) process improvement; and (iv) autonomous teamwork.

Value stream has been probably the most successful lean tool implemented in office área [23]. The main reason may be based on the fact that good results are rapidly achieved from its implementation and therefore it is a good way to attract people interested in the adoption of lean office. The methodology starts by gathering in a room all relevant actors in the selected value stream, mapping all steps of the process (adding value or not) and flow of information. The team then identifies the process tasks that are pure waste and eliminates them in order to reduce the number of process steps, reduce lead time, and improve flow and efficiency. The team also finds ways of improving the efficiency of the needed steps by including low-cost automation solutions and 'poka-yoke' devices to reduce errors.

In literature, recent studies about the implementation of lean office highlight the use of the value stream mapping (VSM) tool for identifying and eliminating waste and processes and, consequently, achieve gains in performance and agility [24]. Rother and Sook [25], cited by da Silva et al. [8], advocate the application of VSM, which is a planning tool that facilitates the visualization of information flows.

Tapping and Shuker [2] propose the value stream management to implement lean office in eight steps, which concepts and tools are presented by de Almeida et al. [18] as follows: (1) Committing to change: to conduct communication, allowing experimentation and flexibility in tool application, where support by top management for conducting such a change is essential; (2) Choosing the flow of value: to understand the flow of value, create an improvement plan and improve processes considering both flow of value and improvement plan; (3) Learning about lean: to understand the concepts and terms associated with lean thinking through training and creating a learning plan; (4) Mapping the current status: to understand lean office concepts and tools as a prerequisite, from the previous steps, to expose workflow and information units by using a set of symbols and icons; (5) Identifying lean performance measures: to determine the metrics to help achieve the objectives of lean thinking, thus promoting continuous improvement and eliminating waste; (6) Mapping the future status: to map the future status to indicate where lean tools will be used. It consists of three phases: the understanding phase of the client's demands, the implementation phase for continuous flow so that the value desired by the client can be established and the levelling phase (distribute work equally); (7) Creating Kaizen plans: to develop a continuous improvement plan—Kaizen and; (8) Implementing Kaizen plans: to carry out the Kaizen plan through its implementation and follow-up.

92.2.2 Lean and Digital Transformation

The case of digital transformation described by Brocke et al. [26] builds on a project that began in early 2013 involving Beiersdorf's market intelligence department, which manages brand performance measurement and is engaged in developing the product pipeline and planning marketing activities. With the emergence of new social media platforms, marketing specialists are introducing changes to their promotion and marketing plans because they now have more ways to interact with customers. Competing in a demanding marketplace like that of skincare requires going beyond realizing 'what happened' and asking questions like how and why it happened and how to ensure it happens/does not happen again. Because traditional generic reporting tools no longer satisfy business requirements for analysis and are too time-consuming and prone to error, more powerful, real-time dynamic analytics solutions are needed. Brocke et al. [26] cite SAP [27], a major player of big data analytics technologies, which notes that 'the key is unlocking data to move decision-making from Sense and Respond to Predict and Act'.

Tay and Low [28] examine the transformation processes and identify evidences that are resemblances of the lean management philosophy in the improvement strategy applied by a Higher Education Institution (HEI). The study follows a case based on a HEI in Singapore that embarked on the journey to convert its traditional printed learning resources to digital formats to simplify its internal operations and create values to the teaching and learning community.

One dominating discussion in research and society is the integration of information technologies and communication technologies into industrial production to handle the increasing complexity. This approach of digital transformation is generally known as Industry 4.0 vision or smart factory in an environment of Internet of Things and Services. The digital transformation brings innovative technologies into lean production environments that may disrupt current principles of automotive electronics production. Wagner et al. [29] present a target-oriented integration concept to realize the potential of this Industry 4.0 technologies into industrial value streams by using elements of design thinking. Based on a qualitative correlation between production targets and Industry 4.0 technologies, the technology selection can be supported.

The digital transformation remains an ongoing challenge in construction and facility management applications [30].

The Textile Learning Factory 4.0, described by Küsters et al. [31], addresses all key elements with the aim of supporting manufacturers in overcoming their implementation barriers and thereby accelerating the adoption of digital operations technologies across the industry. The main aim of the factory environment is to foster hands-on, experimental capability building. Hence, the factory infrastructure needs to meet certain requirements that differentiate it from a real-life factory. One of the key differentiators is the ability to change between two implementation levels of the process: Level 1—Current State Operation (Lean) and Level 2—Future State Operation (Industry 4.0).

92.3 Methodology

In contrast with research strategies that are based on data collected at first hand (experimental, surveys and field studies), the available data researcher mines second-hand information [32]. This study adopted a qualitative approach, using available data until 19 September 2018, starting with a systematic literature review in four steps, based on the PRISMA [33] method (see Table 92.1).

No records were found on Scopus and Web of Science databases for the search sentence 'digital transformation' AND 'lean office', representing a gap to be filled with this study.

The second work stage was developed in the company, through a case study, whose main features are [34]: (a) selection of a single case of a situation, person or group of interest or concern; (b) case study in this context; and (c) collection of information through a variety of data collection techniques including observation, interview and documentary analysis.

The information was collected through informal conversations with a manager and data analysis from the company. Based on the gathered information, it was defined to start the lean office implementation at the operations department. First, the current state of the value stream map (VSM) was drawn including all involved processes. Second, after analysis and identification of opportunities for waste elimination in the 'scheduling' macroflow, a VSM of the future state was developed, to be deployed with the application of lean principles, techniques and tools. The third step, to be done, is the digitalization of some processes from the VSM to eliminate waste. Results measurement will be accomplished through performance indicators.

Table 92.1 The four steps of the PRISMA method

Database	Search sentence	1. Identify	2. Screening	3. Eligibility	4. Included
Exclusion criteria ============➔			Duplicated registers (#10)	Text, method or authors not available (#40)	Full-text not aligned with this work (#3)
Scopus	'Lean office'	38	6	15	12
Web of Science		11			
Scopus	'Digital transformation' AND lean	16	4	7	7
Web of Science		7			
	Total	72	62	22	19

92.4 Case Study

The company, object of this study, hereinafter referred to as Brazilian Internet of Things (IoT) for reasons of secrecy, delivers IoT solutions for large companies, through a platform which allows the connection of things, people, data and processes.

In order to identify waste in Brazilian IoT, the value stream map (VSM) of the current state was initially drawn (see Fig. 92.1), showing in the same diagram the client and main processes involved, as well as improvement opportunities in 'kaizen explosions'. The 'scheduling' macroflow of the operations department has been identified as the one with the main opportunities for waste removal. The VSM of the future state (see Fig. 92.2) shows the improvement proposals for elimination of the identified waste.

Table 92.2 presents a comparison between the current and future state of the operations department of Brazilian IoT.

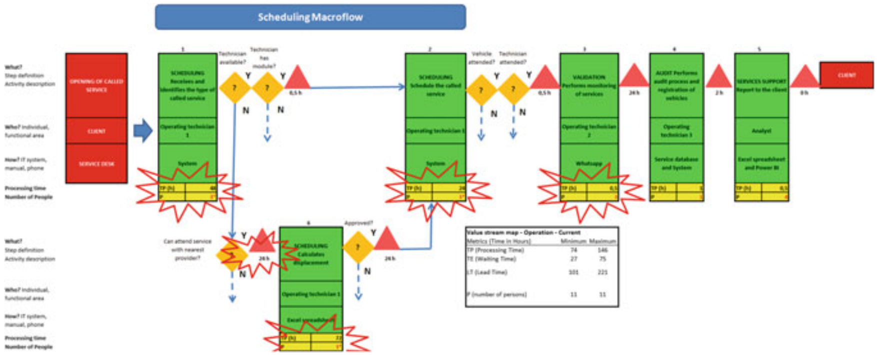

Fig. 92.1 VSM at operations department—current state

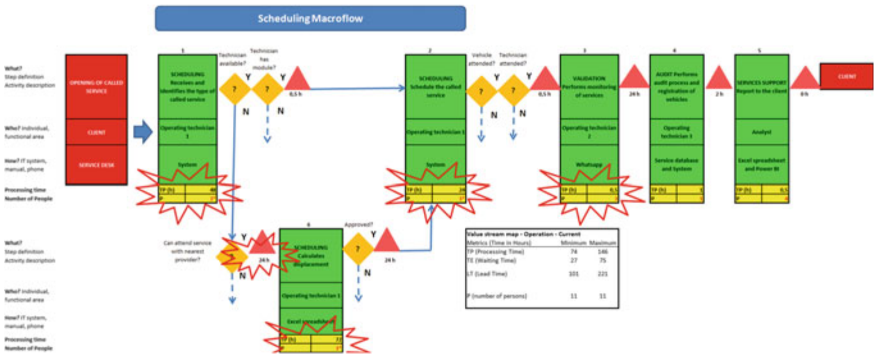

Fig. 92.2 VSM at operations department—future state

Table 92.2 VSM comparison at operations department

VSM	Processing time (h) value-add	Wait time (h) not value-add	Lead time (h)	# Process	# People
Current	74–146	27–75	101–221	6	11
Future	37.65–61.65	27–53	64.65–114.65	6	11

The current value stream map (VSM), including the 'scheduling' macroflow, comprises five processes and operates under normal conditions with 11 people, with a total processing time of 74 h and wait time (waste) of 27 h, thus, a corresponding lead time of 101 h. If there is no technician from Brazilian IoT available, then it is necessary to find and negotiate with a local provider (process #6), which delays the whole operation, increasing the total processing time to 146 h, wait time (waste) to 75 h and corresponding lead time to 221 h.

The future VSM shows the digitalization of processes #1, 2, 3 and 6, thus, expecting the productivity increase of the operations department, falling to a total lead time of 64.65 h under normal conditions and 114.65 h if there is a need to bypass through process #6.

92.5 Conclusion

Lean office, based on the Toyota Production System, is an alternative to increase productivity of companies and make them more competitive, with respect to cost, quality, deadlines and waste elimination. A case study was developed in IoT solutions provider company located in Brazil, and it was possible to demonstrate how the implementation of lean principles, techniques and tools can bring benefits to the operations department. The value stream map (VSM) in the current and future state allowed the identification of waste in the 'scheduling' macroflow, which will be attacked by the use of digital devices. Despite the expected positive results with the digital transformation, there are limitations in this study, basically the time frame until the digitalization of the processes #1, 2, 3 and 6 will be implemented, when it will be possible the comparison with the original expectations described in the VSM of the future state.

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Chapter 93
Mathematical Model for the Assignment of Participants in Selection Processes

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Abstract This work proposes two mathematical models for the assignment of selection processes candidates, such as the distance traveled by the participants and the organizing entity total cost are minimum. A trade-off curve is indicated, based on the two models.

Keywords Personnel assignment · Trade-off · Selection processes

93.1 Introduction

In several countries, selections, evaluations, and certifications are carried out by means of open public processes. The world's second largest test for access to higher education occurs in Brazil [1], the High School National Examination (Enem) that allows admission of participants to higher education, in public or private institutions.

Among the several activities in this process, the logistic planning has considerable importance, because it must cover the rental of test venues and cost of hiring staff. The objective is to minimize leasing and personnel hiring costs and to meet an appropriate level of service for the participants, who prefer to perform their tests in a venue which is closer to their residences, reducing travel time.

In addition to the need to make the process more efficient, logistics is responsible for studying ways to make the activities more profitable. This can be achieved by an improvement in the level of service, which can be converted into a competitive advantage or into a cost reduction advantage [2].

Despite the need for optimization tools to aid in the decision-making and the importance of minimizing costs within the desired service level, the authors of this article have found no mathematical optimization model in the literature for the assignment of participants in selection processes, with application in a real case study.

Thus, this work aims to develop mathematical models to support the decision capacity of managers in charge of selection processes. This analytical effort makes

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use of a specific case study. The selected case was at Cebraspe, a organization in charge of planning and executing the application of Enem, from 2009 up to 2016, in a consortium with Cesgranrio Foundation.

Although no studies containing decision support tools have been found, Lima and Lima Filho [3] and Arraes [4] discussed themes for processes improvement at the center of selection and promotion of events (Cespe) of University of Brasilia and at Cebraspe. Arraes [4] included in his work a trade-off analysis between the use of rented or free venues.

This paper has an applied research nature with technical-documentary procedure. For data collection, public documents were analyzed and interviews were performed with Cebraspe's employees, for the description of the public selection process. The mathematical models were developed and solved, using random and real data, by Lingo 17.0 software with the use of an educational license.

The study demonstrates the possibility of minimizing logistical operational costs and to reduce the total distance traveled by participants to the designated test venue. The study also indicates a trade-off curve between cost and level of service.

According to Wanke [5], trade-offs are used to identify the way in which certain logistical and functional costs are interrelated. When well analyzed and mapped, such trade-offs can generate rich essential information for decision-making.

93.2 Mathematical Solution Approaches

This chapter proposes three mathematical models: the first maximizes the participant's level of service, by reducing the distance traveled; the second aims to minimize the costs of hiring employees and venue leasing; and the third is a mixture of the first two, in order to develop a trade-off curve of cost versus level of service.

93.2.1 The Problem Definition

The activities related to the process studied are summarized in: venue lease for test application, herein called coordination; determination of the number of participants allocated in each room; and personnel hiring for test application, according to pre-existing rules regarding the amount of employees and their remuneration, which can be set depending on the event.

For the lease of physical space, a remuneration is agreed according to the number of participants performing the test at the venue. The functions of employees acting at test application events can be aggregated in three groups: coordination functions hired taking into account the number of rooms used in the coordination; coordination functions hired by number of participants in coordination; and room functions hired according to the number of participants in the room.

Coordination functions hired by considering the number of rooms assigned coordination which are: 1 (one) “Application Assistant”, when amount of rooms in coordination is greater than 15, and 1 (one) “Inspector” for each group of 15 rooms.

Coordination functions, which are hired according to the number of participants in coordination is provided by “Operating Support—Cleaning,” of which all coordinations have at least 2 (two) employees and 1 (one) additional hired for each group of 500 participants.

Room functions hired by amount of participants in room are: “Room Head” in all rooms with participants, and “Room Inspector,” being 1 (one) in rooms with up to 60 participants; 2 (two) inspectors in rooms with more than 60 and up to 80 participants; 3 (three) inspectors in rooms with more than 80 and up to 100 participants; and 4 (four) inspectors in rooms with more than 100 participants.

Besides this, there are 3 (three) employees who are necessarily provided by all coordinations: Application Coordinator; School Representative; and Doorman.

93.2.2 Mathematical Model for the Maximization of Participants’ Level of Service

A linear programming type model was proposed to minimize the distance traveled by candidates, from residence to test venues.

This model is associated with an assignment model as designated personnel cannot be divided [6], so each participant must be allocated to exactly a coordinate. Along with the assignment model, the model seeks to allocate the personnel in a coordination with the objective of reducing the global traveled distance, associating it as a transportation model [7].

Descriptions of sets, in Table 93.1, parameters, in Table 93.2, and variables, in Table 93.3.

Table 93.1 Table of sets

Sets	Description
P	Participants
C	Coordinations

Table 93.2 Table of parameters

Parameters	Description
limit_c	Maximum number of participants by coordination
distance_{pc}	Distance between participant and coordination

Table 93.3 Table of variable

Variable	Description
assign_{pc}	Assignment of the participant in the institution

Objective function:

$$\text{Minimize} = \sum_{p,c} \text{distance}(p, c) * \text{assign}(p, c)$$

Restrictions:

$$\sum_{c} \text{assign}(p, c) = 1 \quad \forall p \in P \tag{93.2.1}$$

$$\sum_{p} \text{assign}(p, c) \leq \text{limit}(c) \quad \forall c \in C \tag{93.2.2}$$

The first restriction (93.2.1) is used such as the participant is allocated in exactly one coordination, while the second (93.2.2) allows the assignment up to the maximum number of participants allowed for each coordination.

93.2.3 Mathematical Model for Cost Minimization

The cost minimization model is of mixed binary integer programming type. The costs are minimized by participant allocation at venues that result in lower establishments and personnel assignment costs. Sets, parameters, and variables are described, respectively, in Tables 93.4, 93.5, and 93.6.

Table 93.4 Table of sets

Sets	Description
I	Coordination
J	Room
F	Coordinating functions hired by number of rooms in coordination
G	Coordinating functions hired by amount of candidates in coordination
H	Room functions hired by amount of candidates in the room

Table 93.5 Table of parameters

Parameters	Description
applicants	Total applicants for the event
$\text{capacity}_{i,j}$	Room capacity for participants in room j of coordination i
lease_i	Cost of leasing by number of candidates in coordination i
room_reserve	Number of rooms in reserve by coordination
$\text{remun\_funct\_coord\_room}_f$	Remuneration of coordinating functions hired by number of rooms in the coordination
$\text{remun\_funct\_coord\_part}_h$	Remuneration of coordinating functions hired by number of candidates in coordination
$\text{remun\_funct\_room\_part}_g$	Remuneration of room functions hired by number of candidates in the room
$\text{rule\_funct\_coord\_room}_f$	Rule for hiring coordinating functions hired by number of rooms in coordination
$\text{rule\_funct\_coord\_part}_g$	Rule for hiring coordinating functions hired by number of candidates in coordination
$\text{rule\_funct\_room\_part}_h$	Rule for hiring room functions hired by number of candidates in the room

Objective function:

$$\text{Minimize} = \text{cost\_total\_lease} + \text{cost\_total\_staff}$$

Restrictions:

$$\sum_j \text{assign}(i, j) * \text{lease}(i) = \text{cost\_lease}(i) \quad \forall i \in I \tag{93.2.3}$$

$$\sum_f \text{Sattf\_funct\_coord\_room}(f, i) * \text{remun\_funct\_coord\_room}(f) = \text{cost\_coord\_staff\_room}(i) \quad \forall i \in I \tag{93.2.4}$$

$$\sum_g \text{staff\_funct\_coord\_part}(g, i) * \text{remun\_funct\_coord\_part}(g) = \text{cost\_coord\_staff\_part}(i) \quad \forall i \in I \tag{93.2.5}$$

$$\sum_{h,i,j} \text{staff\_funct\_room\_part}(h, i, j) * \text{remun\_funct\_room\_part}(h) = \text{cost\_room\_staff\_part}(i) \quad \forall i \in I \tag{93.2.6}$$

Table 93.6 Table of variables

Variables	Description
assign_{ij}	Integer variable of the number of designated participants for each room of each institution
assign_coord_i	Integer variable of the amount of participants allocated by coordination
capacity_coord_i	Integer variable of participants capacity by coordination
qt_staff_coord_i	Integer variable of the amount of staff by coordination
room_avail_i	Integer variable of the number of rooms available by coordination
room_used_i	Integer variable of the number of rooms with assigned participants by coordination
cost_lease_i	Continuous variable of leasing cost by coordination
cost_staff_i	Continuous variable of the cost of staff by coordination
$\text{cost\_coord\_staff\_room}_i$	Continuous variable of staff cost in coordinating functions hired by the number of rooms in coordination by coordination
$\text{cost\_coord\_staff\_part}_i$	Continuous variable of staff cost in coordinating functions hired by the number of participants in coordination by coordination
$\text{cost\_room\_staff\_part}_i$	Continuous variable of staff cost in coordinating functions hired by the number of participants in the room by coordination
$\text{capacity}_{i,j}$	Integer variable of participants capacity in the room j of coordination i
$\text{avail\_room}_{i,j}$	Binary variable to check if the room is available
$\text{use\_room}_{i,j}$	Binary variable to verify that the room has candidates assigned
$\text{qt\_staff\_coord\_room}_f$	Integer variable of the amount of staff in coordinating functions hired by number of rooms in coordination by coordination
$\text{qt\_staff\_coord\_part}_g$	Integer variable of the amount of staff in coordinating functions hired by the number of participants in coordination by coordination
$\text{qt\_}s\text{taff\_room\_part}_h$	Integer variable of the amount of staff in coordinating functions hired by the number of participants in the room by coordination
$\text{staff\_funct\_coord\_room}_{f,i}$	Binary variable to verify if staff with coordination function f hired by number of rooms is eligible in coordination i
$\text{staff\_funct\_coord\_part}_{g,i}$	Binary variable to verify if staff with coordination function g hired by the number of participants is eligible in coordination i
$\text{staff\_funct\_room\_part}_{h,i,j}$	Binary variable to verify if staff with room function h hired by the number of participants is eligible in the room j of coordination i
qt_total_staff	Integer variable of total amount of staff
cost_total_lease	Continuous variable of the total cost of leasing
cost_total_staff	Continuous variable of the total cost of staff personnel

$$\begin{aligned}&\text{cost\_coord\_staff\_room}(i) + \text{cost\_coord\_staff\_part}(i)\\&\quad + \text{cost\_room\_staff\_part}(i) = \text{cost\_staff}(i) \quad \forall i \in I\end{aligned} \tag{93.2.7}$$

$$\sum_j \text{capacity}(i, j) \geq \text{avail\_room}(i, j) \quad \forall i \in I, j \in J \tag{93.2.8}$$

$$\sum_j \text{capacity}(i, j) \leq M * \text{avail\_room}(i, j) \quad \forall i \in I, j \in J \tag{93.2.9}$$

$$\sum_j \text{use\_room}(i, j) = \text{room\_used}(i) \quad \forall i \in I \tag{93.2.10}$$

$$\sum_j \text{avail\_room}(i, j) = \text{room\_avail}(i) \quad \forall i \in I \tag{93.2.11}$$

$$\begin{aligned}&\text{room\_avail}(i) - \text{rule\_funct\_coord\_room}(f)\\&\quad \leq M * \text{staff\_funct\_coord\_room}(f, i) \quad \forall f \in F, i \in I\end{aligned} \tag{93.2.12}$$

$$\begin{aligned}&\text{assign\_coord}(i) - \text{rule\_funct\_coord\_part}(g)\\&\quad \leq M * \text{staff\_funct\_coord\_part}(g, i) \quad \forall g \in G, i \in I\end{aligned} \tag{93.2.13}$$

$$\begin{aligned}&\text{assign}(i, j) - \text{rule\_funct\_room\_part}(h)\\&\quad \leq M * \text{staff\_funct\_room\_part}(h, i, j); \quad \forall h \in H, i \in I, j \in J\end{aligned} \tag{93.2.14}$$

$$\sum_{i,j} \text{assign}(i, j) = \text{applicants}(1); \tag{93.2.15}$$

$$\text{assign}(i, j) \leq \text{capacity}(i, j) \quad \forall i \in I, j \in J \tag{93.2.16}$$

$$\begin{aligned}&\sum_f \text{staff\_funct\_coord\_room}(f, i) + \sum_g \text{staff\_funct\_coord\_part}(g, i)\\&\quad + \sum_{h,i,j} \text{staff\_funct\_room\_part}(h, i, j) = \text{qt\_staff\_coord}(i) \quad \forall i \in I\end{aligned} \tag{93.2.17}$$

$$\sum_i \text{qt\_staff\_coord}(i) = \text{qt\_total\_staff}(1) \tag{93.2.18}$$

$$\sum_i \text{staff\_funct\_coord\_room}(f, i) = \text{qt\_staff\_coord\_room}(f) \quad \forall f \in F \tag{93.2.19}$$

$$\sum_i \text{staff\_funct\_coord\_part}(g, i) = \text{qt\_staff\_coord\_part}(g) \quad \forall g \in G \tag{93.2.20}$$

$$\sum_{h,i,j} \text{staff\_funct\_room\_part}(h, i, j) = \text{qt\_staff\_room\_part}(h) \quad \forall h \in H \tag{93.2.21}$$

$$\text{room\_avail}(i) - \text{room\_used}(i) - \text{room\_reserve} \geq 0 \quad \forall i \in I \tag{93.2.22}$$

$$\sum_{j} \text{capacity}(i, j) = \text{capacity\_coord}(i) \quad \forall i \in I \tag{93.2.23}$$

$$\sum_{j} \text{assign}(i, j) = \text{assign\_coord}(i) \quad \forall i \in I \tag{93.2.24}$$

$$\sum_{i,j} \text{capacity}(i, j) = \text{capacity\_total} \tag{93.2.25}$$

Restriction 93.2.3 creates the cost of leasing in each location. Restrictions 93.2.4, 93.2.5, and 93.2.6 determine the cost by coordination for each type of personnel hiring. Equation 93.2.7 sets the total cost of personnel by coordination. The combination of restrictions 93.2.8 and 93.2.9 determines that the variable avail_room(i, j) is equal to 1 when the room has the capacity to have at least one participant assigned. The 'M' characterizes a very large number, larger than the capacity of a room. Equation 93.2.10 informs the number of rooms used in the coordination, while 93.2.11 reports how many rooms are available by coordination. Restrictions 93.2.12, 93.2.13 and 93.2.14 sets the hiring of employees in functions f related to hiring by quantity of rooms in coordination, functions g related to the number of participants in coordination and staff in functions h related to the number of participants in room i of coordination j, respectively. The number of applicants must be exactly the same as the sum of the assigned participants, represented in inequality 93.2.15. The assignment of participants in the rooms must comply with room capacity, in accordance with restriction 93.2.16. Restriction 93.2.17 sets the amount of personnel by coordination. Restriction 93.2.18 informs the total amount of staff. Equations 93.2.19, 93.2.20, and 93.2.21 add up the number of personnel hired by function, coordination, and room group for each type of function. The result is the number of staff for each contracting function.

Because of security issues, a number of reserve rooms by coordination are mandatory in all events, in case some student must be transferred, therefore, restriction 93.2.22 ensures that a number of reserve rooms are met.

93.2.4 Performance

An example with random data was used, assigning 2,000 participants in up to 7 coordinations, each with distinct assignment capacity and leasing cost. Problem solving occurred after 2,000 interactions and 0.29 s for Model 1 and 3,722 interactions and 0.81 s for Model 2 with LINGO 17.0 software (Educational License), by means of Simplex Primal. The problem was run in a computer with Windows 7 operating system, Intel Core i3-4170 @ 3.70 GHz processor, and 12 GB RAM Memory.

93.2.5 Trade-Off Curve Model 3

One of the main challenges of a company, according to [8], is the identification of possible trade-offs that can reduce costs related to keep a satisfactory level of service to its customers.

In this work, Models 1 and 2 were grouped to generate a trade-off curve. Model 1 objective function (item 93.2.4), which maximizes the level of service measured by distance traveled between participant residence and assigned coordination, became a restriction for Model 2 (item 93.2.5).

$$\sum_{pc} \text{travel}(p, c) * \text{assign}(p, c) \leq X \tag{93.2.26}$$

The new Model 3 replicates Model 2 but with a minimum level of service to be met. Restriction 93.2.26 determines that the total distance traveled by participants be smaller or equal to a value X, defined by the decision maker. Besides that, restriction 93.2.2 was changed to:

$$\sum_{p} \text{assign}(p, c) \leq \text{assign\_coord}(c) \quad \forall c \in C \tag{93.2.27}$$

In which variable "limit(c)" has been replaced for "assign_coord(c)".

For the construction of the trade-off curve, it is necessary to run Model 3 with several values for the desired level of service (X), in accordance with Eq. (93.2.26).

93.3 Conclusion

The models proposed in this work were solved by Lingo 17.0 software, using random and actual data. From simulations in events already executed by Cebraspe, savings between 5 and 25% in logistics costs were estimated. In addition to the financial aspect, the study found that it is possible to have improvement for participant's level of service since this item is not formally taken into account by the institution. In the example analyzed with 2,000 participants, it was verified the possibility of 48.77% reduction in the distance traveled by candidates. In this item, it is also possible to consider the environmental aspect, as candidates travel shorter distances, there will be a reduction in pollutant gases emissions from vehicles that transport the participants.

From Model 3, it is possible to build a trade-off curve, considering costs and level of service, facilitating visualization and decision-making among several possible scenarios.

The models elaborated in this study were able to provide improvements for the organization. Besides, they can be used in different organizations responsible for selection processes, whose processes resemble the one described in this work. This ensures process transparency and enables lower costs and better levels of service. This research also contributes to scientific knowledge presenting an applied model to a case study still unprecedented in academic publications.

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Chapter 94
Servitization as a Startup Driver: A Case Study in a Technology Park

Michele de Souza, Luiz Reni Trento and Michelle Dauer

Abstract Through a qualitative exploratory methodology, the multiple case study investigates the servitization implemented by startups based in a technology park in southern Brazil. The findings show that these processes strengthen operational performance, partnerships, and brand and contribute to innovation.

Keywords Servitization · Startup · Case study

94.1 Introduction

The term servitization or transition from product to service is a trend in manufacturing enterprises [33]. Services include simple, product-related services as well as complex project offerings, integrated systems [32], or product-service systems [31]. Manufacturing companies see the business model served as a way to add value to their products and differentiate from competitors, thereby increasing their market share [32]. Although servicing is becoming increasingly common in large manufacturing enterprises [16, 18, 27], this reality it is still not common in small companies and startups. Such distance is due to the limited resources and the capacity to define the servitization strategies [30]. Startups are premised on developing a product or service that is innovative and that adds value to its customers. A vast majority of these businesses can fail because they are not able to deal with the obstacles encountered. According to studies, 90% of new innovative technology companies fail in the first 120 days. As startups, they are lean organizations and need to develop their business models from innovative ideas or lessons learned from previous models that failed. These companies are still characterized by the need for guidance consultancies [3]. The speed of business, demand for variety and customization require companies to identify the solutions to be deployed in the business correctly [18, 23, 30]. One of the challenges faced are the quality levels that are difficult to control and even evaluate in practice; this requires the manufacturing company's skills to meet the expecta-

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tions of customers. Such skills include team management and length of service due to the high level of operational flexibility needed to respond to market demands [24]. Therefore, many manufacturers face significant challenges in implementing service delivery and performing service operations successfully [24]. Hence, it is crucial to understand how to drive business, especially in startups like startups that are overloaded with challenges and uncertainties [25].

In the literature, it is observed that the studies focus on servicing in large companies. However, few papers have focused on servicing small firms [23, 27]. Suggestions for future work presented in the literature include the need to investigate the leveraging of servicing in small businesses. Also, the analysis of the literature on serviceability also indicates that it has few case studies in startups [22]. Aiming to contribute to filling this gap, the present case study investigates the service in startups located in a technology park in the south of Brazil (TECNOSINOS). The analysis of these elements gave rise to the following research question—RQ: "How can servitization boost the business of startups?"

The article progresses as follows. The first section presents the literature review of the study based on the following fundamental concepts: servicing, servicing in small and medium enterprises, and servicing of startups. In addition to the fundamental concepts, we seek to present opportunities in services, requirements for improvements, risks, and complexities. The methodology of multiple case study is then detailed below, giving special attention to the framing and explanation of data analysis around practices and mechanisms. They follow the findings that unveil and demonstrate some aspects of servicing those drive startups' businesses. The discussion articulates and discusses the propositions regarding the case, problems, and recommendations on servitization and concludes with implications for management and future research.

94.2 Literature Review

94.2.1 Servitization

The servitization consists of the transformation of companies focused on the product to businesses whose focus is the supply of services [19, 20] or process by which the company produces and offers its products by adding services [11, 19, 20, 31]. Among many definitions, the service consists of the strategy of adding value to the products through the provision of services related to them [1, 21, 33]. The companies start to offer product-service solutions by expanding their market and, consequently, increasing their performance [2, 6, 18]. The service-oriented business models aim to increase the value delivered in the interaction between manufacturer and customer [28]; broaden market share and customer relationship; differentiate themselves from competitors; and achieve significant increases in turnover [18]. This strategy enables companies to generate growth and revenue [12, 16, 18]. Corporate customers have been demanding more and more complete solutions; this demand has enabled manufacturers to improve product offerings with services. It influences the purchasing decision positively and consequently increases the sales of products [10, 17]. Manufacturers can benefit from the following business processes: (1) business processes that increase productivity; (2) business processes that increase the value of the customer; and (3) business processes that allow innovation [15]. Servicing can bring countless benefits and gains to companies, but it is also fraught with risks and barriers. Adding service to the business model may require capabilities that firms are not able to meet, such as expanding sales arguments, adjustments, and pricing models [5].

94.2.2 Servitization and Startups

The literature identifies that manufacturers in many industries are adopting focused strategies for services aimed at increasing their market share and thus broaden their sources of revenue [11, 13, 18]. However, this scenario is not limited only to large companies. Startup companies are also operating service-oriented [13]. Servicing in these contexts leads to business models imbued with innovation. It can initiate operations with repairs and maintenance and move to train activities, technological consulting, product development and data processing and analysis [7]. Small businesses like startups have a direct relationship with customers. Startups have a direct relationship with customers. This relationship can be linked to the following aspects: performance in differentiated sectors, production of customized offers, production of small batches tailor-made or in low volume, simply installed, and uncomplicated. The literature shows that these aspects can retain and strengthen relationships with clients and partners [23].

94.3 Methodology

The empirical research carried out in this study employed the method of multiple, qualitative, and exploratory case study. This method has been chosen to contribute to the literature on servicing and how it can boost startups. The analysis of the case study developed took place in startups located in TECNOSINOS, active in the segments of information technology; automation and engineering; renewable energies; and social and environmental technologies. The case study is strategic for examining contemporary events and provides researchers with an opportunity to understand the conditions that are present in a particular situation [34]. The case study as a form of research is adequate to focus on research in environments defined by one or few organizations [29]. The multiple case study methodology is considered more convincing and robust because it allows, in addition to the individual analysis, the analysis between the cases. While the individual analyzes consolidate the information

Table 94.1 Characterization of the interviewees

Company	Role of interviewees	Identification interviewee	Market of performance
Startup1	Director's operation	D1	Clean and renewable energy market through the development and implementation of photovoltaic solar systems projects for residential, commercial, and industrial consumers
	Manager's operation	M1	
Startup2	Director's operation	D2	Development of 3D printing projects and services, developing the print delivery design, sale of 3D printing, and custom CNC
	Manager's operation	M2	
Startup3	Manager's operation	M3	Development of technologies for the agricultural sector. Humidity sensors of the soil intelligent system for control and automation of the irrigation

Source Developed by the authors (2018)

of each case, the analyzes between the cases identify patterns, providing elements for the construction of hypotheses and the development of theories [8, 34]. The present multiple case study highlights the factors of serviceability that may contribute to boosting startup business. In a case study, it is recommended to combine a variety of sources. Such sources include interviews that are one of the most critical sources of facts and opinions, document analysis, questionnaires, and quantitative file records [34]. In Table 94.1 show the characteristics of the companies.

To address the question of this research, the interviews were conducted with professionals directly involved with the operation and administration of startups. The criteria for the selection of professionals were experience and their involvement with the business.

94.3.1 Case Selection and Context

The data collection was carried out through five semi-structured interviews with professionals of the two groups already mentioned: operational directors and administrative directors. The interviews took place from August 2018 to September 2018. For the development of the guide, a bibliographic survey was carried out through the search for scientific articles elaborated on the theme, which made possible the theoretical understanding as a fundamental instrument. The theory studied includes servicing, servicing small businesses, and servicing startups. The questionnaires were based on such topics and contained identical questions for both groups of respondents. The interviews lasted approximately 1 h. All interviews were conducted in person and transcribed [26]. The perceptions and conclusions of each interview were shared and discussed among the researchers. Any remaining questions of the interviews were clarified directly with the interviewees through email and personal contact. The companies were very open to the discussion, but they demanded confidentiality regarding the disclosure of their names.

94.3.2 Data Collection and Analysis

After the interviews, the data were analyzed using qualitative content analysis [26]. Data from the interviews and documentation were analyzed to identify if the case would meet the requirements of the present research. The analysis of these data allowed its classification in categories related to the research question. In this way, it was possible to guarantee that the relevant information had been collected. The triangulation made from the collected data provided the reliability of the findings and validation of the constructs [8, 14, 34]. The guide for semi-structured interviews provided detailed descriptions. Data were transcribed and encoded using the ATLAS.ti 8 Windows, following the coding procedure described in the literature [4]. The transcript of interviews and documents collected provided transparency of the information collected [34]. The researchers discussed and reorganized different codes and interpretations until an agreement was reached. They then transferred the results of the analysis within the case to a tabular format in spreadsheets. Subsequent cross-analysis identified features and differences between the units of analysis based on empirical data and the literature on servicing in startups. Finally, the findings were compared with the findings in the literature. These findings were cataloged in groups to identify lessons learned from the study that may contribute to the academic literature.

94.4 Results and Discussion

The analysis of the multiple case study developed took place in startups located in TECNOSINOS of the segments of information technology, automation and engineering, communication and digital convergence, technologies for health, renewable energies, and socioenvironmental technologies.

Startup1 started a business with a service strategy. Regarding the structure of the business model, Startup1 acts with projects of solar energy, photovoltaic solar energy, energy efficiency projects, and electrical projects in general. Such projects can be carried out both in B2B or B2C markets. The materials used in the projects are purchased from partner distributors; after the acquisition of the materials, the researchers are carried out and the approval of the projects with the local energy distributors. The second stage of the project consists of the operationalization and installation of the project. This job can be operationalized internally or outsourced when a specific operation is required. Besides, the company performs sales and maintenance.

Startup2 started to include services to the products selling due to an internal need to expand business and market. This finding corroborates the literature by indicating that the servitization is a strategy that companies adopt to increase their market share [32]. D2 highlighted "we started with a product that did not exist in Brazil, only in the United States, we were initially an automation company, but we identified endless possibilities of development services, so we became a technology company." Startup2 is active in the 3D printing market. The company started the business by creating 3D printers according to the numerous needs of customers. Currently, the company develops and manufactures 3D printing machines, makes prints to order, performs maintenance on these machines, and also deliver trainings to end users of the printers. The strategy adopted by startup 1 and 2 corroborates with the literature that shows that companies start to offer complete product-service solutions to expand their market of performance and consequently boost their performance [2, 6, 18]. Still, on Startup2, the company reveals that it faces some barriers by adopting the servitization strategy. D2 revealed "today we do not know the type of customer who will request a 3D printing. Numerous demands come in, and we often need to learn to serve the customer. Our business is very open; it makes difficult even to make effective marketing communication actions. Our strategy now is to focus on a specific niche." As evidenced by Frambach et al. [10] and Kamp et al. [17], the offer of complete solutions influences customers in their purchasing decisions.

On the other hand, for companies that have a wide offer of solutions, this practice tends to negatively impact the business. As evidenced by M2 from Startup 2, the company loses control of demand, and budget planning gets hampered, so it is crucial for the survival of the business to define a specific niche. Like Startup1, Startup3 has already started the business with a service-oriented strategy. Currently, the company develops products and technology for the agricultural sector. The current strategy is to serve small and medium farmers with sensor solutions for soil moisture and an intelligent irrigation control and automation system. The startups business model corroborates by revealing that service delivery leads to servicing business [7].

The companies investigated were born with highly technological and innovative products and services. Servicing enabled these companies to expand their market and enter into previously unexplored markets. In the service design aspect, the three startups have a long sales cycle. The marketing and sales process occurs mainly through word of mouth advertising, although they operate with representations, participation in fairs and events, and dissemination in social media. The physical allocation in a technological pole also contributes to the viability of new businesses. The D2 reveals that "we have made great partnerships with companies that, like us, are at TECNOSINOS, and we have received a great demand for jobs from other startups." D1 reveals "what contributes a lot to our marketing and the realization of new business and the fruit of the relationship we have with our customers. We take new or prospective clients to evaluate facilities already in operation. A good customer relationship is everything.” The same goes for M3 when affirming that the strengthening of the relation of the clients with clients is linked to the reliability and agility in the resolution of the problems.

In the companies investigated, the sales process begins with the sending of a budget, closing the deal or not and post-sale. D2 reveals, “A major challenge at the start of the business was the pre-qualification, we did not know how to prepare the projects. We evolve a lot in this sense; we define the prices and the criteria of variation. A contract is only closed after detailing all costs and expenses.” The D1 interviewee claims to be acting with imported items, and this reflects in the price of the products. Startup1 adopts prefix policies with exchange variation, which seems to enable a certainty and reliability in financial results.

The purchase of materials/supplies for the production of equipment and provision of services occurs after the contract is closed. As for execution, all services and products are executed for the project. D1 reveals “we contact partners, suppliers, distributors, and third parties according to the projects. We do not have the physical and financial structure to maintain a fixed set of installers, for example.” The companies investigated have lean physical and administrative structures. These organizations are comprised of no more than four employees including the chief operating officer and the managing director. The companies were unanimous in revealing that the business would not be operational and financially viable if they had opted only for the marketing of products. D1 states “we deliver a complete solution, we are aware of the whole process. We need to have a good knowledge about the product we are going to buy because in the market there are several brands, we have to understand how it works and how to apply it in the best way. There is also the bureaucratic question of our business since it involves electric companies. The project part, processing, and approval of the project in the distributor and then understand the execution part. The great differential of our business and what guarantees us a competitive advantage is to master the process from start to finish, delivering a complete solution.” The startups business model collaborates with the literature [28] when it reveals that servitization raises the value delivered to the client and also to the literature [18] by indicating that servitization of businesses increases participation in the market and makes possible a differential in front of the companies that offer only products or services.

In the context of partner relationships, startups argue that it is crucial to have a secure and dependable relationship. The D2 states that “the relationship with third parties is fundamental, it is the basis of our company, for example: if a partner delays the delivery of a material, I will have to go around and tell the customer that there was difficulty with the distributor.” M3 contributes “in the technological pole we form an essential ecosystem. We use partner companies to support in R&D, and from these exchanges, we can generate new businesses.” The approximation of startups with their partners contributes to the literature [23] where lean and uncomplicated bases allow the strengthening of relations with partners. Table 94.2 presents the drivers of the servitization in the startups investigated. Despite the barriers faced in their business, results have shown that servitization enables and drives the operational and financial performance of its business (Table 94.1).

Table 94.2 Drivers and barriers

Drivers	Barriers
↑ Specific market action (niche) ↑ Full operation knowledge ↑ Integrity in partner and customer relationships ↑ Pricing policies ↑ Marketing strategies	↓ Lean structure ↓ Import-dependent raw materials ↓ Exchange rate sensitive

Source Developed by the authors (2018)

94.5 Conclusions and Recommendations

The present study was designed in order to understand how servitization can leverage startups businesses. First, we discuss the cases were presenting the startups business model and the motivators to follow the servitization strategy. Second, it presents the servitization factors that can boost the operational and financial performance of these companies. Finally, the adoption of a service strategy enabled the companies investigated financially and operationally. The results revealed in this research can guide future entrepreneurs and managers through the development of servitization processes acting with highly innovative, and technological products. To boost their business, entrepreneurs and managers must analyze and consider the drivers: specific niche market; comprehensive knowledge of the operation; relationship with partners and customers [28]; assertive price policies [18]; and appropriate marketing actions. Entrepreneurs and managers should also consider the barriers and difficulties presented in service business. As with any study, the present research has limitations that must be addressed. As the study is of a qualitative nature, the results cannot be generalized to the startup's population with technological and innovative products and services [9]. Future studies could broaden research with startups with diverse products and services. An additional extension of the research can validate and measure essential parameters to boost startup performance.

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Chapter 95
Public Mobility: All the Same Service Level or Some Privileges?

Eder de Melo Freitas, Karen C. de Lima Wolga and Sandra L. Oliveira Facanha

Abstract Public mobility is a major concern for big cities, but even more complex if the main transport relies on public buses, such as Sao Paulo. Despite recent improvements, bus service quality is still below expectations. A survey-based analysis investigates the main issues and evaluates possible differences based on social-demographic aspects.

Keywords Service level · Public transport · Mobility

95.1 Introduction

In the early nineteenth century, an average American traveled 50 m per day, mainly by foot, horse, or carriage. Two centuries later, Americans travel 50 km per day, mainly by car and air and, on a worldwide basis, it is estimated that citizens move 23 billion kilometers per year (Urry *in* Grieco and Urry [10], p. 5).

Given these extraordinary numbers, mobility should be a very relevant concern for all countries but, especially for highly populated places, such as Sao Paulo, one of the largest cities in the world and the largest in South America.

Among the various modes of public transportation, the most popular, due to availability, frequency, and/or capillarity, is the municipal bus, which travels within a certain municipality. Considering Sao Paulo, recent data from the Brazilian Institute of Geography and Statistics [11] indicate that almost 70% of more than 12 million inhabitants in the city of São Paulo use said transportation mode.

Notwithstanding its importance, the bus service level has been below user expectation for decades, however without major protest movements in the last decades until June 2013, when the municipal government tried to raise the ticket price without success. Since then until 2016, the city of Sao Paulo has witnessed popular protest movements in an intermittent manner.

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Unquestionably, some improvements were and are still being made by the city government. However, it is public knowledge that certain areas of the city, e.g., east area, seem to face more challenges than others. So, the main objective for this research can be summarized as follows: is the user—on an overall basis across the different areas in the city of Sao Paulo—satisfied with the current level of bus transportation services and, if so, is the level of satisfaction all the same across different areas, with different social-demographic aspects, in the city of Sao Paulo?

95.2 Literature Review

95.2.1 Quality

In the context of the present research, the quality will be addressed as the set of characteristics of a product or service related to the ability to satisfy customers' explicit needs [13].

Bertozzi and Lima [3] suggest some quality factor from the point of view of the user, such as environment, comfort, accessibility, price, moments of interaction, communication, previous experience, image, and confrontation between what is accomplished, communicated, and perceived.

Concerning services quality, Corrêa and Caon (2002) have presented a very comprehensive list of factors to assess quality, such as access, speed, consistency, flexibility, safety, cost, communication, and cleanliness. Ferraz and Torres [7] have indicated specific factor for bus transportation quality, including vehicle features, ticket price, overcrowdedness, information system, among others.

Regardless of the factor used, Pereira [18] reminds us that quality is the level at which expectations about a particular product or process are met. Such expectations may vary according to the point of view of the user, what adds a subjective character to the concept of quality, especially when it comes to quality in services.

95.2.2 User Service Satisfaction Level

According to Johnson et al. [12], there are at least two concepts of consumer satisfaction: transaction-specific satisfaction and cumulative satisfaction. The first refers to the assessment of a specific purchase or consumption situation; the second is the complete evaluation of a total purchase or consumption experience.

Rossi and Slongo (1997) amplified this discussion by stating that, in practice, accumulated satisfaction is more attractive because it provides a clear indication of the present and long-term performance of a company or a market segment. As the objective of this research is to identify the level of satisfaction of a certain group of consumers with respect to their experiences with public transportation, the cumulative concept of satisfaction presents itself as more appropriate.

Anderson et al. [1] argue that consumer satisfaction is affected by three antecedents or determinants: perceived quality, price (perceived value), and expectations. Perceived quality is the current assessment of the company's performance and tends to positively influence total customer satisfaction over the supplier. Two main components of consumer experience, according to Fornell et al. [9], help in the evaluation of perceived quality: the degree of customization of the company's offer according to the most different needs; and the credibility of this offer in relation to the absence of deficiencies. The second determinant of consumer satisfaction is the perceived value [1, 9]. Price quality has a direct impact on consumer satisfaction. It is important to consider the relationship between the quality of the offer and its price, as well as the effects that confuse the relationship.

95.2.3 Public Transport

According to Fielding [8] (*apud* Cavadinha [8]), among the several functions of the public transport system, the main ones are: ensuring labor mobility, reducing road congestion, contributing to energy saving, and reducing levels of environmental pollution.

In addition, Rodrigues [20] points out that urban collective transportation by bus is an important and necessary means of integration between the various economic and social areas of urban centers, playing an important role in industrial development, trade expansion, health programs, education, among other activities.

In the Brazilian case, the issue of urban public transportation officially became a public concern after the promulgation of the Federal Constitution of 1988 [4], which establishes, in section V of Article 30, that it is the responsibility of municipalities to organize and provide, directly or under concession or permit, public services of local interest, including public transport, which is essential.

Almost 25 years later, Law number 12.587/2012 was enacted aiming to improve the accessibility and mobility of people and cargoes in municipalities, as well as favoring the integration of different modes of transportation. Such legislation establishes the guidelines of the National Policy of Urban Mobility (PNMU) and prioritizes means of transport that are not motorized, as well as collective public transportation. Another relevant feature is the requirement for municipalities with more than 20 thousand inhabitants to draw up urban mobility plans which must be integrated into the city's master plans.

In compliance with the PNMU, in 2015, the São Paulo Mobility Plan (PlanMob/SP 2015) was presented, an instrument for planning and managing the Municipal Urban Mobility System (means and infrastructure for transportation of goods and persons in the municipality), covering a period of 15 years, made official by the City of São Paulo through Decree No. 56.834, dated February 24, 2016.

At the same time, the introduction of the Federal Law on Urban Mobility, promulgated by the National Congress, in accordance with Constitutional Amendment No. 90, dated September 15, 2015, includes in Article 6 of the Federal Constitution transportation as a social right, in addition to education, health, and safety, which meets the clear manifestations of the Brazilian society for a level of decent bus transportation service by companies that offer said service, whether governmental, private, or both.

Since the manifestations of June 2013, when the São Paulo City Hall has authorized the increase of R$0.20 (roughly 5%) in bus tickets to the present day, the subject "urban public transport" has been widely discussed and, without doubt, some minor improvements have been implemented, such as the expansion of exclusive bus lanes at certain locations, during certain time-windows, in the urban perimeter.

In 2017, the National Confederation of Transport (CNT) and the National Association of Urban Transportation (NTU) companies jointly carried out a research aiming with focus on Urban Mobility Assessment in Brazil. Among several issues addressed, respondents were asked about major urban problems. Transportation was the fourth problem highlighted, only behind even major issues such as violence, health, and unemployment.

As highlighted by the NTU [16, p. 07], an important body of the segment in question:

> The provision by the State of a quality urban public transport service that is accessible to all social classes, which meets the basic needs of the population, is a fundamental condition for social inclusion and universal access to education, health and leisure for all Brazilians.

95.3 Method

In general terms, Appolinario [2] argues that the nature of scientific research tends to be polarized between qualitative and quantitative research. In the latter case, research that deals with the "fact" (typical of the natural sciences) predominates; while in the first case the deal with the phenomena (typical of the social sciences). The nature of this research is quantitative.

Among several research techniques that can be used for application in the present paper, the main ones will be bibliographic research and survey.

Martins and Theóphilo [15] point out that bibliographic research is a "research strategy necessary for the conduct of any scientific research," basically because it is an indispensable stage in the construction of the theoretical platform of any scientific research.

The survey can be translated as a "poll." According to Martins [14], this is a "survey of primary sources, usually through the application of questionnaires for large numbers of people."

The questionnaire had closed questions, in order to specifically indicate the level of user satisfaction regarding the main attributes of urban public transportation by

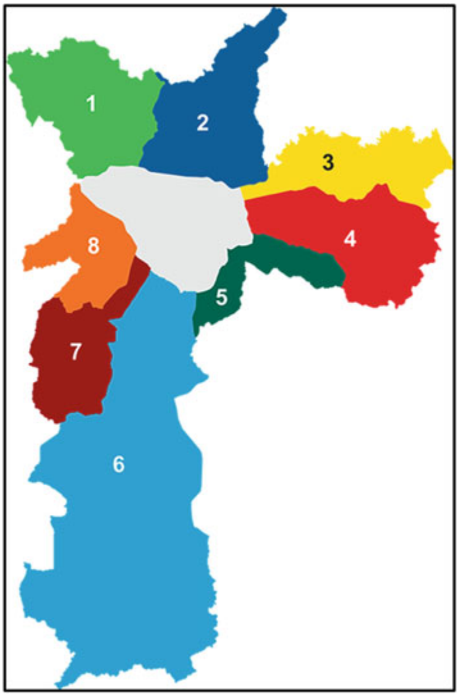

Fig. 95.1 Bus transportation areas in São Paulo. *Source* SP Trans (2018)

bus, following a Likert scale from 1 (very bad) to 5 (excellent), considering grades for each factor and a smaller scale, from 1 (not applicable or not important at all) to 4 (very important), considering the impact of each factor, from the users point of view.

Regarding data collection, it should be clarified that these questionnaires were applied personally by the authors of this research, with the aid of two trained collaborators, at different bus terminals located at all eight areas in the city of São Paulo, from May to September (per Fig. 95.1), on a random basis.

Statistical treatment provides descriptive statistics, also an analysis of variance (one-way ANOVA), based on the following hypothesis:

$$H_0\colon \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5 = \mu_6 = \mu_7 = \mu_8$$

$$H_1\colon \text{not all averages are equal.}$$

95.4 Results and Discussion

A total of 760 samples were collected, divided into eight different areas, following the official map areas published by the municipal government, per Fig. 95.1. Different

Table 95.1 Sample sizes

Areas	Actual sample	Recommended sample
Area 1: Northwest	70	68
Area 2: North	98	76
Area 3: Northeast	76	76
Area 4: East	91	83
Area 5: Southeast	190	63
Area 6: South	90	89
Area 7: Southwest	98	98
Area: 8: West	47	47
Total	760	600

samples sizes were taken, in accordance with the number of average trips in each area, as provided by SPTrans (2017). Considering 95% confidence level, the recommended sample sizes resulted in the numbers shown in Table 95.1; however, actual sample sizes have exceeded these figures in nearly all areas.

The demographic analysis indicates that, as far as gender is concerned, 469 respondents were female, which amounts to 62% of municipal bus users. Regarding age range, the majority (80%) of respondents consist of adults, however young adults, with more than 60% in the range of 18 years to 36 years old. Interestingly, when the level of education is taken into consideration, 50% of respondents have high school degree only, while 22% have concluded a graduation course.

In terms of household, 40% of respondents live either alone or with someone else, while 44% live in a family of three or four members. Household income ranges from one to four minimum Brazilian salaries (total equivalent to maximum US$1.000/month) for 46% respondents, while 37% are in the range of five to ten salaries (total equivalent to maximum US$2.500/month).

As all samples were taken on a random basis, not all respondents were daily users of the bus transportation system; however, nearly 2/3 of them did inform that they use the bus system at least 4 times per week.

In the present research, the "quality" issue concerning bus transportation system in São Paulo was addressed with one general question, followed by nine specific factors: respect to the "stop" sign at bus stations (in Brazil, due to different reasons, it is usual for the bus driver to ignore users' sign to stop at some bus stations at certain times), driver's behavior (basic focus is transit safety), ticket price, itinerary, security (thefts, harassments, and similar disturbances while inside the bus), waiting time (for the bus, at the bus stations), visual communication (inside the bus), cleanliness (inside the bus), and overcrowdedness.

Regarding overall service quality, about 9% of the users rate the service as excellent or very good. A little less than 49% stated that the service is "satisfactory," while a little more than 42% of respondents rated the overall service quality as bad or very bad.

All respondents were asked to quantify the level of satisfaction in each specific factor, as well as how important such factor is regarding the overall service quality. The consolidated results for impact are detailed in Table 95.3, while specific factors grades are in Table 95.4 (Table 95.2).

Basically, the least important factors for all areas were stop signal compliance, driver's behavior, and visual communication, except for area 4 (East), which presents cleanliness instead of visual communication as one of the least important factors.

In general, the most important factors are overcrowdedness, waiting time, and ticket price, except for areas A5 (Southeast) and A6 (South), which regard security as more important than the ticket price and area A7 (Southwest) that considers security more important than waiting time.

As far as grades for each of the previous factor are concerned, numbers on Table 95.3 are quite the opposite as the previous table. The least important factors are the ones highly rated: stop signal compliance, driver's behavior, and visual

Table 95.2 Consolidated results (mean) per area

Factors importance	A1	A2	A3	A4	A5	A6	A7	A8	Overal weighted mean
Stop signal compliance	**2.96**	**2.97**	**3.07**	**3.02**	**2.99**	**2.89**	**3.00**	**3.00**	**2.99**
Driver behavior	**3.06**	**3.05**	**3.05**	**3.04**	**3.01**	**2.82**	**2.97**	**3.06**	**3.00**
Ticket price	**3.40**	**3.45**	**3.59**	**3.55**	3.55	3.53	**3.41**	**3.47**	**3.50**
Itinerary	3.16	3.20	3.20	3.38	3.23	3.11	3.33	3.26	3.24
Security	3.16	3.38	3.41	3.52	**3.59**	**3.54**	**3.37**	3.30	3.44
Service waiting time	**3.47**	**3.65**	**3.61**	**3.51**	**3.61**	**3.43**	3.31	**3.70**	**3.54**
Visual communication	**2.76**	**2.98**	**2.78**	3.09	**2.92**	**2.81**	**3.09**	**2.85**	**2.92**
Cleanliness	2.99	3.18	2.91	**3.01**	3.02	3.08	3.14	3.17	3.06
Overcrowdedness	**3.60**	**3.44**	**3.68**	**3.75**	**3.57**	**3.62**	**3.59**	**3.57**	**3.60**

Table 95.3 Consolidated results (mean) per area

Factor grades	A1	A2	A3	A4	A5	A6	A7	A8	Overall weighted mean
Stop signal compliance	**3.07**	**3.42**	**3.16**	**3.22**	**3.30**	**3.10**	**3.39**	**3.51**	**3.27**
Driver behavior	**3.11**	**3.31**	**3.14**	**3.15**	**3.24**	**3.02**	**3.31**	**3.34**	**3.21**
Ticket price	**1.93**	**1.92**	**1.51**	**1.76**	**1.80**	**1.70**	**1.74**	**1.87**	**1.78**
Itinerary	2.80	3.05	3.01	3.04	2.93	2.77	2.97	3.04	**2.95**
Security	2.69	2.79	2.57	2.44	2.59	2.34	2.41	2.70	**2.56**
Service waiting time	**2.31**	**2.29**	**2.24**	**2.49**	**2.33**	**2.04**	**2.38**	**2.11**	**2.29**
Visual communication	**3.13**	**3.29**	**3.07**	**3.15**	**3.39**	**3.16**	**3.27**	**3.26**	**3.24**
Cleanliness	2.86	2.84	2.61	2.89	2.80	2.62	2.69	2.79	**2.77**
Overcrowdedness	**1.87**	**2.08**	**1.63**	**1.81**	**1.99**	**1.80**	**1.80**	**2.02**	**1.89**

Table 95.4 One-way ANOVA results

Consolidated results	*F*	*P*-value	Critical *F*	Ho
Stop signal compliance	0.2648	0.9673	2.0217	Accept
Driver's behavior	0.6015	0.7550	2.0217	Accept
Ticket price	0.7091	0.6644	2.0217	Accept
Itinerary	0.9375	0.4766	2.0217	Accept
Security	**2.7736**	**0.0075**	**2.0217**	**Reject**
Service waiting time	**2.4752**	**0.0162**	**2.0217**	**Reject**
Visual communication	1.7130	0.1027	2.0217	Accept
Cleanliness	1.0037	0.4272	2.0217	Accept
Overcrowdedness	1.5568	0.1450	2.0217	Accept
Overall satisfaction	1.7708	0.0901	2.0217	Accept

communication, while the most important factors (ticket price, overcrowdedness, and service waiting time) are the poorly rated ones.

In order to assess potential similarities or differences, a one-way ANOVA test (5% significance) for each of the specific factors was run and the final result is presented in Table 95.4.

95.5 Conclusion and Further Research

Notwithstanding a general perception that the service level provided by municipal buses is well below expectations, nearly half of all respondents considered said level to be "satisfactory," although 42% regarded it to be "bad" or "very bad." Consistent with this overall appraisal, when evaluating specific factors, the most important ones, i.e., overcrowdedness, service waiting time, and ticket price (in decrescent order), are mostly rated as bad or very bad, with average mean of, respectively, 1.89; 2.29 and 1.78 (in a scale of 1–5).

It is worth mentioning that, even though ticket price was regarded as the third more important factor, it has received the lowest rate on average across all areas in all factors, but in areas A5 (Southeast) and A6 (South), security becomes more important than ticket price. Security also shows up as more important than service waiting time in area A7 (Southwest).

The one-way ANOVA result confirms a significant difference for security and also for service waiting time on a 5% level of significance; however, the null hypotheses cannot be rejected for all other seven remaining factors.

Further research presents a two-way avenue. One is to investigate the ANOVA results through complementary tests such as Tukey, aiming to identify which area(s) present differences. Another possibility is to focus on more detailed profiles of respondents versus service appraisal. For instance: do frequent users have a different appraisal of the service level compared to non-frequent users? Also, is the level of bus service appraisal somehow correlated to age, and/or education and/or salary?

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Chapter 96
Layout Improvement Study at a Brazilian Non-governmental Organization

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Abstract This study was developed at a Brazilian non-governmental and non-profit organization which provides pedagogical and social assistance to children from poor communities. It aimed to apply layout analysis methods for better use of space and student flow. Results provided reorganization of the work environment and an expansion of service capacity.

Keywords Layout · Process improvement · Social good

96.1 Introduction

Non-governmental organizations (NGOs) are private non-profit organizations that accomplish public purposes [1]. They seek to establish a relationship between State and Society, intervening in areas with social needs, due to a lack of public policies and market inaccuracies [6].

These organizations can develop activities in partnerships with public and private agencies, occasional donors, and volunteers [18]. Due to this informality in collections, NGOs tend to face financial and workforce difficulties [9].

According to Sousa and Sena [18], there are several challenges that threaten an NGO existence, being extremely important to identify the peculiarities of each organization and consider these characteristics at the management model. In addition, it is important to highlight the effectiveness of its work and its benefits to society and local community.

It is evident the difficulty of maintaining an NGO in Brazil due to the negligence of the public power, deficient, and retrograde in the generation of activities of public interest, mainly in poor and disadvantaged communities. The increasing of their visibility and the expanding workload to serve the community expose the restrictions of these organizations due to the lack of financial, physical, and human resources. Therefore, the endeavor to reach such resources becomes a necessity [18].

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Owing to this difficulty to raise funds, the optimization of resources is essential to allow the greatest service to community, besides ensuring the survival of the organization. One of the factors that interferes in productivity and optimization of organizations in general is the layout of the installation.

To understand the importance of a layout, first, we need to understand its concept. In the literature, it has been defined as the study that concerns with the spatial arrangement of the production resources, either machines, men, or materials, in order to establish properly where each one of them will be allocated in an activity or workspace [17].

The ideal layout of the installation is one of the tools that can contribute to reduce costs and to increase productivity. The layout design involves a systematic physical arrangement of different departments, workstations, equipments, storage areas, and common areas within an existing industry [12].

In this context, this article aims to evaluate possible improvements in a non-profit organization, through a case study in an NGO in the municipality of Niterói, Rio de Janeiro, Brazil. Based on the use of layout improvement tools, the project aims to contribute to the daily life of the NGO More Project, enabling new forms of layout, a better use of its resources, improving the processes and the flows of people and assets.

This article was divided into five sections, namely: after this initial presentation, Sect. 96.2 presents the literature review. Section 96.3 characterizes the methodology. After that, we described the case study. At the end, we present conclusion and references.

96.2 Literature Review

The term non-governmental organization (NGO) started to be used by the United Nations (UN) in the 1940s to name numerous entities that received money from public agencies to develop projects of social or humanitarian interest [7]. In this context, they contribute to minimizing inequalities between individuals.

In addition, Pereira [14] highlights the third sector as being a consequence of the revolution of the traditional social roles, in which the society became more participatory in the daily reality, not leaving only to the State the responsibility of guaranteeing people's welfare.

For Cabral [5], NGOs deal with actions to fulfill the desires, perspectives, and expectations of groups and segments of society. Muraro and Lima [10] point out that, in general, NGOs differ little from other organizations in terms of management difficulties. As NGOs do not seek conventional forms of profit and depend on donations, they need to determine their exact mission and performance so as not to expend efforts or resources that do not produce expected results.

To improve the living conditions of disadvantaged people, it is essential that NGOs seek to use tools, procedures, and processes that contribute to the better management of their human, financial, and tangible resources [8]. Within this search for improvement opportunities, layout is part of the manufacturing area and has a significant impact on costs and organizational efficiency [16].

According to Slack et al. [17], the layout arrangement concerns the physical positioning of the transforming resources of a production process. That is, the physical arrangement is an operation that will be concerned with determining the locations where all the machines, equipment, and manpower involved in the production process will be allocated, also being concerned with determining the way in which resources flow through the process [19].

Layout is one of the most important aspects to analyze within an organization, since it requires long-term planning due to its complexity and high financial costs, resulting from the adaptation of equipment, machinery, staff, and the entire process within the organization [15]. Given these factors, it is evident that a good layout must be done in a conscious way, taking into account the production processes and management objectives involved.

The study of the productive process, using tools such as the flow diagram, allows the improvement of the process, with the reduction of the distance traveled and the limited use of materials and tools. The flow diagram is a tool used to better visualize a process, by drawing flow lines in the building plan or in the area where the activity takes place and the process flowchart symbols, to indicate what is being executed [3].

Also, the relationship chart is a qualitative method of indicating the relative importance of facilities being close to each other. Thus, the method benefits the layout design or adaptation, through an enlightened vision of the proximity needs of each area [17].

Oliveira [13] defines that the objectives of layout in an organization are: (a) to promote the best use of the available area; (b) to provide cost reduction of material treatment; (c) to minimize production time; (d) to ensure flow efficiency; (e) to promote good coordination among employees, providing a pleasant environment for customers and visitors; (f) to be flexible in case of possible changes; (g) to provide a favorable climate for work and, consequently, greater productivity gains, guaranteeing the company a better performance.

On the other hand, Araujo [2] points out that the inadequate design of the layout can cause: (a) excessive processes delay due to deficiency in the spatial distribution of elements; (b) bad projection of workplaces, which can lead to accidents and losses in the process; (c) loss of time in circulation and, consequently, in productivity.

96.3 Methods

In this work, the bibliographic research was used as a support to the case study. We performed the literature review to better understand the themes layout and NGOs; it includes, besides books, scientific papers published, thesis, and dissertations.

Data for this study was collected from three visits to the headquarters of the NGO. In the first visit, the aim was to know the infrastructure and the main stakeholders;

in the second, we identified the main processes, understood the daily life of the organization, and conducted interviews with seven employees to recognize the most critical problems that would be selected for this study. In the last visit, the purpose was to measure the equipments and room areas.

Initially, we constructed one operation flowchart and a flow diagram (flow lines put on a plan of drawing of the building) aiming to know the operations and flow of people in the organization. After identifying the main areas for improvement, different alternatives of physical arrangement were proposed and evaluated, people' and material's flows could be measured qualitatively, adopting as parameters the values of the proximity relation approached by Muther [11]. Furthermore, the relationship chart was elaborated, with the sectors related to the processes, and it was also established the proximity and objective relationship between them.

Therefore, through the tools previously mentioned and with the analysis of viable alternatives, it became possible to identify and point out possible improvements.

96.4 Case Study

96.4.1 Description of the Non-governmental Organization Analyzed

The More Project Brazil is a non-governmental and non-profit organization which provides pedagogical and social assistance to children and teenagers from poor communities. The Organization was founded in 2006 and for many years was entirely supported by the sponsorship of a foreign company. However, the sponsorship was withdrawn, and the project currently operates through donations from companies and individuals. Currently, the Institution presents three units, for different publics. Two units, the CRER Project (for kids from 5 to 11 years old) and the DECOLAR Project (for teenagers from 12 to 18 years old), were visited for the present study.

96.4.2 Mapping Problems

The first step was identifying the main problems in the organization. Through structured and semi-structured interviews with the director, employees, and volunteers, different issues were reported, regarding lack of funds and need for layout improvement.

Firstly, as previously mentioned, the scarcity of capital has been a huge difficulty, since the withdrawal of sponsorship.

Also, many interviewees mentioned the shortage in the kitchen staff as a problem. Since one of the projects is lacking a kitchen assistant, all of the teenagers from DECOLAR are being transferred to the CRER unit to have lunch. Therefore, despite adopting different lunch schedules, the refectory is overcrowded. The other two meals, breakfast and afternoon snack, remain as usual, being served in both units.

Furthermore, the location of the bathrooms at the DECOLAR Project is another issue observed. The toilets, which are also used as changing rooms, are well away from the sports court, especially the women's one, located on the second floor. The director and staff are striving to build changing rooms near the court in order to improve this situation for students.

Although not directly reported, it was noticeable during the visits the difficulty of circulation in the roofed patio of DECOLAR. Currently, besides the presence of a tree in the middle of the area, tables and chairs are located in this space in an unsettled way, instead of being at the small dining area (which will also be called cafeteria) as it was planned. It would be important to reorganize this space to better coordinate the breakfast and snack times and, in the future, lunch again.

Lastly, the CRER Project coordinator pointed out the main issues she identified. Other than concerns with relationships and management, she revealed problems in the organization of the courtyard at this unit. In this area, meals, foosball games (four foosball tables), jumping ropes, and pool activities take place. The organization of this multipurpose space is quite complex, especially on rainy days, as it is not fully covered and the pool overflows. In these situations, the space assigned for ballet and fight classes ends up being used to store the foosball tables, which damages its floor.

96.4.3 Definition of Critical Processes

Analyzing each of the issues reported or observed, we verified that most of the problems were related to the DECOLAR unit. In addition, it was possible to observe that the issues regarding the courtyard of the project CRER have been temporarily intensified, due to the arrangement of the lunch schedule. Meanwhile, the situations of lack of changing rooms near the sports court and layout organization of the cafeteria are permanent issues in the DECOLAR unit.

Therefore, we decided to prioritize the problem of the cafeteria organization at the DECOLAR Project, because it is an important area, with high daily demand and intense circulation of people. Also, the allocation of changing rooms was analyzed in a limited way. The decision to consider both problems was due to the acknowledgment of a direct relationship between them, pursuing adjustments in the layout that could improve both.

96.4.4 Data Collection

The analyzed area is located next to the sports court, including four other facilities: kitchen, cafeteria, patio, and an area that we call kitchen extension.

The organization serves about 18,000 meals monthly including both units, approximately 600 meals daily. The cafeteria, with an area of only 17.69 m^2, is very limited for the number of people attended and, therefore, has been used only for receiving and delivering the dishes through the serving hatch. Because of that, the patio, which area is 41.70 m^2, is being used by students during meals.

Another important aspect is that there is a big tree in the center area of the patio. The employees informed us that there are plans evolving its removal, since the roots are ruining the floor. Their idea is to expand the second-floor area, building more classrooms, in the near future. Also, they intend to relocate or remove the cabinet, which is leaning against the power panel and the countertop. The layout studies proposed here were organized based on these premises.

The authors analyzed the whole process related to the daily meals in the DECOLAR Project, observing the flow of the teenagers during the time of a meal. Figure 96.1 shows the flowchart and the flow diagram of the process. The initial layout shown in Fig. 96.1 was made based on the floor plan provided by the organization.

For the preparation of the layout proposals, we adopted a few criteria. First, regarding the table sizes, the measures of the two existing tables were used as a parameter: 2030 mm (length) × 900 mm (width) × 790 mm (height). Capacity per table is based on chair types/sizes. We considered only castored chair (not swiveling). However, this kind of chair could be found with or without armrests. If armchairs are used, there are 8 seats per table, and for those without armrest, this number reaches 10. As the organization has only seats of the first type, tables with the availability of 8 seats were considered.

In relation to the spacing between objects, criteria based on NR 24 (Brazilian Regulatory Standard that regulates Sanitary and comfort conditions in the workplace)

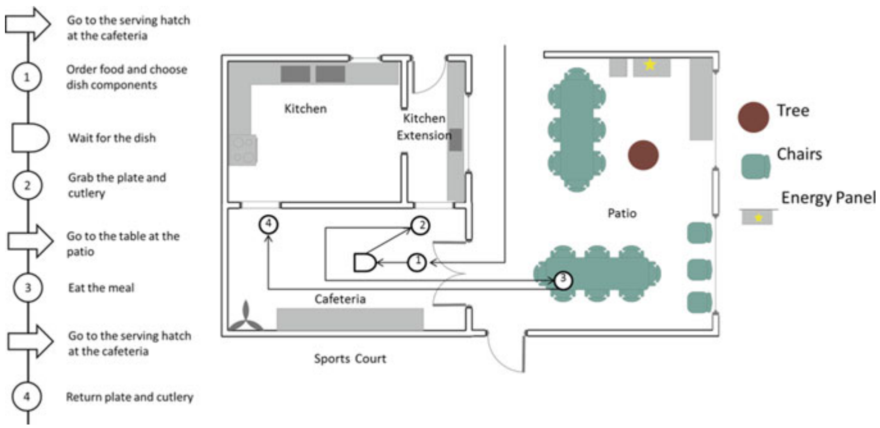


Fig. 96.1 Flowchart and flow diagram of the analyzed process at the DECOLAR project. *Source* Authors

were adopted [4]. Thus, the main circulation shall be at least 75 cm wide, while the circulation between chairs and wall shall be at least 55 cm wide.

96.4.5 Proposed Solution

The alternatives proposed are divided into three categories: (1) place to deliver dishes; (2) tables and chairs arrangements; and (3) new use to the space of the former refectory.

Firstly, a good possibility of improvement is the elimination of the displacement of teenagers from the patio to the old cafeteria, both to serve themselves and to return used dishes and cutlery. A change in the layout that favors the new process is lowering the window between the kitchen extension and the patio, allowing the employee to serve the dishes, with the food, plates, cutlery, and glasses organized on the countertops. In this way, with the construction of a serving hatch between the kitchen extension and the patio, the flow of students to the old cafeteria would be eliminated, the patio would be the assigned dining area, and the former cafeteria could have a new use. In addition, it would not be feasible to eliminate the kitchen extension and to adapt the kitchen to a new configuration that would attend to the functions of the kitchen extension, due to the limitation of its size in relation to the number of meals served.

Concerning the second category, the proposed layout of tables and chairs aims at the best use of space and the optimization of people circulation in the area. With the removal of the tree and the adoption of the parameters previously determined, it is possible to analyze three basic alternatives: the arrangement of the tables parallel to the largest side, perpendicular to the largest side or a mixed form (Fig. 96.2). The cafeteria measures 6.00 m × 6.95 m (the largest side is the one that has the two windows).

The evaluation of the three presented alternatives was carried out adopting two basic criteria: capacity and accessibility. Capacity is related to the number of seats available and accessibility to the ease of circulation of people in the area.

Among the proposals for table and chair layout, layout 2 (tables perpendicular to the largest side) was selected because it has greater capacity and easier access to the different tables. It should be noted that the organization will continue to adopt

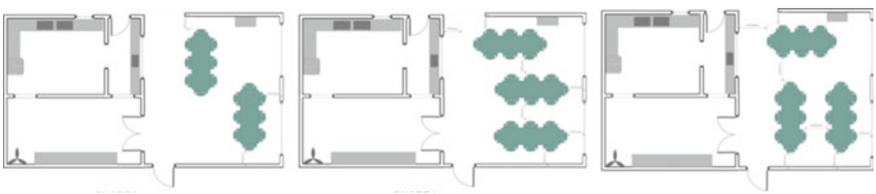
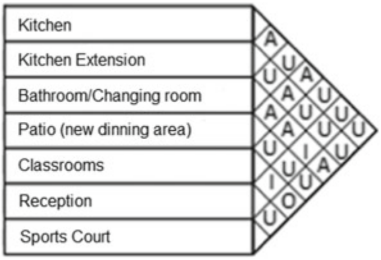


Fig. 96.2 Proposals of tables arrangement (layouts 1, 2 and 3, from left to right). *Source* Authors



Value	Proximity
A	Absolutely Necessary
E	Especially Important
I	Important
O	Little Important
U	Not Important
X	Undesirable

Fig. 96.3 Relationship chart evolving the main facilities. *Source* Authors

distributed schedules for breakfast, lunch, and snack, to meet the required demand. However, the capacity increased as there were only two tables before.

Finally, we will analyze the proposals regarding the use of the space of the former cafeteria. For this purpose, a relationship chart, shown in Fig. 96.3, was drawn up.

Analyzing the layout shown in Fig. 96.1, it is possible to notice that the old cafeteria is located near the following areas: kitchen, kitchen extension, patio (new dining area), and sports court. Through the relationship chart, it is possible to identify the activities with the greatest need of proximity and that could be allocated in the idle space of the old cafeteria.

Among the areas with proximity classified as necessary or important to the facilities in the region, except for the bathroom/changing room, all are located in that environment. This means that the options would be to expand the areas of one of the existing departments (kitchen extension, kitchen, or dining room) or to build bathrooms/changing rooms in the idle area. Evaluating these alternatives, it is noticed that, if necessary, there is a possibility of expansion of the kitchen to the kitchen extension intended space. The refectory was significantly expanded with the change of place, going from 17.69 to 41.70 m^2.

Therefore, we decided to use the idle area of the old cafeteria for the building of two changing rooms, one male and one female. This is due to the importance of bathroom/changing room near the sports court and the cafeteria, for the preparation for physical activities and for the students to wash their hands before the meals.

Finally, the proposed layout is shown in Fig. 96.4, encompassing the three proposals: serving hatch between kitchen extension and cafeteria, the arrangement of tables perpendicular to the largest side and building of changing rooms in the space of the old cafeteria.

96.5 Conclusion

It is important to emphasize the important role played by the NGOs in the society, as they function as a complement to the State. In this context, engineering can contribute

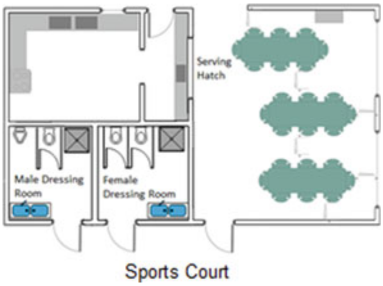


Fig. 96.4 Proposed layout. *Source* Authors

to the better use of space and optimization of resources, as well as the improvement of processes and flows.

The proposed solution shows gains in the previously mentioned aspects. Despite the need for investment to implement the layout proposed, the benefits would compensate: The layout of the cafeteria was rearranged, accommodating 24 or even 30 people, compared to the initial 16 places; the process of serving the meal, as well as the preparing for physical activities, was optimized and the circulation of people on the first floor was significantly improved, reducing approximately 18 m per students for meals and 12 m per students for use of bathroom/changing rooms.

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Chapter 97
Application of the Structural Equations' Modeling to Assess Student Satisfaction

Wallace Giovanni Rodrigues do Valle and Mariana Rodrigues de Almeida

Abstract This work aims to identify the factors that determine the satisfaction of higher education students in Brazilian Federal Institutes of Education, Science, and Technology. A structural equations model with partial least squares was applied, and it can be inferred that the convergence of the model and structural results are satisfactory.

Keywords Structural equation modeling · Students' satisfaction · Education

97.1 Introduction

Considering the organizational dynamics of Higher Education Institutions (HEIs), financial and economic aspects directly impact on existing strategic planning, as well as the achievement of academic objectives. This may affect not only the performance (quantitative factor), but also the perception (qualitative factor) of students about the elements contributing to their formation.

The standard way of assessing the performance of these students in Brazil is the National Student Performance Exam (Enade). The objectives of the exam are related to the evaluation of institutions, courses, and student performance, as well as their skills and competences acquired through training. Thus, in order to fully achieve the goals, information is collected through the student questionnaire. The purpose of this, which is mandatory, is to support the construction of the student's socioeconomic profile and to obtain an appreciation for its formative process [6]. Despite the grouping of items, the questionnaire may not be enough to gain insight into a more global, interactive, and measurable overview.

A research problem arises: based on the information acquired in the questionnaire, how to quantify and analyze student satisfaction so that there is an investigation of the relationships responsible for structuring the main aspects of the questionnaire? Inspired by the original study by Paswan and Young [24], later adapted by Vieira

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et al. [28]; Lizote et al. [19] and; Gomes et al. [12], this paper aims to evaluate and investigate the interaction between the factors that determine the Brazilian student's satisfaction of higher education, through the structural equations modeling.

According to Liu et al. [18], student satisfaction may be an important index of organizational self-assessment. By means of studies like this, institutions can guide their planning by virtue of factors that are more sensitive and that can directly affect students' satisfaction. Focusing on specific items can reduce efforts in the search for continuous improvement and optimization of the use of resources in the provision of the service.

We structured this paper in five main topics. The second presents the studies used for theoretical basis for the construction of the model, while the third topic exposes the methods adopted to reach the objectives established herein. Finally, the results obtained and the conclusions that can be address with such implications are revealed.

97.2 Structural Equations' Modeling and Education

Clayson and Haley [8] already warned about the simple and hasty conclusions that a researcher can obtain from their data. According to the authors, the use of structural equation modeling (SEM) avoids nomological errors that may impair correlational studies. This technique makes possible the simultaneous evaluation of a series of dependency relations, which allows the researcher to measure the main affinities between the variables [22]. Thus, SEM emerges as the dominant analytical tool for testing cause–effect models with latent variables [13].

Anekawati and Otok [3] infer that the determination of the quality model of education may be related to many dimensions, such as infrastructure and facilities, and even the socioeconomic condition of the region. In this context, educational administration aims to establish efficient human relationships that facilitate the contributions of people working in the sector to improve the educational process [27].

The breadth of the course organization reflects in some studies that approach the modeling of structural equations in this area. Manwaring et al. [21], for example, when using course organization as a variable, indicate that the methods adopted in the didactic–pedagogical area allow us to explore how much student involvement is a stable trait of the student and how much the involvement varies according to the elements of course formation that are controlled by an instructor or institution.

Predicting the importance of this relationship, Paswan and Young [24] proposed that student–instructor interaction exerted influence on the two endogenous variables of their research: student interest and teacher involvement. Such interaction may be represented by items such as the student's opportunity to discuss, question, and clarify their doubts during class [28], as well as the stimulus and academic apparatus offered for the development of activities.

Some studies connect life satisfaction and academic satisfaction, demonstrating that the most relevant associations are found with the increase in the perception of social opportunities through education [10] and with perceived social support [16], among other factors. López et al. [20] explain that an educational institution can be considered as a place where social well-being is very important in training and performance.

Considering the incentives that the teacher can offer his students, Paswan and Young [24] and Vieira et al. [28] considered the relationship of interactivity between the teacher's involvement and the student's level of interest.

Some authors also declare the variable "learning opportunities" in different contexts. Adukaite et al.'s [1] study, for example, presents the structural relationships between selected individual differences and teachers' perceptions of how beneficial a specific learning system might be for their students. However, Bourgonjon et al. [5] presented the same theme from the perspective of the student, highlighting the degree to which a person believes that the use of a given system can offer him opportunities to learn.

Student satisfaction research has become an essential tactic for the world's universities, especially in developed countries, enhancing the relationship between schools and students, improving school development, monitoring teaching quality, and guiding selected choices [2, 15, 25].

Based on this scenario, Fig. 97.1 outlines the theoretical model adopted for this research, as well as the enumeration of the hypotheses to be validated and discussed.

97.3 Method

For carry out this study, we adopted three central steps: (a) model development and hypotheses; (b) data collection; and (c) application of structural equation modeling. In order that construction of the measurement model and hypotheses' establishment, we analyzed the items present in the student questionnaire (version 2015). Subsequently, we searched in the academic literature for authors who evaluated the satisfaction of students with similar objectives, so that to base the theoretical model.

Considering the contribution of the questionnaire for evaluation of the higher education standard in Brazil, the modeling of structural equations was elaborated from the answers to items 27–68. The questions belonging to this interval were analyzed and associated with the respective constructs. The other questions on the form (1–26) are socioeconomic, only for the purpose of tracing the profile of the participants, and are not used in this study.

The scale used in the questionnaire varies in degree of agreement, and it may be from 1 (total discordance) to 6 (total agreement). All responses are recorded in a database and sent to the National Institute of Educational Studies and Research Anísio Teixeira (Inep), where they are virtually available for public consultation. Data from all Brazilian Federal Institutes of Education, Science and Technology (FIs) were

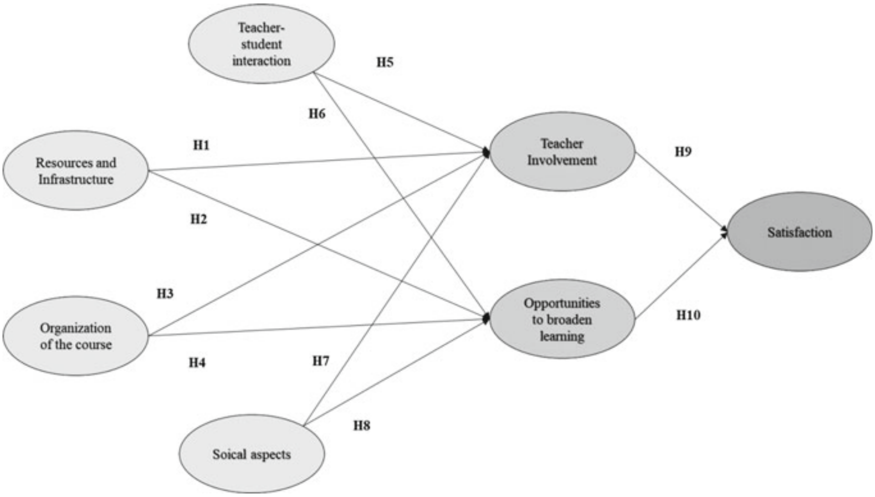

Fig. 97.1 Theoretical model. H1: Resources and infrastructure positively influence teacher involvement; H2: Resources and infrastructure positively influence learning opportunities; H3: The course organization has a positive influence on the teacher's involvement; H4: The course organization has a positive influence on opportunities to increase learning; H5: Teacher–student interaction positively influences teacher involvement; H6: Teacher–student interaction positively influences learning opportunities; H7: Perceived social aspects have a positive impact on teacher involvement; H8: Perceived social aspects have a positive impact on learning opportunities; H9: Teacher involvement positively impacts overall satisfaction; H10: Opportunities for learning enhancement positively influence overall satisfaction

used, resulting in 1333 respondents. Universities (both public and private) were not included in the sample, since they have different characteristics.

According to Hair et al. [13], data collected for social science research generally do not follow a multivariate normal distribution. Thus, the use of structural equation modeling with covariance (CB-SEM) would induce underestimated standard errors [17]. To apply structural equation modeling, this study utilized the partial least squares (PLS-SEM) model.

Beebe et al. [4] and Cassel et al. [7] corroborate the idea that PLS-SEM is less intransigent when working with non-normal data. The authors even if explain that such phenomenon occurs because the PLS algorithm transforms this data according to the central limit theorem.

PLS is an SEM technique based on an iterative approach that maximizes the explained variance of endogenous constructs [11]. PLS-SEM generalizes and combines factor analysis, principal component analysis (PCA) and regression analysis by separate estimation procedure between latent variables and their indicators [3].

In order to implement this technique effectively, the collected data were arranged in the SmartPLS 3 software. Figure 97.2 demonstrates the structural model adopted, including the identification of the issues related to each construct.

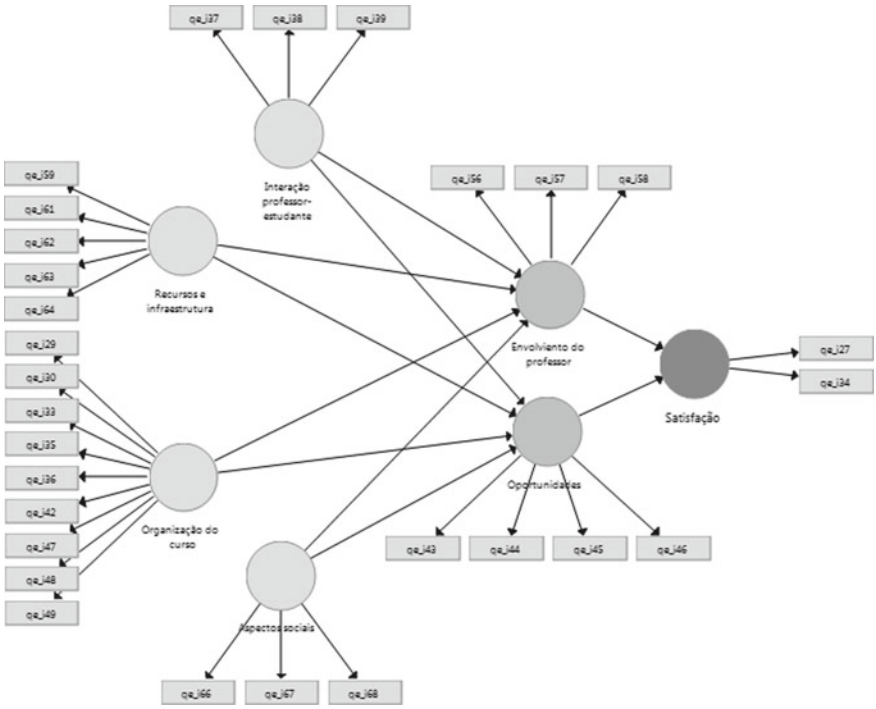

Fig. 97.2 Structural model

In contrast to the fundamental models developed by Paswan and Young [24], Vieira et al. [28], and Santos [26], the social aspects and opportunities of learning are into this study. As observed in the previous topic, the use of these variables is recurrent in studies such as Ferrante [10], Cárdenas et al. [9], Hirschi [16], Bourgonjon et al. [5], López et al. [20], Adukaite et al. [1].

This insertion occurs mainly because the student's questionnaire itself has undergone changes in its version of 2015, highlighting increasingly the number of items related to these constructs that would not fit in the models elaborated previously. In addition, the work of Santos [26] already presented rejection of hypotheses related to the interest of the student.

For this reason, the construct previously called as student interest [24, 28] was replaced by opportunities for learning expansion. This is due to in his new version, since the student questionnaire no longer directly refers to the learner's interest in learning, but rather whether he given the opportunity to acquire knowledge. Therefore, it is possible to focus more attention on the evaluation of institutions from the perspective of the student, and not a self-evaluation.

Similar process occurs with the course demands' construct, used in the previous studies. The items related to this variable were dissolved and absorbed by questions related to the organization of the course, in general.

97.4 Results

Figure 97.3 schematizes the results obtained for the complete structural model, including the paths established between the constructs. It is observed that all the coefficients of paths are positive; the lowest of them occurs in the relation between resources and infrastructure and opportunities to broaden learning (0.008).

Although some relationships are weak, such as teacher–student interaction and opportunities to broaden learning, all hypotheses have returned positive impacts on each other and on the structural model as a whole. The H9, which analyzes teacher involvement and satisfaction, returns the largest impact factor found (0.469).

The resources and infrastructure of IES influence the perception of teacher involvement more than the learning opportunities offered. The teacher–student interaction behaved in a similar way. Nevertheless, unlike the study by Lizote et al. (2011), this relationship between teachers and students was not the most relevant in the model.

The course organization construct demonstrated the best affinity with endogenous constructs directly connected to satisfaction. This corroborates with the research by Marsh et al. [23], who also notes that a more structured and organized course can lead to a favorable evaluation of the instructor as well as the student's own interest.

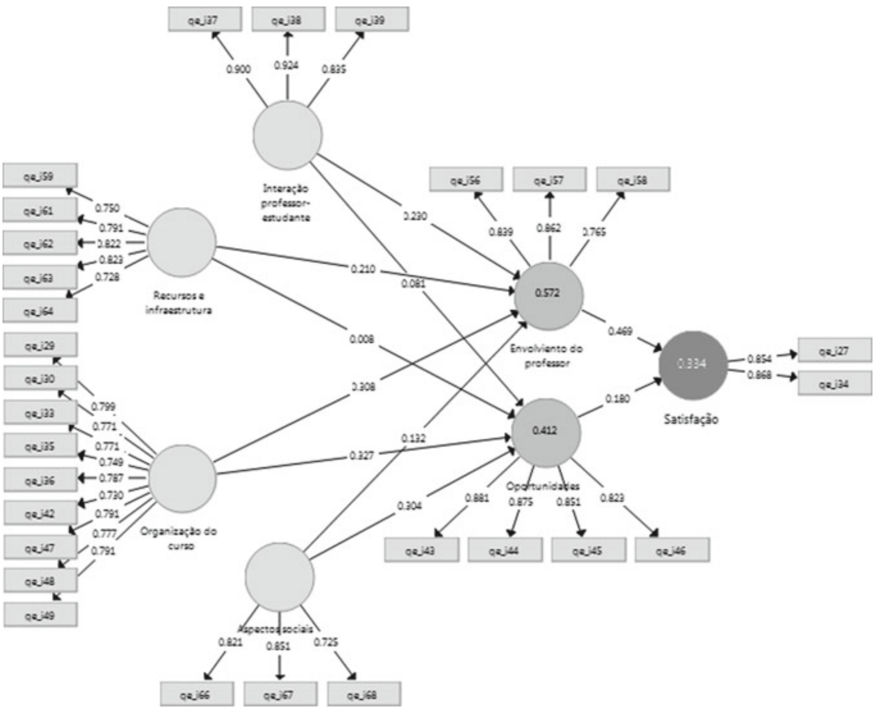

Fig. 97.3 Model results

Table 97.1 Convergence and reliability

	Alfa de Cronbach	Compound reliability	AVE
Social aspects	0.721	0.842	0.641
Teacher involvement	0.762	0.863	0.678
Teacher–student interaction	0.864	0.917	0.787
Opportunities	0.880	0.918	0.736
Course organization	0.917	0.931	0.600
Resources and infrastructure	0.843	0.888	0.614
Satisfaction	0.652	0.852	0.741

The social aspects related to the formation of students, unlike the other constructs, had a positive impact more on opportunities to broaden learning than on teacher involvement. This can be explained by the fact that the teachers are not so connected to the students' extra-class experience. On the other hand, opportunities to increase learning, to a lesser degree, behaved positively as a factor of impact on satisfaction. Thus, it is understood that the more the student has contact with unexplored learning in traditional classes, the greater his satisfaction.

The construct involvement of the teacher present as the most significant in the model, both to be impacted and to impact student satisfaction. This is in line with Gomes et al. [12] research, who found a low significance in the relationship between teacher involvement and general satisfaction.

Other important factors in the analysis of structural equations modeling are those summarized in Table 97.1. Considering that Cronbach's alpha values and composite reliability need to be higher than 0.7 [13] and that of the mean extracted (AVE) should be greater than 0.5 [14], we identified only one deviation between the adopted variables. Satisfaction has Cronbach's alpha of less than 0.7, but when the compound reliability and the AVE are analyzed, a satisfactory and quite positive behavior is observed.

97.5 Conclusion

The results obtained provide a fundamental apparatus for the decision making in the FIs, since they present what influences satisfaction to a lesser degree and greater degree. In this way, the model helps the institution to define the area that must interfere in order to obtain a more satisfactory result, depending on its pedagogical and administrative reality.

The adoption and validation of new adaptable constructs for future studies with similar objectives represent a relevant practical and theoretical contribution of this work. The inserted constructs were stable in the model, allowing the use adapted according to the new reality pointed out in the Student Questionnaire 2015 version.

Opportunities to broaden learning, for example, demonstrated a good relationship mainly with the course organization and social aspects. On the other hand, social aspects did not behave eccentrically in relation to the other constructs, being able to be considered, adapted, and tested in other circumstances.

Therefore, in future studies it is suggested the application of the model in universities, both public and private. This will contribute to the identification of similar (or not) behavior of the sample used in this study, as well as to validate, more broadly, the model in question.

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Part X
Sustainable Operations

Chapter 98
New Organizational Models and Technology Growth: Ethical Conflicts in Today's Business Scenario

Thaís Quinet Villela de Andrade

Abstract This research analyzes the ethical conflicts in new business scenarios, raising issues on the impact of new organization models and technologies on the professional's behavior considering an ethical perspective. The result shows that part of them are not thinking about ethics and many of them are limited in consolidated and already known impacts.

Keywords Ethics · Ethical · Innovation · Technology · Business scenarios · Organization model

98.1 Context

Business scenarios have been changing along with technology improvement, causing some companies to grow exponentially. According to Ismail et al. [7], the world now belongs to the more intelligent people, to the smaller and agile companies. It is indeed a reality in information-based sectors, and this will soon be a reality in most traditional industries.

In addition to this, new tools such as innovative analysis of big data and machine learning allow a better understanding of the market, its customers, and results. Those new tools can predict and automate a business process using artificial intelligence or robots, leaving workers free to handle exceptional situations—the ones that do need human participation [7].

Those changes require not only companies' internal adjustment but also the whole society to develop new professional profiles and specializations demanded by the market. According to Howard [6], the developing world's service sector represents 80% of the total employment—but services are the exact things that computers have just "learned" how to do. As a consequence, unlike what people used to think, new jobs for data scientists will not replace today's traditional jobs because data scientists do not take long to develop machine learning codes that replace traditional activities.

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In the Industrial Revolution, there was social disruption and a change in people's capabilities thanks to engines, but once engines were used to generate power in all situations, things settled down. On the other hand, the Machine Learning Revolution is going to be very different from the Industrial Revolution because the Machine Learning Revolution never settles down, as well as technology evolution itself. The better computers get at intellectual activities, the more they can build better computers to be better at intellectual capabilities. It is a change that the world has never experienced before [6]. The important thing is that professionals, in general, need to be aware of the constant change and the demands of the companies to be prepared in time to meet the needs of the market.

Above this evolution, there is an analysis-lacking aspect comprising new technologies and new business models: the ethical conflicts. Cortella [3] describes ethics as the border of our coexistence. It is a point of view that allows us to look at our principles and values to live together. Therefore, it is important to evaluate the ethical perspective every time we deal with new technologies and business models to keep people thinking about good manners to live in society.

98.2 Theoretical Reference

The question is: who is thinking about the ethical issues that are very likely to arise shortly? There have been previous studies on ethical matters regarding big data, for example, but the main discussion revolves around legislation and it seems as though that laws will not solve all the conflicts. According to Bishop [2], the ethical practice has to be developed, in part because the law nearly always lags what is possible, and there will still be situations that are legal but not ethical.

According to Andrade [1], no one seems to be aware of the ethical impacts of technology, in order to evaluate how technologies are going to change behaviors and ethically affect the individual's daily activities. As observed in the exploratory data, the main issues, noticed by the respondents of this study, regard the lack of legislation, which shows the distance of the professionals, in general with the technology growth and its impacts in everyone's daily lives. People's primary focus is still on the company's results and profits other than the ethical implications. It does not mean that the profit should not be a concern, but the result needs to be thought under the ethical perspective to prevent consequences on business and also on the professional personal lives.

As we can infer, the society, in general, does not seem to be thinking about the ethical impact. For instance, what is going to be the impact when brain scanners are capable of revealing lies with the click of a button or when digital teachers meticulously monitor each answer given by the student, identifying weakness and strengthening students. Or even, that family, social, or emotional conflict can be caused when Watson has been intimately familiar with the family's genome and the medical history of the individuals. It would also know the genome of the whole family, neighbors, and friends, besides knowing instantaneously if the person has been to a tropical country if he had stomach infections or balls cancer in the family [5].

98.3 Methodology

This paper is an initial and exploratory study to start identifying the main ethical conflicts that the professionals identify when questioned about new technologies. The main goal was to begin to understand what professionals are reflecting about ethics.

The sample was not designed and sized to be representative, as described in Forza [4], for example, because the purpose of the study was to identify some relevant issues as an initial approach, so the study could be unfolded deeply considering these aspects. The study analyzed the answers of 53 professionals from companies of different sizes and sectors. The group of respondents included professionals that I have worked or studied with while working in two different consulting and technology companies, who agreed to participate in the study.

Questions aimed to collect information to analyze the main ethical conflicts identified by these professionals in the new business scenario of technology growth and different organization models. Respondents were asked to answer freely, thought an Internet form, with no predefined positions that could lead to biased results, to allow a comprehensive analysis.

The main aspects described in this paper are based on the questions below:

- E-mail, age, and gender
- Does your company provide training regarding ethical behavior and corporate governance?
- If your answer was positive for the previous question, what were the main aspects addressed in training?
- Do you identify elements in new technologies, processes, and business models that may cause ethical issues? Which ones? How can they be addressed?

98.4 Results and Discussion

Based on the answers provided by them, the data were consolidated and plotted on the next charts (Figs. 98.1 and 98.2).

As shown in the charts, 60% of the respondents were male, and 75% have a leadership position. More than 80% are over 30 years old.

The answers also intended to analyze the topic of training provided by companies on ethical matters. People were asked to answer if their companies offer training on

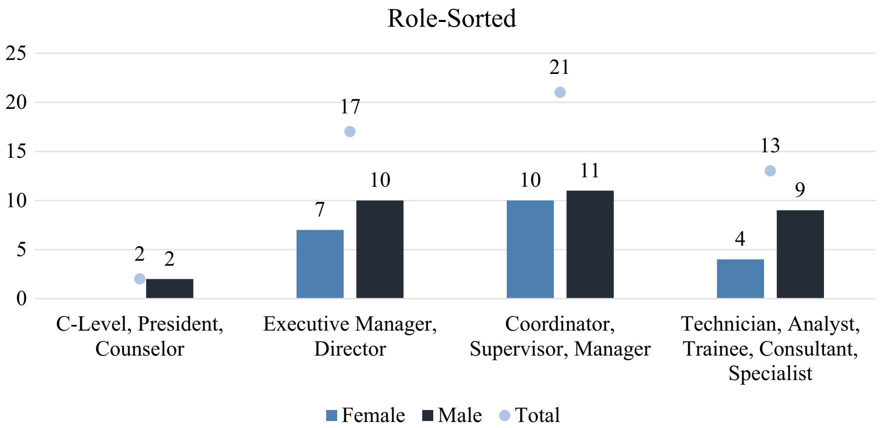

Fig. 98.1 Graph based on the individual's role [1]

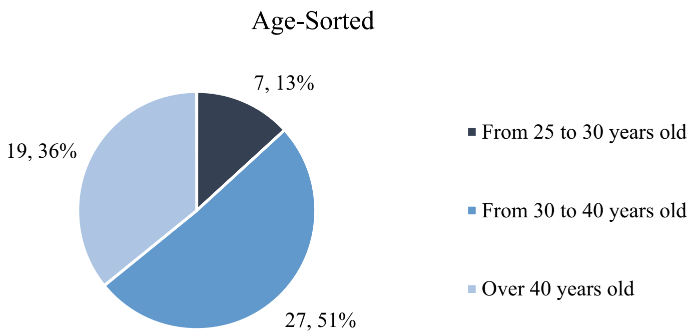

Fig. 98.2 Graph based on individuals' age [1]

ethics. From the respondents, 43% of them do not have any training on ethics in their companies (Fig. 98.3).

The subject of most of the training provided by companies included topics of the concept of ethics and in some cases, the resolution of conflicts, especially when it comes to specific laws and internal policies on some matters such as data protection laws and non-corruption. There are some cases, in which the training also comprehends ethics in a relationship with both customers and suppliers as well as information security and conduct in the work environment. One of the respondents pointed out the approach given by his company in training by mentioning the behavior and policies in different cultures, leading to a wider discussion than the organization policies themselves. Local cultures are also a critical aspect to be taken into account.

The answers have also been analyzed from a qualitative perspective. They were consolidated considering the main factors identified as ethical issues (considered only the respondents that identified any conflict and some answers included more

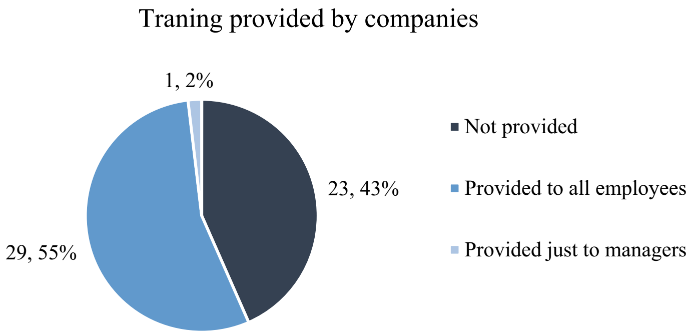

Fig. 98.3 Training provided by companies on ethical behavior and compliance [1]

than one issue). The central points of each response have been grouped to allow us to analyze the topics most and least mentioned by the respondents. Grouping the similar aspects, we have the data as follow (Fig. 98.4).

As we can observe in the list of primary factors identified by the respondents, the most mentioned aspect regards the misuse of privileged information, such as the use of customers' information without their consent or even their knowledge to get benefits for the company. As an example, we can highlight the answer from one respondent who mentioned that issues concerning customers' information, geolocation, and predictive analyses are examples of new technologies that may invade people's privacy.

Another respondent mentioned examples that call for attention: the use of data, intangible assets, robots, and artificial intelligence (AI), which under his point of view, need to be treated within limits not to harm human rights.

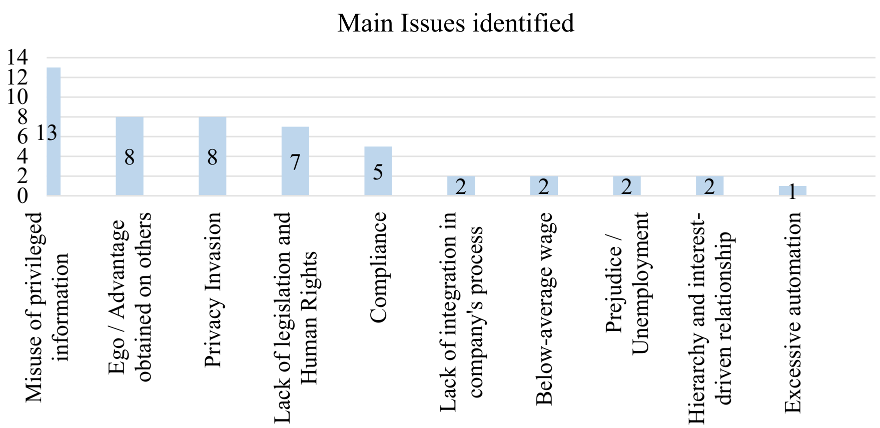

Fig. 98.4 Main issues identified [1]

The shortage and even lack of legislation and the impact on human rights were also aspects mentioned for some respondents. They emphasized their relevance to the present context. There is still too much to be developed considering ethical issues. For example, another respondent raised a question regarding Uber. It is unquestionable that Uber has changed the taxi and private drivers' business model; however, how fair is it not being required to comply with the same laws of the sector? These examples show that the misuse of privileged information, as well as the lack of legislation, is many people's worry mainly because companies still prioritize business over ethics.

One datum that catches our attention is that 30% of the respondents did not identify any ethical conflicts and 13% had a non-specific answer. For example, one professional mentioned that new markets could bring new aspects to matters that people are not used to, so it is important to consider cultural issues in the new business models. Another professional mentioned that training is essential to recycle knowledge and to promote effective governance. These aspects are essential; however, they do not represent an actual thought on the ethical matter.

The non-identification as well the lack of specification and the general answers show that professionals are not dedicating a deep thought over ethical issues in their daily jobs. It means that companies, in general, do not encourage their employees to think over the ethical problems that may be arisen after releasing a new product, service, or technology or even creating new functionalities and different uses for already existing ideas and processes. It is noticeable that most professionals neither realize the real ethical impact of the latest technologies and business models nor they are aware of how fast it is moving.

It is possible to observe a correlation on the data of training, as well as the identification of issues (ethical thought more accurate). It shows that people trained by their companies on ethical matters are more likely to reflect on the ethical impacts of the advancement of technology and business models, as we can observe on the data below. It shows that most people who identified ethical issues in those new scenarios had some training provided by their companies. (70% of the professionals who identified any issue had some training on this subject) (Fig. 98.5).

The professionals also suggested that some actions should be taken by companies so that ethical issues can be more properly addressed [1]. In the following table, each action appears associated with the corresponding item. However, most of the actions are still discussing issues that are already a reality in our society nowadays. They are not addressing issues that are still to come and that will require an actual more profound thought on the matter (Table 98.1).

98.5 Conclusions

It seems that people will only think about ethical impacts in their lives when the issues become a reality and they actually need to deal with established problems. However, when we get to this point, the new technologies and organization models

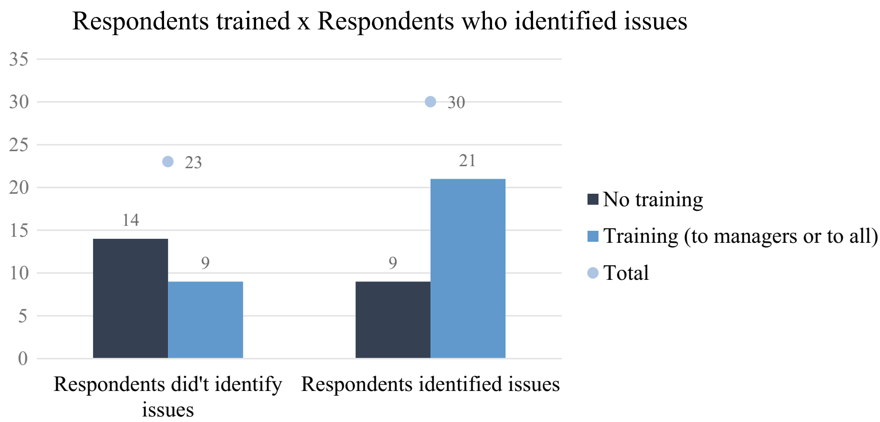

Fig. 98.5 Relation training and issues identification [1]

Table 98.1 Main actions and to-dos to address the ethical issues

Issues	Actions (by companies)
Misuse of confidential and privileged information	Commit the business process to personal data governance
	Establish clear rules and checking mechanisms throughout the business process
Lack of legislation/competitive advantage	Improve laws to address new situations arising with the new technology
	Strengthen awareness on ethical issues/impacts
	Mitigate ethical impacts before releasing new significant-changes technologies

will have been developed so exponentially that the impacts in our daily lives are going to be immediate.

The purpose of this study was to identify some important issues to provide a guideline to get a deeper understanding in subsequences studies. Therefore, one thing is already a call for attention for everyone: it is crucial that we think in advance about the ethical implications so we can face them before we have to deal with the consequences.

It is important that we actually think about the impacts of new technologies beyond the legal and information privacy aspects. Even because, the misuse of privileged information is something that has been an issue for a while, so, it is not a new impact identified in advance of new technologies. There are many different issues that we, as a society should be thinking, as well as a lot more yet to come.

In conclusion, ethical conflicts is a crucial matter to be discussed. So, the following studies are needed and recommended to achieve more precise and expressive results.

It is important to select a representative sample to analyze deeper into new issues other than privacy information and legislation and also how to make this subject a concern in people's everyday's life, so they are not just required to think about these issues when asked about it or have to deal with it.

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Chapter 99
Modern Slavery Analysis in Global Production Networks

Luiza Ribeiro Alves Cunha, Adriana Leiras and Paula Ceryno

Abstract Even abolished, slavery is still practiced in the world. Through a literature review, this paper aims to analyze modern slavery in global production networks. We present definitions of modern slavery and contribute to increasing awareness of rethinking the favoring of the global economy to the detriment of modern slave laborers.

Keywords Modern slavery · Global production network · Systematic literature review

99.1 Introduction

Global Slavery Index (GSI) [10] pointed out the existence of 35.8 million slaves in the world in 2014. This number becomes more shocking since the authors claim that this is the largest quantity of slaves in humanity, even though slavery is illegal and condemned [11].

Kevin Hyland, an independent commissioner against slavery, in his speech to the Lowy Institute on May 2017, states that modern slavery exists for the same purpose it has throughout history: maximizing profit for exploiters to minimize or eliminate the cost of labor. He also points out that the International Labor Organization (ILO) evaluates that the total profit illegally obtained from the recent crime of world slavery is more than 150 billion dollars per year [12].

The modern slavery is a term that covers many severe cases of abuses, such as forced labor, child slavery, and different forms of trafficking in persons (sexual exploitation, forced crime, removal of organs, and domestic servitude) [12]. New [22], in turn, adopts the 2005 ILO's classification of modern slavery that considers

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six indicators of forced labor in such a way that a modern slave is defined by framing a worker in any of the topics listed below:

- Physical damage to the worker or threats to his integrity;
- Restriction of movement, incarceration, or imprisonment;
- Cases in which the worker is not paid, for example, when the employee works to pay a debt;
- Situations in which agreements are violated, for example, withholding or reduction of salary;
- Conditions in which employees are kept at work by retaining their documents.

Kara [15] understands that slavery is related to daily life, whether in food, clothes used, or technological devices of modern life produced in global production networks. The author also supports the view that slavery is a business that explores a vast and vulnerable layer of people whose brutalization is agreed by all participants in the world economy.

Over the years, slavery has remained linked to production processes and, although forbidden, it is currently part of the global production network. Phillips and Sakamoto [24] emphasize that global production networks (GPNs) are or should be characterized by new job opportunities for vulnerable employees, as well as better conditions at work, new or different sources of income for people in need, and social protection. However, in several cases, GPNs may be characterized by the opposite, precarious, and unprotected forms of work, exploitation, and lack of socio-economic security.

One of the most significant examples of slave work today is the textile industry. Leite et al. [18] argue that production chains have become global, centering the design of models and collections in developed countries, with sewing activity in countries where labor is cheaper. This restructuring of the production chain in the sector, based on an intense outsourcing process that separates the brands from the production, ends with a disclaiming of the big brands by the conditions of the work carried out in factories and domiciles in the countries that concentrate the confection. The result is inhumane working conditions.

The present study covers the problem that there still exists in society. Working conditions similar to slave labor and the lack of studies relate the theme to global production networks. Thus, through a systematic literature review (SLR), we propose a taxonomy on modern slavery in global production networks, demonstrating different definitions attributed to modern slavery and the country and economic sector addressed by the papers selected in the SLR.

The remainder of the paper is organized as follows. The next section addresses the research methodology supported by a section presenting the results of the study. Section 99.4 exposes the concluding remarks and possible future studies.

99.2 Research Methodology

According to Thomé et al. [28], the present study adopts the eight-step methodology to conduct the SLR: research problem formulation, literature search, data collection, quality assessment, data analysis and synthesis, interpretation, presentation of results, and updating of the review.

The introduction section already discussed the research problem formulation. For the second step of the SLR, the literature search, Thomé et al. [27] recommend the use of five stages, as illustrated in Fig. 99.1.

The Scopus and Web of Science databases were selected because of their extensive catalogs of indexed journals, according to Mongeon and Paul-Hus [21].

The keywords were selected in order to have a group of words related to global production networks and a group of words related to modern slave labor.

The searches followed the following structures:

- In Scopus data base: (TITLE-ABS-KEY ("production chain") OR TITLE-ABS-KEY ("value chain") OR TITLE-ABS-KEY ("production network") OR TITLE-ABS-KEY ("commodity chain") OR TITLE-ABS-KEY ("global network") OR TITLE-ABS-KEY ("global chain")) AND (TITLE-ABS-KEY (slav*) OR TITLE-ABS-KEY ("traffick*") OR TITLE-ABS-KEY ("involuntary servitude") OR TITLE-ABS-KEY ("unfree labour"))
- In Web of Science data base: TS = ("production chain" OR "value chain" OR "production network" OR "commodity chain" OR "global network" OR "global chain") AND TS = (slav* OR "traffick*" OR "involuntary servitude" OR "unfree labour")

The Scopus database search resulted in 53 documents and the Web of Science database search presented, in addition to 11 papers repeated and 3 additional papers. Table 99.1 summarizes the steps of SLR.

After presenting the steps until the definition of the sample of papers to be used for the accomplishment of the present study and data collection, the fourth step, the quality assessment is guaranteed by the transparency of each stage of the review.

Fig. 99.1 Five steps proposed by Thomé et al. [27]

Table 99.1 Steps used to define the sample through Scopus and WoS databases

	Scopus database	Web of science database
Sources identified through the database search	53 documents	14 documents
Exclusion of duplicate documents	11 duplicate documents	
Review title and summary	31 documents selected	
Document without access	9 documents	
Full-text review	6 document excluded	
Final sample	16 documents	

The fifth, sixth, and seventh steps, data analysis and synthesis, interpretation and presentation of results, respectively, are addressed in the following sections.

The last step, the update of the review, is out of the scope of the present study and is suggested in the fourth section as a future study.

99.3 Results and Discussion

The documents found through the SLR use several terms to define modern slavery such as: "contemporary forms of forced labour," "modern-day slavery," "unfree labour," "contemporary unfree labour," "modern forms of slavery," "modern slave," "new slavery," "neo-slavery," "new world slavery," "labour chain," and "forced labour."

According to Fast et al. [8], slavery is not easy to define as its definition often rests on historical, social, and cultural concepts. Table 99.2 presents different meanings attributed to modern slavery in the literature. Papers that discuss modern slavery but do not show its definition were not included in the table.

The ILO uses the term "forced labor" and, as noted in Table 99.2, various papers refer to this convention. It is possible to note that the term studied deals with several aspects and that each author approaches the aspects that seem most relevant to his/her study. However, the clearest and simplest definition of slave labor, in which several other details can be added, is the definition proposed by ILO [13]: "involuntary entry and participation in work or a service which is extracted under menace of any penalty and for which the said person has not offered himself voluntarily." According to Barrientos [3], the ILO estimates that 7.8 million people (63% of the total number) are in economic exploitation. The gender bias is also pointed, where women are economically explored 56% of the times while men are 44%.

According to Crane et al. [6], the topic is covered by both developed and developing countries. In that way, the sample of papers from the SLR include studies in countries such as Chile, India, Jordan, South Africa, Romania, UK, USA, Thailand, Brazil, Greece, Singapore, Nepal, Malaysia, United Arab Emirates, and China.

Table 99.3 shows the countries and sectors of the economy mentioned in the papers in which both of these topics were identified.

The sectors covered by the papers selected by the SLR, some shown in Table 3, are fruit, garments, horticulture, gold, electronics, coffee, fishing, media industries, cotton, footwear, diamonds, bricks, sugarcane, soybean, cattle sector, chocolate, coal, toy industry, pornography, and sex industry.

As an example of the electronics industry, Fast et al. [8] discuss the exploitation of workers by Foxconn, the largest Apple subcontractor, and manufacturer of iPhones and iPods, including the use of child labor.

An example of the commodities industry, Philips, and Sakamoto [24] demonstrate that the significant occurrence of slave labor in Brazil is in the production of commodities sectors, such as cattle, soybean, cotton, sugar, and coffee grain. Cattle farming reports the most significant number of properties with slave labor in

Table 99.2 Modern slavey definitions

Reference	Modern slavery definition
Barrientos [3]	ILO [13], as presented in the Introduction section
Bonfanti and Bordignon [4]	ILO [13], as presented in the Introduction section
Crane et al. [6]	Crane et al. [6] corroborate with the ILO 1930 Convention in which forced labor is the service provided not voluntarily or under threat
Davidson [7]	Davidson [7] corroborates with Bales [2] by pointing out that the slave does not control his free will, and agree with Craig et al. [5] by pointing out that the slave suffers from violence and/or economic exploitation
Fast et al. [8]	Fast et al. [8] support Fnley [9] and Nieboer [23], in the way that slavery is an economic system supported by unsalaried workers, that is, the employees do not receive compensations for their work
Lazaridis [16]	As Wijers and Lap-Chew [29], Lazaridis [16] consider forced labor as services employing violence or threats, abuse of authority, fraud, or services to pay off debts
Lebaron [17]	Lebaron [17] states that the control of one person for economic exploitation is what defines slavery, corroborating with Bales [1]
Leite et al. [18]	ILO [14], as presented in Crane et al. [6] definition
Mcgrath [20]	Mcgrath [20] defines slave or unfree labor as those where the choice of work is restricted as well as the economic mobility of workers
Phillips and Sakamoto [24]	Phillips and Sakamoto [24] present and corroborate with the Brazilian law definition of slave labor, in with, subjecting workers to extended hours of work, degrading working conditions, restricting their movement and employing people to pay off debts is considered unfree labor
Stringer et al. [26]	ILO [14], as presented in Crane et al. [6] definition

Brazil, while the sugarcane sector has a higher number of workers freed from these conditions since 2000.

In addition to the topics discussed above, the papers cite diverse conferences and resolutions such as: World Conference on Human Rights, resolution on “Traffic in Women and Girls,” Commission on Human Rights (Resolution 1996/61), conference on “Trafficking in Women in Vienna,” ILO Conventions on forced labour (No. 29 and No. 105), Minimum Age (No. 138), and Child Labour (no. 182), ILO Conventions on freedom of association and collective bargaining (Nos. 87 and 98), ILO Work in Fishing Convention (No. 188), ILO Migration for Employment Convention (No. 97), and the Migrant Workers (Supplementary Provisions) Convention (No. 143).

Table 99.3 Countries and economic sectors cited

References	Cited countries	Economic sectors cited
Barrientos [3]	South Africa, United Kingdom, Chile, India, Romania, Jordan	Fruits, Garments, and Horticulture
Bonfanti and Bordignon [4]	United States, Thailand, United Kingdom	Seafood market
Crane et al. [6]	United Kingdom	Construction, food, and cannabis industries
Lazaridis [16]	Greece	Sex Industry
Lebaron [17]	United States, United Arab Emirates, Canada	Gold, diamonds, cotton, sugarcane, footwear, garments, bricks, coffee, chocolate and coal industries
Leite et al. [18]	Brazil	Textile industry
Mahdavi [19]	United Arab Emirates	Domestic and sex industry
Mcgrath [20]	Brazil	Sugar cane and Ethanol industries
Phillips and Sakamoto [24]	Brazil	Cattle sector, sugar cane, soybean, biofuels, charcoal, cotton, coffee, fruits, onion, corn, tea, timber and pinewood industries
Robins [25]	Congo and other African countries	Cocoa and red rubber industry
Stringer et al. [26]	New Zeland	Fishing industry

99.4 Conclusion and Future Studies

In addressing less explored themes, the present study contributes to the academic knowledge by developing an SLR encompassing global production networks and modern slavery, and by delivering a modern slavery taxonomy. The SLR was able to demonstrate how few studies related to these themes were found in the academic literature. Besides, it should be noted that the subject is present in developing countries as well as in developed countries and diverse sectors of the world economy.

The question that emerged from SLR and deserves attention is the need to rethink whether it is coherent to favor the global economy in detriment of so many modern slave labors. For example, the restructuring of the production chain of the textile industry with the separation of the productive process in places with cheaper labor (sewing) and more expensive labor (design of models and collections), culminated in a lack of responsibility of the major brands about the condition of work performed in the outsourced manufactory. Leite et al. [18] cite international brands such as Zara, C&A, and Gap as examples of brands restructured in this way.

Corroborating with Phillips and Sakamoto [24] and Stringer et al. [26], the current operating model of GPNs deserves close observation, and researchers need to be done to identify why and how slavery persists in the global economy. In this scenario, the present study focused on the different terms used in the academy for the current term, developing a taxonomic table and, in more detailed studies regarding the effect of GPN in forced workers.

Therefore, as future studies, besides the update of the review presented in the present study, unfreedom in labor needs to be studied more earnestly to be understood, particularly concerning race, gender, and birthplace (nationality), as suggested by Lebaron [17]. Also, in the agreement of [17], there is a need for more studies about the root causes of unfree labor.

Consent with Lazaridis [16], there is also a need for a regular policy dialogue about immigration, about trafficking and its dangers, and measures to prevent traffic. We also suggest further in-depth studies of women and children trafficking and the need to rethink about existing decrees and regularizations. Those who profit from slavery should be penalized, so the law must be strengthened so that these cases do not go unpunished.

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Chapter 100
Addressing Environmental Risks in Supply Chain Management: A Systematic Literature Review

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Abstract The environmental supply chain risk management has emerged as a prominent research topic in the past few years. This work proposes, through a systematic literature review, a taxonomy for environmental risks and presents the findings to support future works on environmental supply chain risks.

Keywords Environmental risk management · Supply chain management · Systematic literature review

100.1 Introduction

Supply chain risk management (SCRM) has recently gained more attention from practitioners and researchers [6]. Several risks emanate from supply chains and managers have to be aware of these risks [18]. Understanding how to perform supply chain risk management is a priority issue to prevent potential losses such as reputation and financial losses, poor relationships with the other members of the supply chain, and conflict between the organization's stakeholders [8].

According to Freise and Seuring [14], researches have focused on risk management in a purely economic way. Hofmann et al. [18] reinforce this discussion and note that supply chain risk management has largely neglected environmental and social issues in supply chain operations, although these issues may be an important source of risk.

Coherent with the triple bottom line (TBL) perspective of sustainability initially proposed by Elkington [11], companies' strategy should simultaneously consider and balance not only the economic perspective but also the environmental and social aspects [4]. Social and environmental risks need to be included into the risk management besides economical risks [14], generating, thereby, what is known as sus-

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tainable supply chain management (SSCM) [10]. Seuring and Müller [32] point out that companies are being pressured by stakeholders (e.g., non-governmental organizations—NGOs) to incorporate the environmental and social issues present in their supply chain.

The Gulf of Mexico oil spill (2010), the Samarco dam collapse in Brazil (2015), the explosions from hazardous chemicals at Beijing's Maritime Gateway (2015), and nitrogen oxide emissions scandal at Volkswagen factory in Wolfsburg, Germany (2015), bring to light, environmental abuses in supply chain of large firms.

In this context, the present work focuses on the environmental view of the triple bottom line and considers environmental risks. Through a systematic literature review, this study aims to analyze environmental risks present in supply chains, as well as the consequences of these risks, proposing a classification into categories of risks and their consequences. The remainder of this paper is organized as follows: The next section presents the research methodology. Section 100.3 addresses environmental risk analysis and Sect. 100.4 summarizes the findings and proposes future directions for the research.

100.2 Research Methodology

The present study was conducted through a systematic literature review (SLR). According to Cronin et al. [9], systematic reviews use a more rigorous and well-defined approach to review literature in a specific area. To perform the SLR, we used the step-by-step approach proposed by Thomé et al. [34], with eight steps to follow: (i) formulation of the research problem, (ii) research in the literature, (iii) data gathering, (iv) quality assessment, (v) data analysis and synthesis, (vi) interpretation, (vii) results presentation, and (viii) revision update.

Scopus and Web of Science databases were selected to conduct the bibliographic research because they have wide coverage of indexed journals and are typically used in literature reviews [12]. The keywords used for the research were divided into two groups: keywords related to supply chain risk management and another group related to environmental perspective and sustainability. Thus, the keywords of group 1 were "supply chain" and "risk management" and the keywords of group 2 were "environment*," "sustainab*," and "green."

The last database search was carried out in May 2018, resulting in 684 Scopus database documents and 360 Web of Science database documents, with no initial exclusions. Two hundred and six of the 360 documents present in the Web of Science were also in the Scopus database, and after the removal of duplicates, the number of articles was reduced to 802.

The first exclusion criterion was to remove books and book chapters. Then, with the reading of the titles and abstracts, documents not related to environmental risks and their management were excluded. One hundred and twenty-four documents were then retained to continue with the SLR.

Documents without access were excluded, resulting in ninety-nine documents to read in full. The third exclusion criterion was the retention only of documents related to environmental risks that companies can generate for the environment and for society or documents related to the environmental risks caused by the natural environment that can impact companies and their supply chains. This procedure resulted in thirty-eight documents eligible for research. To complete the RSL, a "snowball" backward and forward was performed, resulting in 45 papers eligible for the present study.

To build the taxonomy, the environmental risks were classified into categories, according to their similarity. The categories used to classify the environmental risks were defined based on a content analysis that represents an effective tool for analyzing a sample of research documents in a systematic way [31]. The categories were used to structure and synthesize the findings of the literature about the studied theme and were structured basically by familiarity.

100.3 Environmental Risk Analysis

Among the 45 articles selected for the study, the first article to be published was in the year 1995. Only five articles were published in 1995–2004; 33% were published in 2005–2011, and 55% were published in 2012–2018.

Thirty-seven of the 45 documents selected are peer-reviewed papers, whereas the other eight are classified as conference papers. The journals with the largest number of publications are the "Journal of Cleaner Production" followed by the "International Journal of Production Research," with four and three publications, respectively.

Regarding the industry sector, the ones that most appeared was the automotive, chemicals, and oil/gas sectors, followed by the textile industry. This is fully expected since the most frequent risks found in the literature are those related to the emission of greenhouse gases, energy efficiency, and chemical risks (mainly due to the use of solvents, toxic products in clothing industry). According to Levner and Ptuskin [22], the risk types should be specified for every individual industrial enterprise and each specific case.

100.3.1 Data Analysis

This section presents the identification and categorization of the environmental risks found in SLR. Based on the classification of Giannakis and Papadopoulos [16], the risks were divided into endogenous and exogenous environmental. The endogenous environmental risks represent the ones that companies might generate for the environment as a result of their activities. Levner and Ptuskin [22] define these risks as ecological risks, such as threats for living organisms, natural environment and facilities by effluents, emissions, wastes, and resource depletion, coming from the supply chain's activities. According to Torres-Ruiz and Ravindran [35], the endogenous environmental risks evaluate the exposure related to climate change issues (greenhouse gas emissions), resource use including water, land, energy and materials use, recycling and disposal, etc.

Exogenous risks represent risks related to natural or man-made disasters that affect companies and their supply chains [27]. Figure 100.1 shows this division and

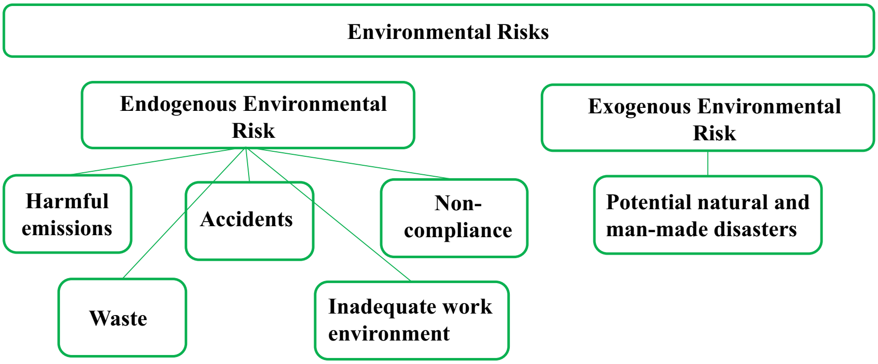

Fig. 100.1 Categorization of endogenous and exogenous environmental risks

the categorization used for the endogenous and exogenous environmental risks.

Each category has a set of environmental risks and is described below:

- Harmful emissions
  - (a) Greenhouse gas emissions and other harmful gases [1, 6, 7, 16, 18, 22, 30].
  - (b) Fugitive atmospheric emissions of chemicals substances [1, 20].
  - (c) Chemical and toxic effluents released into the water [14, 26, 29, 36].
  - (d) Chemical and toxic effluents released into the soil [23, 29, 33, 36].
- Waste
  - (a) Inefficient use of natural resources [7, 17, 18, 21, 25, 36].
  - (b) Inefficient use of energy [10, 16, 23, 25, 35].
  - (c) Inefficient use of raw materials or packaging [3, 16, 25, 28, 35].
  - (d) Intensive use of chemicals in the manufacturing process [2, 14, 22, 25, 33, 35].
- Inadequate work environment
  - (a) Unhealthy and dangerous working environment [20, 22, 25, 26, 36].
  - (b) Inadequate warehouse area for hazardous materials and waste storage [7, 15, 26].
  - (c) Unaware of the amount of chemicals used [26].

- Accidents
  (a) Fires, explosions, floods, chemical accidents, oil spills, etc. [7, 16, 18, 22, 29].
- Non-compliance
  (a) Non-compliance with environmental and safety regulation [7, 16, 30].
- Potential natural and man-made disasters
  (a) Earthquakes, storms, floods, hurricanes, heat waves, droughts, water scarcity, hail, terrorist attacks, etc. [6, 13, 16, 19, 28, 36].

Matten [24] argues that human commercial activities can result in damage to the environment which, in turn, threatens a company with adverse consequences. It is important to note that while the environmental risks described above can be found in papers that focus on the focal company, all risks affect companies and hence their chain, spreading the disruptions and consequences along the supply chain.

The most frequent consequences found in the literature are related to the company's reputation and losses in financial terms. Damage to human health has also been highlighted, especially in papers dealing with the use of solvents and chemicals. The consequences were also divided into categories. The description of each one is given below:

- **Reputational**: embraces the consequences generated for the company related to its reputational capital [1, 3, 6, 17, 25, 35].
- **Financial**: financial consequences that can be generated from unmitigated risks in the company's supply chain [18]. It includes liquidity reduction, profit decrease, declining of competitiveness, increase costs, and financial penalties [3, 5, 6, 10, 16, 22, 25].
- **Damage to human health**: any damage to human health or ecosystems due to exposure to environmental hazards [5, 13, 14, 16, 26, 36].

100.4 Conclusion and Future Research Avenues

The present paper focuses on the environmental risk management in supply chains, and through a systematic literature review, was possible to identify the environmental risks and their consequences discussed in the literature. From the theoretical point of view, the introduction of the environmental perspective in the discussion of supply chain risk management is relevant to the academy since many studies in this area do not incorporate the environmental issues in this field of research.

From a practical point of view, managers need to be aware not only to consider the obvious risks in production, but also they should pay attention to managing the potential risks that may occur in the future, especially the environmental risks that, as discussed in this work, can cause losses and serious consequences to the companies and their supply chains.

Cousins et al. [8] argue that these high perceived losses and consequences can motivate companies to manage the environmental risks. Thus, it is important to note that environmental risks need not only be identified but also treated. Managers must anticipate these risks and mitigate them, through specific risk management strategies. To extend the research in the field of environmental supply chain risks, researchers should concentrate their studies on the environmental risk management strategies existing in the literature. An efficient environmental risk management is critical to the longevity of a company.

Future works can also carry out case studies to strengthen the field of the research and add new evidence to the present study, as well as to build a basis for comparison between academia and practice. Comparative studies can be conducted in different economic and climatic regions in order to investigate the perceptions and effects of sustainability-related risks, including environmental and social risks.

Freise and Seuring [14] propose that the empirical study on sustainable risks should be extended to different industrial sectors and extended to other parts of the world. Busse et al. [3] corroborates this idea and argues that future research should systematically investigate how companies identify, assess, and manage their environmental risks in the supply chain, which may diverge significantly between industries.

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Chapter 101
Systematic Literature Reviews About Operational Improvement Programmes Headed for Sustainable Development: A Tertiary Study

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Abstract Using a systematic review method to identify systematic literature reviews (SLRs) that address quality operational improvement programs toward green manufacturing, this paper aims to categorize SLRs that address Lean, Six Sigma, or Lean Six Sigma with sustainable aspects to map gaps, emerging issues and paths for future research.

Keywords Lean six sigma · Sustainability · Systematic review

101.1 Introduction

Over the last two decades, much has been written about the principles of sustainable development and the need for organizations to pursue sustainable practices that drastically change the way they do business [22] and have a strong impact on business performance [34]. It is noticed that in the literature, there are many pressures for the transition of organizations and industries toward sustainable development (SD) [4]. In recent years, there has been a considerable increase in research on the alignment between operational improvement programs (OIP) and SD [3, 6, 8] . A large number of research papers that discuss issues related to the integration of Lean Production (LP) and Six Sigma with environmental practices have already led some researchers to perform systematic literature reviews (SLRs) [12, 13]. In this context,

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this research aims to conduct a tertiary review of systematic reviews related to OIP and sustainability. A tertiary review is a systematic review of secondary studies [20].

This exploratory research sought novelty through the critical review of SLRs that simultaneously address LP, Six Sigma, or Lean Six Sigma (LSS) themes with sustainability. In this sense, this research brings multiple new contributions, providing academics and professionals with a better perspective to achieve sustainable development through the alignment of operational improvement methodologies with sustainability. The research aims to contribute to the scientific community on the subject studied, since it presents a representative selection of international research in an interdisciplinary area. In summary, the main distinguishing characteristics of this research are: (i) to expand the literature review on LP, Six Sigma, and sustainability; (ii) to map gaps and emerging issues; and (iii) to provide paths for further research.

The rest of the paper is structured as follows: Sect. 101.2 gives an overview over the existing literature of LP, Six Sigma, LSS, and sustainability. The methodology of this study is introduced in Sect. 101.3. Section 101.4 synthesizes and discusses the main findings in the selected reviews in details. Section 101.5 concludes this paper, pointing out recommendations, implications, and trends for future research.

101.2 Operational Improvement Programs Toward SD

In the last decade, academics and practitioners have extensively cited the benefits of operational improvement programs implementation as LP or Six Sigma to tackle economic, environmental, and social issues. Lean production evolved from the conceptualisation of the Toyota Production System (TPS) by Taichii Ohno's initiatives at the Toyota Motor Company [25] in the 1950s to reduce waste, achieve a holistic approach to relationships with employees, suppliers, and customers, and practice *kaizen* problem-solving events [23]. In today's business world, LP represents an operational philosophy for all and should be adopted by employees at all organizational levels to produce truly sustainable results [33]. Moreover, Lean practices have some synergies with sustainability such as waste reduction, decrease of environmental impacts (e.g., emissions to air, water, and soil as well as water efficiency and energy conservation), creation of greener supply chains, reduction of the time of delivery, product design and techniques to manage people [8, 13], and these actions could be improved when used together [32].

Six Sigma was created by Bill Smith at the Motorola Corporation in the 1980s and sought to reduce variability in order to reduce errors and defects by applying the DMAIC methodology, consisting of the following steps: (1) Define, (2) Measure, (3) Analyze, (4) Improve, and (5) Control [23]. The Six Sigma methodology evolved from the total quality management (TQM) methodology and consists of a managerial approach focused on long-term success through a focus on customer satisfaction, involving all employees for the continuous improvement of processes, products and services, strategic and systematic approaches focused on processes, integrated systems, and application of statistics to identify and eliminate defects and quality problems [16]. Furthermore, it can be seen that the Six Sigma methodology aims to reduce defects and cost by controlling the consumption of necessary resources [8] and can contribute to improving sustainable production and service systems because, through its principles, companies can manage energy use and implement, manage, sustain, and improve sustainability performance [13], since the DMAIC cycle can be adequate for the measurement of sustainability.

George [14] states that the merging of LP and Six Sigma methodologies is essential for reducing cost and complexity. Just as LP cannot statistically control a process, Six Sigma alone cannot dramatically improve process speed or reduce invested capital [15]. Six Sigma helps connect business leaders and key project teams in a potent two-way fact-based dialog, which is considered a blind spot of the LP [33]. In this way, LSS practices are progressively becoming widespread in the manufacturing industry, as it incorporates the principles of speed and immediate action of LP with the vision of Six Sigma of quality without defect and reduction of the impact of the variation in the times of queue [15]. In this sense, Lean Six Sigma represents a cultural transformation that makes organizations consider and accept environmental innovation and can reduce the marginal cost of sustainability initiatives [5]. LSS techniques also contribute to a more environmentally sustainable supply chain and to process improvement [27]. In fact, LP and Six Sigma are catalysts for the implementation of sustainability in manufacturing companies [32].

101.3 Methodology

This section aims to show the proposed SLR methodology, also known as tertiary systematic reviews (TSRs). TSRs are studies that synthesize data and information from a number of SLRs in a particular area [30] and are particularly useful when several overlapping systematic reviews have been performed in a certain thematic area (as is the case of the relationship between the themes: LP/Six Sigma/LSS and sustainability), in order to explore the consistency between the results of the individual analyzes [31]. As well as other systematic literature reviews carried out in the management area [2, 11], the preparation and maintenance of this review of SLRs followed transparent, explicit, and consecutive steps (Fig. 101.1).

As observed in previous SLRs, this review seeks to locate the most relevant existing studies based on previously formulated research question to evaluate and synthesize their respective contributions. The research question of this research (Step 1) was: *What are the gaps and research problems to be explored in future researches that relate LP, Six Sigma, or LSS and sustainability?* Thus, as a starting point for this research, we sought to analyze systematic reviews on the themes LP, Six Sigma, and sustainability, in order to find the research gaps and emerging issues (shown in Table 101.2). The review was carried out in Science Direct (www.sciencedirect.com), Scopus (www.scopus.com), and ISI Web of Knowledge (wokinfo.com) databases, by combining "AND" and "OR" boolean logical operators with the following keywords: "systematic review," "systematic literature review," "Six Sigma," "Lean Thinking,"

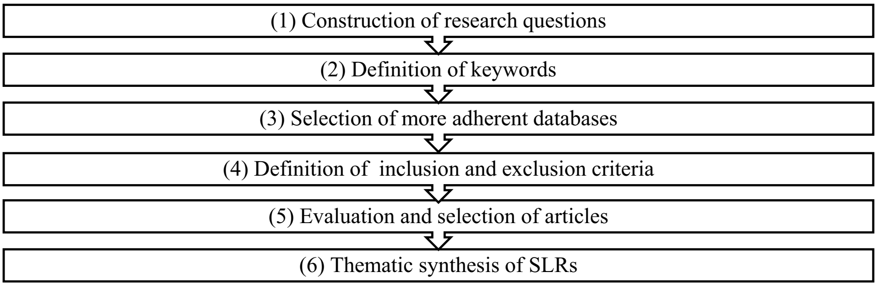

Fig. 101.1 Steps of tertiary systematic review

"Lean Production," "Lean Manufacturing," "Lean Management," "Lean Philosophy," "Lean Six Sigma," "Green," "sustainable development," and "sustainability". Table 101.1 shows the sequence of inclusion and exclusion criteria used to select the studies.

In addition, data abstraction (selection of data to be extracted from each contributing article) and the data extraction are essential parts of any systematic review. In this review, several individuals—three authors—independently performed the data extraction, comparing the results and solving any discrepancies by consensus. This step consisted of deleting articles that somehow made up the raw database articles, which did not fit the interests of the search. To ensure complete coverage, at a later stage of the process, additional academic studies have also been identified through manual screening of cross-references. According to Denyer and Tranfield [11], once all the studies related to the research question were collected and evaluated, and the analysis process was carried out to examine and dissect individual studies and to explore how the components relate to each other. Thus, after identifying the relevant studies, the articles were extracted into a Microsoft Excel worksheet. The results of the thematic synthesis of SLRs (Step 6) will be further explored in the next section.

Table 101.1 Inclusion and exclusion criteria

Sequence	Criteria	Inclusion	Exclusion
1.	Period	1998 until August 2018	Any study published before 1998
2.	Type of publication	Reviews published in peer-reviewed journals	Any other type of publication (e.g., books, working papers, and conference papers)
3.	Language	English	Any other language
4.	Relevance	Relevant according to the authors' multidisciplinary perception	Irrelevant

101.4 Results and Discussion

Table 101.2 points out some key topics to be further explored and that can be used as a guide to conduct and inspire new relevant researchers interplaying OIP with sustainability. It is observed that there is a great variety of authors approaching the subject, and in general, previous studies are focused on some of the dimensions of sustainability (such as green), while few studies have a simultaneous approach that takes into account the triple bottom line dimensions.

After mapping the gaps and emerging issues present in SLRs, this research looks at the following categories of needs to indicate paths for further research: (1) philosophical integration; (2) models and frameworks; (3) evaluation and measurement.

101.4.1 Philosophical Integration

There are still some challenges for aligning quality operational programs such as LP, Six Sigma, or LSS with sustainable philosophy, with regard to training specialists, supporting management, customer engagement, and whether an organization has technologies, facilities, human resources, time management, and organizational culture [21]. It is necessary to standardize both the training and the certification of the LSS curriculum for companies (of all sizes) of manufacturing, services, public and third sector. There are few empirical studies on the current status of LSS in small- and medium-sized enterprises (SMEs) [1]. In addition, the expansion of work to analyze the different organizational cultures and management lenses that permeate the Lean (in manufacturing, quality, and continuous improvement) and green (through environmental compliance and regulatory function) can provide new insights and lay the foundation for successful Green–Lean Change Management [12, 13]. Chugani et al. [8] highlight some gaps in the literature such as the scarcity of research exploring the impact of Six Sigma on the environment; positive or negative consequences on the environment, as a result of the implementation of LP/Six Sigma programs that have not yet been explored in all industries and the need to research synergies and divergences between LP, Six Sigma and the environment that will contribute to the advance in the area. These authors also claim that such gaps can be filled by examining the individual organization style and application programs of LP practices, Six Sigma, and LSS [3]. Organizations also need to carry out their projects taking care that the benefits achieved under one of the three pillars do not generate negative impacts on the other pillars of sustainability in order to achieve a better balance between them and a healthier global performance for the organization [10]. Moreover, the LSS should be integrated with other philosophies, such as the supply chain, agile manufacturing, sustainability, and environmentally correct techniques (LSS focused on Green) [7, 6, 28, 29].

Table 101.2 Summary of gaps and emerging issues

Source	Gaps and emerging issues
Raja Sreedharan and Raju [29]	There are no clear guidelines available to organizations regarding the deployment of LSS in different situations
Albliwi et al. [1]	It is necessary to identify critical failure factors for LSS implementation for countries at different stages of evolution
Mclean and Antony [24]	It is suggested that future researches validate the model through empirical in-depth research, with each of the themes identified
Garza-Reyes [12]	There is a need to understand how the synergies and divergences between Lean and Green affect the effectiveness of these initiatives when deployed sequentially or concurrently, analyze if Green–Lean synergies and divergences are equal across industries or at any level
Garza-Reyes [13]	There is a need to validate the Green, Lean, and Six Sigma compatibilities proposed, for example, by establishing them quantitatively and testing them empirically to seek their statistical validation
Hartini and Ciptomulyono [18]	There is no clear and adequate measure for Lean and sustainable manufacturing; it is necessary to measure the impact of Lean systems on Green outcomes, supporting the synergy between Lean and sustainable philosophies
Albliwi et al. [1]	There is a lack of an LSS sustainability framework and a systematic framework that guides organizations to choose the appropriate continuous improvement for a particular scenario; lack of research that addresses the relationship between LSS and organizational learning, addressing social, cultural aspects of human action, cognitive, work techniques and change
Cherrafi et al. [5]	There is a need to develop integrated metrics and measurement systems to measure or assess Lean/Six Sigma performance and sustainability
Hallam and Contreras [17]	New studies should seek to understand why Lean and Green management philosophies are implemented within companies as independent efforts in order to more deeply understand the requirements for their integration

(continued)

Table 101.2 (continued)

Source	Gaps and emerging issues
Pejić et al. [26]	Based on the two basic objectives (minimum costs and reduction of CO2 emissions), a hybrid model of Lean and Green intralogistics is proposed in the future
De Freitas and Costa [9]	Lack of research on the positive/negative impact of implementing Six Sigma on the environment. In addition, the impacts presented by the LSS in social and environmental pillars of sustainability need to be better explored through the selection of indicators related to the guidelines of these pillars
De Freitas et al. [10]	There is a need to analyze the influence of LSS projects on organizational sustainability, using real data based on sustainability indicators considering the most influential impacts previously identified by this study. Integrated models are also required to measure LSS, based on triple bottom line (TBL) performance
Cherrafi et al. [7]	More than four projects are needed to identify critical success factors (CSFs) to implement Green Lean Six Sigma in order to generalize the findings. In addition, it would be appropriate to classify CSFs using data from other emerging and developed countries, given that data from this research came especially from developed countries
Cherrafi et al. [6]	Further research can be aimed at identifying and analyzing specific barriers, taking into account the country, industry, and size factors of the company
Chugani et al. [8]	There is no research exploring the impact of Six Sigma on the environment and how this methodology may be adequate to measure sustainability. Pressures affect the choice of quality improvement programs
Ruben et al. [28]	The proposed LSS with environmental insights framework should be validated through industry-related studies and simulations in order to explore its application potential, possibilities for improvement, and its limitations
Caiado et al. [3]	Further research can be done to improve discoveries such as proposing an integrated GLSS business model or a roadmap for implementing sustainable LSS in the service industry

101.4.2 Models and Frameworks

A robust LSS framework is needed to meet changing demand for critical activities from industries such as agriculture, food, construction, education, and pharmaceuticals, a generic model for LSS implementation for most industries and a clear picture of the use of tools in the various phases of LSS implementation [1, 29]. In this sense, the literature review highlights the importance in developing a framework, through empirical research, to address all areas of sustainability with continuous improvement implementation [24]. The development of a framework specifically tailored to the needs of manufacturing of SMEs will benefit them as they operate with budgets and limited resources and more time constraints. In addition, developing the framework will require the initial validation of the topics by academics, business leaders, and practitioners and will serve as a benchmark at the beginning of an implementation, providing valuable insight for a business leader who wishes to pursue continuous improvement. Thus, it is necessary to validate the themes and identify other potentials, in order to develop a conceptual framework for the implementation of continuous improvement. Finally, future research can therefore test and adapt existing models considering multiple needs through the combined use of multi-criteria decision-making (MCDM) models as AHP in order to measure operational and sustainable organizational performance with the alignment of sustainability, LP, and Six Sigma approaches, seeking continuous improvement [6].

101.4.3 Evaluation and Measurement

Due to constant change in economic, political, and organizational scenarios, where organizations interact with a variety of areas in a dynamic environment, being at any time vulnerable to crises, measure sustainability is a challenge [5, 8, 18]. Helleno et al. [19] contribute to the current methods of sustainability assessment by developing and applying a method to integrate a new set of key performance indicators (KPIs) based on the concept of value stream mapping (VSM), a Lean Manufacturing Tool to evaluate the parameters of the manufacturing process in the Brazilian industry. This method helps to measure the parameters that influence productivity and thus to promote the improvement of sustainability. However, there are no practical studies that point to performance measures aligned to the operational and TBL dimensions to simultaneously achieve operational excellence and sustainability objectives, while highlighting the integration of operational improvement programs with sustainable performance measures [3].

101.5 Conclusions

Therefore, this exploratory research fulfills its objective of conducting a systematic tertiary review of gaps and emerging issues in SLRs that relates OIP and SD. Thus, the article provides academics and practitioners with a better picture of trends in achieving sustainable organizational development by aligning LP, Six Sigma, or LSS methodologies with sustainability, expanding the literature review on the subject studied, since it proposes a research agenda in an interdisciplinary area, raising possible contributions and ways to be explored in future researches. Furthermore, it was noticed that there are several models presented in the literature, however, few applied in empirical studies, exploring GLSS. Moreover, few works in the literature propose a performance measurement system, which would be one of the critical success points of an LSS approach inherent to the work processes in sustainable organizations. From the practical point of view, there is a need to develop performance measurement systems with well-defined processes, as well as considering aspects and principles of GLSS. Finally, the political implication is perceived, due to the increasing demand for determinations or decrees in favor of sustainability in various aspects or dimensions (e.g., environmental, economic, social, technical, and governance) that motivate future research on GLSS. The tertiary review was carried out in August 2018, including: method construction, databases searching, articles selection, analysis, and synthesis. Just as in any revision, there was a temporal limitation, because the data was collected on a date and the perception of the authors who developed this research is limited, from the decision on the alignment with the theme or even observations. In addition, as the focus was on reviewing articles published in academic journals in English, articles from other languages, as well as other types of publications, were excluded. Lastly, because of the keyword-based identification of publications, it is possible that we did not find publications that match the focus of the search because they did not contain the required keywords in their titles or summaries.

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Chapter 102
Operations Strategy and Environmental Management: Sustainability as a New Competitive Priority of the Operations

José Roberto Soares Ribeiro and Alceu Gomes Alves Filho

Abstract This research studied the relationship between operations strategy (OS) and environmental management (EM) through an ISO-14000 certified industrial enterprise. The analysis concluded that EM is a new competitive priority of operations, in association with innovation, being present in its OS, but with EM considered as sustainability or *triple bottom line*.

Keywords Operations strategy · Environmental management · Business sustainability

102.1 Introduction

The objective of the qualitative research presented in this article was to verify if environmental management can be considered a new competitive priority of the operations, being able to be included among the traditional four—cost, delivery, flexibility, and quality. If this occurs, it will be deployed in the various structural and infrastructural decision areas.

To verify this issue, a case study was carried out at *Natura Cosméticos S/A*, a ISO-14000 company recognized for having placed the environmental factor at a strategic level. The research focused on its Cajamar-SP industrial plants.

Theoretical data were collected through bibliographic research and the practice data through semi-structured interviews with executives of the industrial board, systematic observations in the company's factories in Cajamar-SP, and consultation of documents available on the company's Web site.

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102.2 Competitive and Operational Strategy

For Treacy and Wiersema [18], three competitive strategies or disciplines are possible for a company to lead its market: *customer intimacy, operational excellence,* and *product leadership*. In *product leadership*, companies develop new technologies and constantly put new products on the market.

This approach to competitive strategy (CS) is consistent with that posed by Hayes et al. that a company can achieve “a defensible competitive advantage in a number of ways, including some generic ones.” These generic strategies, according to the authors, are: (1) *low cost/high volumes*, (2) *product innovation and unique characteristics*, and (3) *customized service in select niches*.

According to Porter [14], three CSs are possible to face the five competitive forces present in a given industry: *cost leadership* and *differentiation leadership* in a broad market and *focus* on a restricted or niche market. For strategic planning, in the view of the industrial organization, the operations strategy (OS) is a functional strategy that should support the competitive strategy. Thus, “each type of strategy demands certain tasks of production and specifies certain objectives called competitive priorities” [4, p. 159]. The consistency between the competitive and operations strategies is the determinant of the competitive success of the organization [2].

For the OS concept formulator, the OS carries specific requirements for the production function and operations, and conversely, it must be specifically designed to fulfill the task required by the strategic plans, with cause-and-effect factors determining this connection [16, pp. 138, 139].

Figure 102.1 presents the classic structure of the operations strategy derived from the competitive strategy, according to Horte et al. [8, p. 1574], which makes it clear that this is a summary of how different authors dealt with the concept of manufacturing strategies. This classic model is adopted broadly by the researchers of the subject.

As for the “strategic manufacturing planning process,” the model brings the OS derived from the competitive strategy and is deployed in structural and infrastructural decision areas. The CS considers the generic strategies of Porter [14], influenced by the macroenvironment, and unfolded in the traditional objectives (cost, quality, delivery, and flexibility).

102.2.1 Competitive Priorities of Operations—Qualifying Factor and Winning Order Factor

According to Garvin [7], most of the strategy authors cite the following four competitive priorities: quality, cost, delivery, and flexibility. This author has added a fifth: Services. Dangayach and Deshmukh [5, p. 910] adds the goal of Innovation.

Qualifying factors (CF) are those that if they are below a certain level of performance, customers will not even consider the company’s product against competitors.

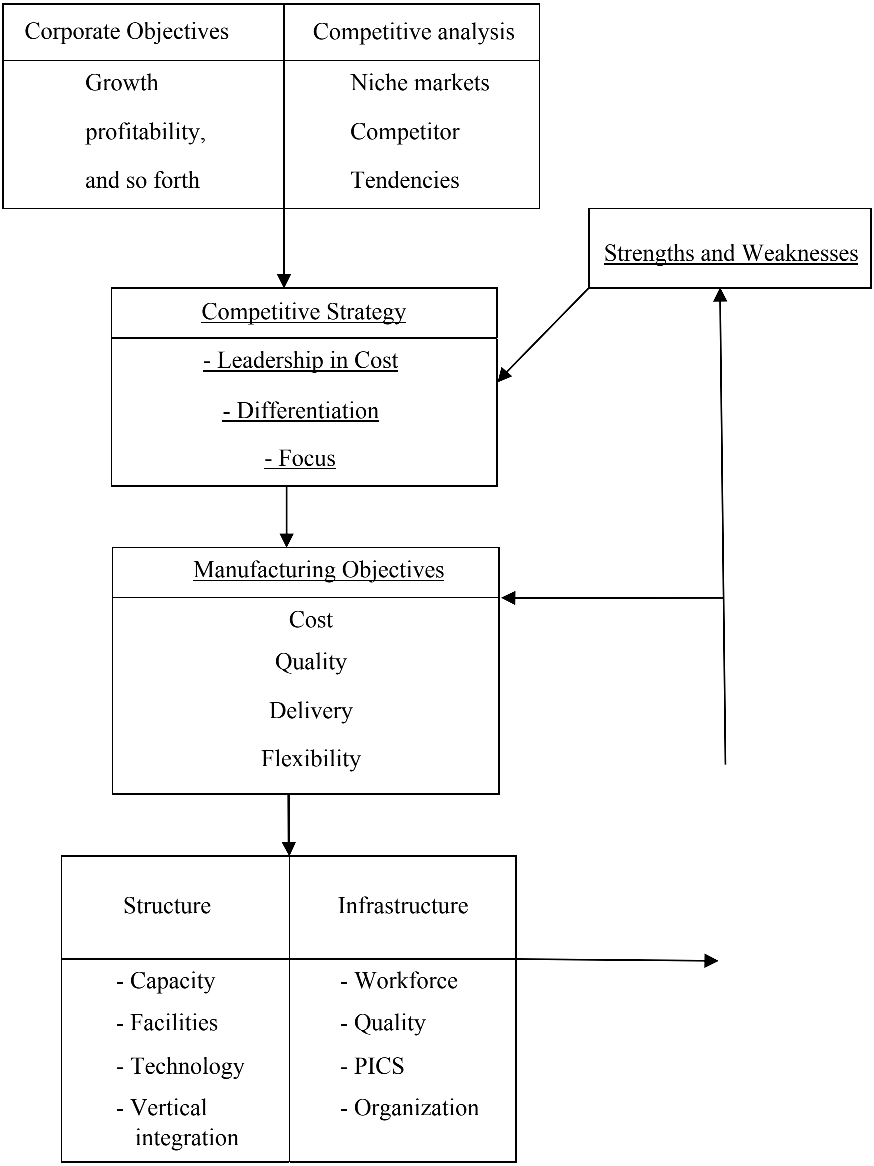

Fig. 102.1 Strategic manufacturing planning process. *Source* Horte et al. [8, p. 1574]

The order winning factors (FGP) are those considered by customers to choose and buy the company's product.

102.2.2 OS Decision Areas

Skinner ([16], p. 140), considering the notion of trade-offs in operations decisions, already posed the existence of areas in which "top management needs to recognize alternatives and become involved in the design of the production system" in order to select among alternatives more appropriate for the operations task "determined by the corporate strategy".

Decision areas can be structural or infrastructural. The following definitions of those most widely accepted in the literature [10].

The structural decisions areas impact in the long term and require large investments, resulting in the definition of the company capacity, in its installations, technology and vertical integration [10].

Infrastructure decision areas may be less difficult to alter in the course of the company's activities [10]: human resources, quality management, production planning and control and organization [10, p. 61].

Skinner [16], considering the notion of trade-offs in operations decisions, already posed the existence of areas in which "top management needs to recognize alternatives and become involved in the design of the production system" in order to select among alternatives more appropriate for the operations task "determined by the corporate strategy."

102.3 Environmental Management

The vast majority of scientists "recognize in human actions the origin of major problems that have adversely affected environmental and socioeconomic resources in different parts of the world." The productive sector has long ignored "the negative effects of human activities on the environment," but this situation has changed radically. "Today, a company that risks infringing environmental laws risks high fines and bad image with its customers" [1, p. 2]. The new environmental consciousness places "the protection of the environment as one of the most fundamental principles of modern man" [3].

With regard to companies, production management "must include all its factors" (materials, people, equipment and process), and functional aspects such as productivity and quality. Moreover, there is also a need to manage the "dysfunctions of the production process", the negative impacts on people working (occupational health and safety management) and on the environment (environmental management), as well as possible damages to the consumers of their products (Customer Satisfaction Management) [1, p. 3].

From the business point of view, GA can be considered as a "global managerial function that treats, determines and implements an environment policy in the organization," leading to the inclusion in the management of the company of the externalities caused by its activities [17, p. 5].

The approach to expanding the traditional business model in dealing with GA brought the concept created by Elkington [6] of triple bottom line, taking into account the environmental and social performance of the company in addition to economic—financial evaluation factors. This concept is also known as 3P (People, Planet, and Profit) [13].

With respect to EC, EO, environmental management and innovation, Porter and Van der Linde [15, p. 374] denounce a static mentality behind the incorrect conduct of the debate on the relationship between competitiveness and the environment by various social actors. According to the authors, there is a focus on the costs of regulation and the compensatory benefits of innovation—higher productivity is ignored. According to them, it is possible to increase competitiveness by reducing pollution, which means inefficiency in the use of resources and economic waste. In this sense, they point out that innovation can reduce or eliminate what was once considered fixed, and the companies that recognize environmental improvement as a first, economic and competitive opportunity, rather than an "annoying cost" or "unavoidable threat", and embrace "solutions based on innovation" will "reap great competitive advantages".

102.4 Case Study—Operations Strategy and Environmental Management

The Brazilian and multinational company of the cosmetics sector *Natura & Co* has three distinct and independent Global Business Divisions. The focus of this article is on the Operations of *Natura Cosméticos S/A*, present in Latin America in more than six countries. Throughout its history, this company has deepened its commitment to sustainable development, aiming to generate value and develop technologies by the objective is to have a positive financial, environmental, and social impact by 2050, considering all stages of the production cycle [12].

As for its competitive strategy (CS), *Natura* has a *broad market differentiation strategy* [14] and of *product innovation and unique characteristics* or *product leadership with a focus on innovation* [18]. Sustainability is an integral part of its strategy, which has the innovation and triple bottom line (TBL) as key pieces that guide its goals and indicators, which are deployed to the areas of the company in a top-down model.

As company with shares in *BM&F Bovespa (B3)* since 2004, *Natura* participates in the highest governance segment—*New Market*—and is present on the basis of the *BM&F Bovespa Corporate Sustainability Index* (ISE) since its creation in 2005. In addition, it is "in the top 20 of the most sustainable companies in the world," according to the *Global 100* ranking of *Corporate Knights* [11]. In 2017, "for the fifth year in a row, has been awarded the *World's Most Ethical Companies* award, which lists the world's most ethical companies" from the *Etisphere Institute*, "a global organization that enhances ethical business practices" [11, 12]. In addition, in 2017 it achieved *Union for Ethical BioTrade (UEBT)* certification, "of 100% of the communities that supply 65 socio-biodiversity supply chains"; uses the GRI—*Global Reporting Initiative*—format since 2001 in its sustainability reports. In 2014 was "the first limited company to become *B Corp*"—a global movement of companies that give equal value to its economic and social-environmental results—and in early 2017 concluded "the process of renewing this certification, valid for two more years". In addition, it linked "sustainable design to traditional and scientific knowledge for product development, in one model that union sustainable design to traditional and scientific knowledge for product development, through an open innovation model". These model involving a network of national and global partners, sharing "traditional knowledge, science and design in the development of new lines" [12, p. 21].

Its business model is composed of four pillars: ethical trade in inputs, sustainable manufacturing, sale by relationships and conscious consumer, with which it seeks to generate value "throughout the network." This model begins with "ethical and fair trade to obtain raw materials, on the one hand, and the transformation of socio-environmental challenges into more inclusive and sustainable business opportunities, on the other." In this sense, the company has developed relationships "with communities in the Amazon region, encouraging productive chains that preserve the forest while at the same time generating resources for traditional communities." Through an "open innovation model, national and global partners share traditional knowledge, science and design in the development of new lines," and there is also a performance of the company "in conjunction with suppliers to reduce the impact" of production "developing the chain of use of recycled materials such as PET and glass." The result appears in more than 80% of plant formulas ("renewable, therefore"), and all the alcohol used is "organic, produced with methods that conserve ecosystems and plant and animal life" [12].

About sustainable manufacturing, the formulas have been vegetated and "recycled packaging" is used. It has "own factories in Brazil and outsourced in Argentina, Mexico, and Colombia." The highlights of this point are: Carbon Neutral Company ten years ago, meaning it reduced and offset "the emissions of the entire chain, 2.8 million tons of CO2 offset by 2016, equivalent to the pollution of 480 thousand car revolutions on Earth"; "83% of the ingredients are of vegetable origin" (renewable). On the conscious consumer, *Natura* encourages "new consumption patterns"—use of refills and correct disposal of packaging—20% of the packages are eco-efficient. In 2016, the total recycled glass used in its perfumery was equivalent to 597,000 bottles of 1 L; "*Natura movement*, a platform that unites volunteers to socio-environmental projects" obtained "more than 50 thousand people benefited in the areas of health, education, culture, sports, and others." *Natura* associates its brands with causes: "*Ekos*: *standing forest*; *Chronos—female empowerment*"; "*I am—smart consumer;* "*Believe to see—Quality education*—non-cosmetic product line whose profit is reverted to education actions—R$ 38 million (US$ 11 million) collected in 2016" [11].

As for business behavior, the guideline is that all decisions seek to balance the three TBL variables.

Thus, sustainability (TBL), including environmental management (EM), is part of the Natura strategy and its OS, a fifth objective, being among the "traditional" competitive priorities. Its competitive operations priorities include *delivery*, *quality*, *innovation,* and *TBL* as order winning factors, and as qualifying factors *cost* and *flexibility*. EM is treated as a competitive priority of operations in the full sense [9] because it influences operational performance and all *decision areas* and is capable of creating a clear competitive advantage. In addition, the sustainability guideline in its business model and CS is outlined with targets and indicators for all areas, including the supply chain, logistics, manufacturing, and *structural and infrastructure decision areas*, as follows. The quotation marks are quotes of company executives.

- **Location**—One hundred percent of the soaps produced by the company are plant-based, which led *Natura* to build its soap factory in Benevides-PA, close to the source of raw materials for Brazilian biodiversity. In this way, it obtains the *oleína* (70% of the formulation), fruit only of region Ecuadorian. The other three factories of the company have an excellent location in Cajamar-SP, thirty minutes from São Paulo-SP, along major highway margins, close to airports and to the main consumer markets of the country.
- **Technology**—From a general point of view, regarding technology, the choice of sustainability has already made when it installed the reactors, the equipment, the production process; that is, these choices do not happen on a daily basis. They are the big choices that later support a well-built floor that only has to work with delivery, term organization etc. In addition, the company develops technologies to help its *EM: environmental* table detailed by product, *environmental impact calculators* and of recyclability of packaging and incorporation of green polyethylene in refill packs.
- **Innovation and New Product Development (NPD)**—This is a key competitive point of the company, due to the market sector where it operates which requires frequent launches of new products. About 30% of the portfolio is renewed each year, with an average of two hundred and thirty new products launched annually in the last three years ([12], p. 21). When launching a product, there are indicators to be achieved of environmental, economic, and social sustainability, and trade-offs occur in this process because it is developed through a multi-step innovation funnel. Products that arrive in a certain stage with consumptions higher than the expected average of water, energy, paper, and cardboard, generating more waste, etc., come back and loop until you get to the planned.
- **Logistics and Supply Chain**—*Natura* has four production plants—three in Cajamar-SP-BR and one in Benevides-PA-BR—that send products to a logistics hub and eight distribution centers in Brazil and six in Latin America, which use technologies advanced. These CDs in turn send the products to 1,084 million of sellers (called of consultants) in Brazil to the "direct sales model" that was

renamed “Sale by Relationship” [12, p. 23, 24]. Working with Brazilian socio-biodiversity adds greater complexity also in logistics, due to the planning need to contemplate harvest periods and times to obtain extracts from the vegetable raw materials, leading to the requirement to maintain regulatory stocks.

- **Personnel Management—**As for the profile worked with employees and in contractings “beyond basic,” *Natura* has been working “very strong” in four behaviors: to pursue the result of the whole, to put the consultant at the center of all decisions, solve constructively and celebrate all the achievements. It was also mentioned “the issue of diversity”—bringing different people “because the belief is that diversity has better solutions,” being that “it has around 8% of the company’s staff with people with some kind of disability,” than required of by Brazilian law. “Pursuing the result of the whole” means a “person who can see the whole, be able to bring about social and environmental economic results that can see the result of the company versus the result of its area.”
- **Quality Management**—All Competitive Priorities of Operations are worked by quality management in balance, although trade-offs occur. The sustainability of quality is sought in sustainability.
  - **Quality Management and Innovation**—“Quality is the voice of customers!” There is an interconnection with the service area bringing input to feed innovation and improvement projects. The quality area monitors, verifies, and prioritizes the main complaints from customers and defines improvement projects to solve the mentioned quality problems. This information is used early in the innovation processes “to work the product on what they are claiming.” At the end of this process, the Industrial Directorate arrives at the product design approved to be manufactured already with a predetermined standard, with specifications and characteristics that should be evaluated in the production process—active of a shampoo, perfume specification, color, etc.
- **Production Planning and Control**—PCP also becomes complex by involving socio-biodiversity, since it requires greater flexibility in production scheduling. The speed of nature’s response cannot be controlled and operates according to the harvests of the species. For all products, there is a definition of minimum production batches. The PCP contributes to the TBL regarding the indicators and goals set by the strategic planning. For plant management, production sequencing impacts on sustainability indicators: larger lots bring fewer stops and washes on the production line, generate less effluent, lower water and energy consumption, and lower costs.
- **Organization—**Aiming at greater focus, in Natura EM and work safety belong to different sectors. And the marketing, sustainability, and innovation areas constitute a vice presidency (VP). The environmental management (EM), in turn, is allocated to the Industrial Directorate that belongs to the other VP (operations and logistics). The attributions are distinct: “Sustainability proposes guidelines and long-term goals, seeks benchmarks, and makes sectoral articulation for topics of interest.” The EM “implements actions on waste and effluents and influences projects of efficiency gains in the use of resources such as energy and water, gener-

ally executed by areas of the industrial management—engineering, maintenance, factories, facilities, etc."

- **Environmental Management**—The achievement of sustainability goals occurs through implementation by the areas. Sustainability has as its role to propose the goals and methodologies and charge the areas and units to make happen what was planned. "Every carbon footprint project has a strong relationship with the strategies." Each area is charged for its performance, and in general, it is the role of the sustainability and environment areas highlight and charge environmental performance.

102.5 Final Considerations

The objective of the research was to verify if the environment can be considered a new competitive priority of operations. A case study was developed, and a theoretical work model was applied in the company *Natura Cosméticos S/A*, recognized for including sustainability in its CS. The results pointed out that, due to this, the company inserted the environment composing its OS together with the traditional competitive priorities (cost, delivery, flexibility, and quality). As a result, this new competitive priority began to be worked in the decision areas of the OS, but together with another competitive priority, innovation, also directed to the differentiation EC.

Therefore, the analysis of the data points in the direction to consider the Environment as a factor of competitive differentiation however associated with Innovation and being part of the Triple Bottom Line approach, becoming a new competitive priority of the Operations.

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Chapter 103
Lessons Learned from Sustainable Value Stream Mapping (Sus-VSM) Application in a Small Enterprise

Mariele Canal Bonfante, João Carlos Espíndola Ferreira, Suélen Fernandes and Henrique Back

Abstract Opportunities and difficulties of sustainable value stream mapping (Sus-VSM) application in a small enterprise were explored as part of the greening production plan. It was noticed a lack in understanding social and environmental sustainability, even in management levels. The flexibility of small companies was noted as a driver to Sus-VSM application.

Keywords Sus-VSM · Small enterprise · Sustainability

103.1 Introduction

In the industrial field, sustainability must consider the creation of products from materials and processes that do not negatively impact nature [13]. Productive processes must conserve energy and resources, being safe for workers and consumers, besides economically viable [19]. A natural way to develop better strategies for sustainable manufacturing is to examine the best practices currently used and how they can be adapted to meet the requirements of sustainability [5]. Lean manufacturing has been largely used in industries and it is based on the identification and elimination of waste [22]. Therefore, the relationship between lean thinking and sustainable manufacturing is an increasing theme in researches [4, 15, 22].

Lean operations meet a wide range of sustainability outcomes as supply monitoring, transparency, workforce treatment, and community engagement [15]. According to Leme et al. [12], it is possible to create value with less environmental impact through the adoption of lean and green manufacturing concepts and tools. Value stream mapping (VSM), introduced by Rother and Shook [17], is one of the most employed lean tools and it was first adapted to sustainability by [3]. EPA [3] added environmental issues to VSM and defined environmental waste as any unnecessary use of resources or substances released into the air, water, or soil that could harm

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human health or the environment, and like other types of waste, do not add value to the customer and represent costs to the company and the society.

Later, other authors extended VSM to the complete concept of sustainability, including social, economic, and environmental issues [8, 18, 9]. Sustainable value stream mapping (Sus-VSM) presented by Faulkner and Badurdeen [5] covers the three aspects of sustainability and was used as reference in this research. The aim of this research is to investigate difficulties and opportunities that small enterprises face in Sus-VSM application, thereby contributing to the knowledge on how to overcome it, and encouraging future researchers to provide suitable tools and methods.

103.2 Methods

In order to conduct the study, a theoretical and an empirical approach were used. Figure 103.1 shows the tree steps followed to accomplish the objective.

In the first step, a systematic literature review was conducted aiming to identify the difficulties pointed out in the literature about VSM applied to sustainability. For that, the tree steps recommended by [10] were followed: planning, execution, and analysis of the review. The QUERY applied to Web of Science and Scopus databases was: (“value stream mapping” and (sustainab* or environment)). Only publications that clearly present VSM applied to sustainability issues were selected, resulting in 13 articles.

In the second step, Sus-VSM was applied in a small Brazilian enterprise producer of flexible packaging. The objective of this step was to provide an overview about practice application of Sus-VSM in a Brazilian context of a small enterprise. The Sus-VSM application followed the methodology of action research, where four steps were followed: plan, act, describe, and evaluate [21]. In the third step, it was attempted to link the difficulties from literature with the ones found during the practical application. This step seeks to guide future researchers to overcome the reported difficulties.

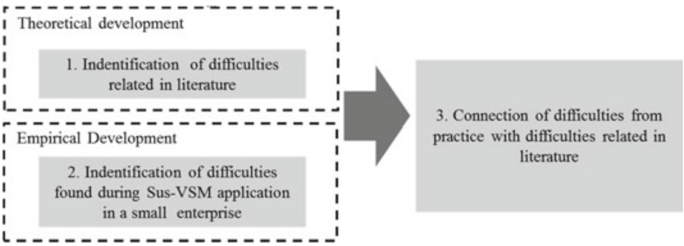

Fig. 103.1 Steps of methodology

103.3 Results

From literature review, it was noticed that most studies apply VSM focusing in the environmental aspect of sustainability [2, 6]. Many have adapted the VSM method by adding metrics concerning use of energy and material resources, such as water and feedstock, in order to reduce costs and, at the same time, reduce environmental impacts [2, 11]. Jarebrant et al. [9] are the only to use VSM exclusively to approach the social aspect. Faulkner and Badurdeen [5] and Brown et al. [1] are the first to present Sus-VSM, covering the three aspects of sustainability. The difficulties reported in the literature are shown in Table 103.1.

Authors point out the need to verify application of methodology to other contexts [7, 16]; Vinodh et al. 2015. Extending the analysis to a whole life-cycle approach is ideal, but information may be sparse and difficult to acquire and sometimes inaccurate [11, 14]. Hartini et al. [7] suggested the building of a sustainable index that can be used in assessing a system's sustainability. Garza-Reyes et al. [6] indicated that their approach could be used in other type of operations, such as logistics and transport, health care, services, among others. As noted by Rosenbaum et al. [16], the approach is limited by the adaptation effort that is required to implement VSM into processes, and results could depend on individual researcher and/or lean coach [9]. Future research may also focus on defining guidelines to determine how interventions should be performed and how future state maps should be approached [18, 20].

Brown et al. [1] verified the application of Sus-VSM in three diferent manufacturing system contexts and noted that the tool brings valuable insights to identify opportunities for sustainability improvements, irrespective of the nature of the system configuration. Adding psychosocial factors of importance to health and well-being as well as improving sustainability indicators in the direction of assessment of the workplace motivation and the development of people and the community in which the company operates (social KPIs) can be seen as future improvements regarding the social aspect [8, 9]

A practical application of Sus-VSM was performed in an enterprise that processes 130 tons of flexible packaging per month and has 80 employees. The main product is the low-pressure polyethylene density packaging, which production line was chosen to be under study. The group involved in the application of the method was: the production manager, a production supervisor, the quality manager, and the researcher. The action steps were followed and the indicators presented in Table 103.2 were monitored.

The current state map was constructed after a month of production monitoring of the following processes: extrusion, printing, lamination, curing rewinding, and packing. The current state map was analyzed, and the main points of waste identified were: chemical hazards, high inventory, long setup time, high variability in the curing time, high material losses, high physical efforts, long processing time, and energy usage for simple coils model. Eight improvement points were identified and prioritized. Figure 103.2 shows the current state of the production and the identification of economic, environmental, and social wastes.

Table 103.1 Bibliometric analysis of studies on the VSM in the context of sustainability

Authors	Aspect	Difficulties
Lai et al. (11)	VSM adapted	Integrating cost, energy, and environmental impacts across a network of manufacturing and logistics operations
		Standard data for the model might vary a lot between sources
		"Globally homogenous market" assumption is limited
Torres and Gati [20]	Environment VSM	Find alternatives after application of the method
Paju et al. [14]	SMM (Sustainable manufacturing mapping)	Environmental and social concerns bring new parameters, making it more difficult to design products and processes
		Data collection could be a bottleneck to assessment methods that take a life-cycle approach
Brown et al. [1]	Sus-VSM	Difficulties in identifying the value stream in job shops, due to complexity of flow; data collection may be time-consuming and sometimes inaccurate; energy or water consumption data by production step may not be available
Faulkner and Badurdeen [5]	Sus-VSM	Definition of metrics and data collection may be difficult in some applications
Sparks and Badurdeen [18]	Sus-VSM for supply chains	The scoring system used to compare the interventions weights metrics equally and not according to importance
Jarebrant, et al. [9]	ErgoVSM	Application is more time-consuming than traditional VSM
Vinodh et al. (2016)	MFV/LCA	Lack of expertise, facilities, and eco-awareness
Cosgrove et al. [2]	Adapted VSM	Some process steps may be external to the factory, thus making it difficult their identification
		Data collection may be limited by points of measurement
		Complexity of products families in the value stream

(continued)

Table 103.1 (continued)

Authors	Aspect	Difficulties
Helleno et al. [8]	Adapted VSM	Data are sparse between sectors of the company, making them more difficult to be collected
Hartini et al. [7]	Adapted VSM	Adapted VSM has not yet considered products entire life cycle
Garza-Reyes et al. [6]	E-VSM	Results are limited to the manufacturing context of this factory, and need to be verified in a diverse context
		Research needs to be extended to external factors of production
Rosenbaum et al. [16]	Adapted VSM	Approach limited by the adaptation effort that is required to implement the VSM into construction processes

Table 103.2 Indicators monitored

Aspect	Indicators
Economic	Lead time (s)
Environmental	Use of energy during the process (kWh) Waste of plastic film during the processes (%)
Social	Physical Load Index (PLI) Environmental risks

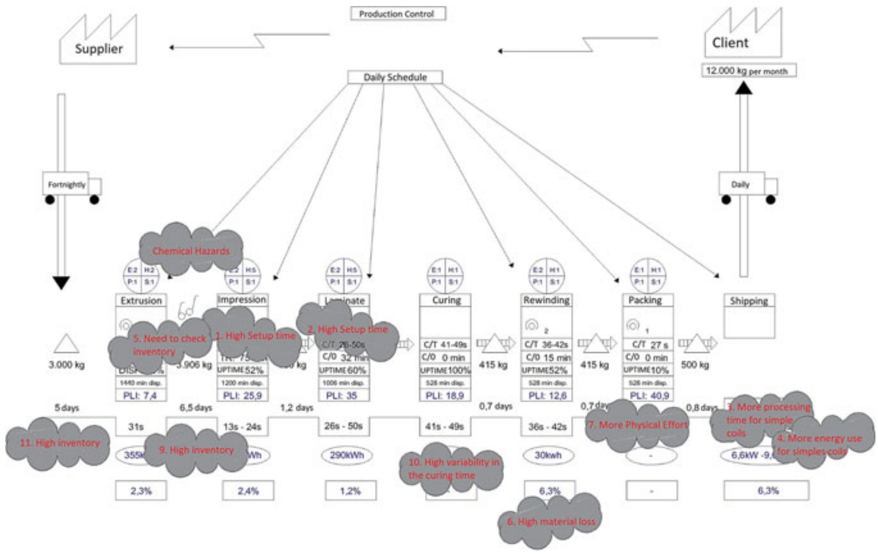

Fig. 103.2 Current state map and waste identification

During Sus-VSM application, difficulties on management and operational level were identified. The first difficulty found was in sensitizing the managers about the relevance of monitoring indicators with no direct financial gains. There was a difficulty in understanding social waste, at the beginning the managers thought it was about obeying the law and, after some explanations, they understood that social waste goes beyond the laws. The first operational difficulty was in defining how to monitor production. Each invoice takes about 8 h and it would be exhaustive to one person to monitor all the process, so it was decided to train the machine operators to take notes during the process.

Another difficulty was in defining the method for monitoring the waste of raw material. Faulkner and Badurdeen [5] recommend monitoring the input and output, and then calculating the waste. It was defined in the practical application that it would be better to monitor directly the waste of plastic film that rests from the process. Monitoring the entrance of painting, solvents, paste, and additions would be very complex and not so significant. For that, weighing machines were used. Measuring the

Table 103.3 Link between practical difficulties and literature related

Difficulties in practical application	Link with literature
Monitoring non-financial indicators Understanding Social waste Availability of employees	Lack of facilities and eco-awareness (Vinodh et al. 2016)
How to monitor a complex production system	Complexity of products families in the value stream [2] Data is sparse between sectors of the company, making them more difficult to be collected [8]
How to measure the waste of material and energy	Definition of metrics and data collection may be difficult in some applications [5] Energy or water consumption data by production step may not be available [1]
How to solve the identified wastes	Find alternatives after applying the method [20]

energy waste was another activity with difficulties; there was no suitable equipment available in the enterprise. Faulkner and Badurdeen [5] recommended monitoring the energy usage during and between the processes; since the energy consumption between processes (i.e., for transportation) was not significant, only the usage of energy during the processes was considered.

The availability of employees to be in charge of Sus-VSM was another difficulty; usually, an employee is responsible for many tasks and monitoring social and environmental indicators was regarded as overwork. The action research took two months, and during this period, some employees left the company, resulting in difficulties in training new employees. Table 103.3 summarizes the practical difficulties and connects with related literature. After the waste identification, there were difficulties to solve the identified problems. The opportunities for applying Sus-VSM in a more efficient way concern in overcoming these difficulties, mainly in training employees about eco-awareness and process monitoring.

103.4 Conclusions

The objective of identifying difficulties and opportunities in Sus-VSM implementation in a small enterprise was accomplished, contributing to the knowledge on how to adopt Sus-VSM in small enterprises. Researchers reported the difficulty to apply the method as being related to the complexity of systems analyzed. Thus, defining a general methodology to be applied at different operational levels and contexts seems to be a common barrier. Thus, future research should verify its generalization. Another concern is the need for specialized personnel, which demands more investments. Data collection, as well as definition of metrics, is widely reported to be time consuming and, sometimes, difficult and inaccurate. Data are usually sparse inside companies and some processes are external, increasing the difficulty to obtain accurate information. Current publications do not specify the size of the enterprise where the study was conducted; this is the first work that focuses on identifying difficulties of small enterprises in applying Sus-VSM.

With action research, it was possible to clarify the practical difficulties in conducting a Sus-VSM application. It was noticed a lack in understanding social and environmental sustainability, and difficulties in fitting the social and environmental measures in the daily operations. The studied enterprise is ISO 9001 certified but does not apply lean thinking and environmental management, which can justify the lack of eco-awareness and difficulties found in measuring and monitoring the processes. Besides these difficulties, it was noticed that the flexibility of a small enterprise is a driver for the implementation; managers made data available and changes in the process were easily made. The opportunities identified in a practical application concerns mainly in providing trained employees with sustainable issues and process monitoring.

Future researches should analyze a wider number of packaging industries in order to get a more complete overview of this process.

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Chapter 104
Green Logistics: A Tertiary Study and a Research Agenda

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Abstract Our work intend to provide a tertiary review of the literature related to green logistics, answering the following research questions: What are the main green logistics reviews? What are their characteristics? What are the objectives of the studies in which researchers are most involved? And what are the main gaps for future research?

Keywords Tertiary review · Green logistics · Sustainable logistics

104.1 Introduction

In recent years, depletion of natural resources and their environmental impact have attracted significant attention from organizations that need to adopt green practices at different stages of their supply chain [9, 15]. The implementation of green practices provides multiple paths for innovation, maintaining a sustainable competitive advantage over competitors with process improvement [18] [9].

Among, the main processes of an organization are the logistics [1]. Therefore, green logistics emerges in the later twentieth century due to the concern with the environment attempting to maximize the net benefits by minimizing the adverse environmental effect of the logistics processes such as handling, packing, warehousing, and transportation [6, 9].

Despite its considerable concern with the environment, green logistics is a multidimensional discipline, which comprises economic, environmental, and social elements; it focuses on actions to minimize harmful effects on the environment and introduces the tools and behaviors that contribute to improving society and its economic level [6]. Thus, paying attention to green logistics not only can decrease the environmental impact of industrial activities but can also be able to increase quality, reliability, performance, energy efficiency, or decrease cost [6].

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In this context, green logistics has become a competitive advantage for organizations [2, 21], as it provides better operations efficiency, improved productivity, and cost savings [21]. As a result, implement green logistics might make enterprises sustainable because sustainability concept in logistics is about delivering profitability for long-term causing the minimum impact on the environmental [5]. Consequently, researches related to green logistics practices are in constant ascension [12]. However, there is no analysis of existing systematic reviews of the literature related to the topic of green logistics. Thus, the objective of the article is to provide a tertiary review of the literature related to green logistics. According to Glock et al. [8], a tertiary review deals with a systematic review of the literature of other secondary studies.

The article has two important contributions: it presents an integrated vision of the different perspectives on green logistics and offers a research agenda that exposes the main current gaps on the subject, through a tertiary bibliographic review.

This paper is organized as follows. Section 104.1 is dedicated to the introduction, where the justification and objectives of the study were delimited. Section 104.2 presents research methodology used in this study. Next, Sect. 104.3 presents the results obtained through the analyses, in addition to the proposed research agenda. Finally, Sect. 104.4 presents the conclusions, limitations, and potential future work.

104.2 Research Methodology

This paper is characterized as a tertiary review of the literature. According to Kitchenham et al. [10] and Glock et al. [8], it is used to analyze the methodology, the results, and the central themes which were addressed in secondary studies of a certain area. In this context, the analysis of this study was based on systematic reviews of the literature related to green logistics. For this, the work was conducted from the eight steps proposed by Thomé et al. [24] to conduct a systematic literature review: (i) planning and formulating the problem; (ii) searching the literature; (iii) data gathering; (iv) quality evaluation;(v) data analysis and synthesis; (vi) interpretation; (vii) presenting results; and (viii) updating the review.

The scope and the research problem are presented in Sect. 104.1 of this article and, based on the existing literature on green logistics, the research questions were formulated: (i) What are the main green logistics reviews and their characteristics? (ii) What are the objectives of the studies in which green logistics researchers are most involved? (iii) What are the main gaps in green logistics that serve as a proposal for future research?

For bibliographic search, the Scopus and Web of Science (WoS) databases were selected because of their range of journals from the main publishers of peer-reviewed articles in Operations Management [24]. To perform the bibliographic search, the term “green logistics” followed by the keywords that define the types of systematic literature review, according to Thomé et al. [24] have been inserted into the search space and can be found in the title, abstract, or keywords of the documents.

The first search returned 160 documents (140 in Scopus and 20 in Web of Science) obtained from the keywords applied to the databases selected for all titles, abstracts, and keywords. The articles were exported to a spreadsheet in which the authors were able to read the titles and abstracts to select the articles that would participate in the research, according to the criteria described below:

- Inclusion criteria: (i) Use of green logistics concepts; (ii) Issues related to green logistics in supply chains.
- Exclusion criteria: (i) The literature review is not the research method (empirical studies, case study, etc.); (ii) Do not directly address green logistics; (iii) Anything other than the English language; (iv) Anything different from article, article in press and conference paper; (v) Papers in biological and health areas; (vi) Duplicated.

The authors evaluated articles with the numbers 0 (documents discarded from the analysis, following the exclusion criteria) and 1 (documents that should certainly participate in the analysis). After this analysis, the final sample of articles to be analyzed was obtained. It is important to emphasize that there was no limitation on periods, covering all years of publications, aiming to reach a maximum number of studies.

Once defined the criteria were applied, from the review by the two authors, the articles that were not in the scope of research were excluded. According to the exclusion criteria, 73 documents were excluded because they did not have the systematic review as a research method; 12 did not directly address green logistics; 5 articles were excluded because they were different from English language; 18 documents were different from article, article in press and conference paper; 34 were papers on biological and health areas and 5 were duplicated.

The Criteria 1 was still stratified in research types, considering the method used. Scopus database were found 32 empirical studies, 18 mathematical models. 8 heuristic applications, 3 panel studies, and 7 surveys. Web of Science database were found 1 empirical study, 3 studies in mathematical modeling, and 1 survey.

As a result, the final sample consists of 13 articles in total, in which they were read individually by each author for content analysis. According to Seuring and Gold et al. [23], content analysis is a method within the empirical social approach and can be applied both quantitatively and qualitatively. In this work, it will be in a qualitative way, in order to describe the results obtained.

From the complete reading of the reviews, a descriptive analysis was carried out to identify the characteristics of the articles, main objectives, and future research proposals. The results were presented according to the synthesis of the data described in Sect. 104.3.

104.3 Results and Discussion

This section presents the characteristics of the revisions, main objectives, and gaps found.

104.3.1 Studies' Characteristics

Table 104.1 summarizes the 13 final articles selected, presenting the authors, year of publication, journals, and area of study.

The first review of the literature was conducted in the year 2012, characterizing green logistics as a relatively new topic for research, which has remained consistent over the years. The constant interest in research in this area can be related to the growing interest of researchers in the best business practices and actions to mitigate the impact of logistics operations on the planet, resulting in a competitive advantage

Table 104.1 Summary of papers

Author	Year	Journal	Area of study
Dekker R. et al.	2012	European Journal of Operational Research	Computer Science
Bajdor P.	2012	Polish Journal of Management Studies	Business and Economics
El-Berishy N. et al.	2012	Conference on Management and Control of Production	Business and Economics
Martinsen U., Huge-Brodin M.	2014	Logistics Research	Transport and Logistics
Lin C. et al.	2014	Expert Systems with Applications	Computer Science
Kumar N. et al.	2015	Conference Paper Archive	Business and Economics
Zhang S. et al.	2015	Engineering Applications of Artificial Intelligence	Computer Science
Pejić V. et al.	2016	Transport Logistics	Transport and Logistics
Lerher T. et al.	2016	International Conference on Industrial Logistics	Transport and Logistics
Frehe V., Teuteberg F.	2017	Management Review Quarterly	Transport and Logistics
Ellram L. M.; Murfield M. L. U.	2017	Transportation	Transport and Logistics
Qaiser, F. H. et al.	2017	Industrial Management & Data Systems	Computer Science
Evangelista P. et al.	2018	Sustainability	Transport and Logistics

Table 104.2 Publications by country

Country	Publications
China	2
Slovenia	2
UK	2
Germany	2
Italy	1
Netherlands	1
Poland	1
Sweden	1
USA	1

for companies over its competitors [3, 9]. In addition, green logistics can be seen as a multidisciplinary topic addressed in journals from different areas of study, there are three major areas in which researchers are more focused, which are transportation and logistics, business and economics, and computer science. The greater emphasis on transport and logistics can be explained by the fact that this area is one of the main drivers of ecosystem imbalances, which 15% of global CO_2 emissions are attributed to it [22].

In addition, the number of publications per country was analyzed (Table 104.2), according to the institution of the first authors of the articles studied, according to Frehe and Teuteberg [7].

Table 104.2 shows that there is a large concentration of publications in continental European countries, 77% of the reviews published in green logistics, while only 15% of publications are from Asia and 8% from the American continent. This result is similar to Ellram and Murfield [4], in which the authors affirm that a great number of researches have been growing in European countries in the last decades as a consequence of strict environmental regulations in the European Union because the block has targets to reduce emissions caused by transport in the coming years.

104.3.2 Studies' Objectives

After the analysis of the 13 selected revisions, five main objectives were identified in which researchers are more involved in the theme of green logistics, as follows:

- Review the current state of the art related to green logistics and propose recommendations for future research;
- Show the interrelationship between green logistics and sustainability;
- Identify the green practices required in the logistics market;
- Identify associations of practices of green logistics with lean logistics;
  Identify how information and communication technology tools are used in green logistics.

Some reviews have been aimed at revising the current state of the art, some focus on broader research related to green logistics, while others seek to review specific problems of green logistics, such as Lin et al. [14], who performed the mapping of the Green Vehicle Routing Problem and Zhang et al. [25] which provide a review in which shows the use of Swarm intelligence algorithms to solve green logistics problems, such as production scheduling, network project construction, and transport problems.

Meanwhile, other reviews aimed at presenting the relationship between green logistics and sustainability and show how important the concept of sustainable development is for the growth of green logistics in the business sector. Although green logistics is concerned only with environmental issues by introducing other elements of the triple bottom line according to Bajdor [1] and El-Berishy et al. [6] can make logistics operations more efficient and sustainable, which can help popularize the term sustainable logistics.

In addition, some studies aimed to identify the main green practices offered and required by the logistics market and identified that there are a small number of publications with this approach. Martinsen and Huge-Brodin [17] and Kumar et al. [9] state that there is a need for research that addresses green logistics practices and their financial impacts.

The reviews that aimed to identify associations between green logistics and lean logistics observed that despite having different goals, they complement each other due to their common focus on waste removal even though they have different perspectives, while green logistics seeks to eliminate waste by identifying inefficient forms of resource use, lean logistics seeks to remove the eight wastes from lean philosophy related to efficient flow. Therefore, Lerher et al. [13] and Pejic et al. [19] argue that there are gaps for future research on how to combine both concepts efficiently without conflict over their primary goals.

Finally, some studies have sought to identify how the information and communication technology tools used in green logistics have practical and academic implications since they are studied and applied in several logistics activities with transportation, handling, and storage, as well as assisting in the decision in companies. The number of researches in the field of green logistics is still considered low, but according to Qaiser et al. [20], the numbers tend to increase, especially in decision support systems, since these systems help logistics managers make decisions not only considering the economic side but also the environmental and social impact of their logistics operations.

104.3.3 Research Agenda

Overall, green logistics has attracted the attention of researchers, organizations, and governments in recent years. Based on the literature and the results of previous analyses, it was possible to identify that the theme is still growing and, therefore, there is still scoping to be explored with new research.

Although the green logistics literature is growing over the years, actual database studies are still scarce. Case study, survey, and action-research studies are significant for literature and, especially, for organizational practices, as they illustrate the extensive and detailed knowledge about the reality of a process, which is challenging with the use of other methods of search. In addition, the results of the researches using these methods can be used as benchmarking by organizations that intend to adopt green practices in their logistics process.

The use of green practices in organizations, mainly in the logistics sector, is usually approached individually by a single company of the supply chain. However, integrating other members to these practices often means better productivity rates, reduction of costs along the chain, increase of competitive advantage, and it is fundamental for the organization to meet the expectations of customers and other stakeholders when operating in a sustainable manner. In this way, future research could address tools or methods for involving all members of the supply chain in the application of green actions in business. According to Mackelprang et al. [16], supply chain integration can be related to the processes, relationships, information technology, infrastructure, operational, tactical, and strategic planning.

Also, based on the analysis of the articles, it was verified that the use of information and communication technology in the context of green logistics comprises researches that address the energy efficiency of cargo transportation mainly due to the increase in CO_2 emissions caused by the sector. Advanced technologies and management information systems are of significant importance in terms of rapidly changing market dynamics, helping in decision making. Thus, the benefits of technological and managerial innovations directly influence the efficiency of an organization's processes and this can happen without any visible effect on CO_2 reduction. In this way, future research may address suggestions of alternatives related to information technology aimed at improving the energy efficiency of the transport sector and the rapid decision making.

In addition, many studies argue that for the business market, the implementation of green practices in logistics is a strategic decision in which it results in a competitive advantage over other competitors. However, the literature on performance measurement after insertion of these practices is still lacking. The importance of indicators is related to the categorization of information to generate necessary decisions, from the measurement of some aspects, such as time, speed, and costs which can be a source of competitive advantage [11]. Thus, future research may address the development of performance indicators, for example, based on CO_2 emissions that can guide the company in the creation of strategies and actions for improvements.

Finally, the implementation of green logistics, besides guaranteeing improvements in the logistics management of the organization, also presents improvements in the relationship with the customer, in the reduction of environmental impacts, in the increase of added value, and in the reduction of operational costs. However, there is still a need for research that clearly emphasizes the relationship of various environmental issues to their financial impact.

104.4 Conclusion

This paper presented a tertiary review of the literature on green logistics, analyzing the secondary studies contained in the Scopus and Web of Science databases on the subject, following the criteria established in the research protocol developed for the construction of the research. The study contributes to the literature from the development of a tertiary study on the subject, which 13 papers were reviewed and analyzed. The analysis of the articles was stratified in year, area, country, journal, and objectives, and a research agenda was also proposed to address the main gaps that can be used for future analyses.

As the main results, the study showed that green logistics is a relatively new and consistent theme and that although transportation and logistics are the main areas addressed in the reviews, the theme is also explored in the areas of business and IT. The article also shows that the number of publications is greater in the European continent and that the subject is multidisciplinary being approached by journals from different areas of concentration.

The analysis of the revisions presented some common objectives, even with the time interval between the works (2012–2018): to review the current state of the art in research related to green logistics and to propose recommendations for future research; show the interrelationship between green logistics and sustainability; identify the green practices required in the logistics market; identify associations of practices of green logistics with lean logistics; identify how the tools of information technology and communication are used in green logistics.

Although the theme of ecological logistics has become consistent over the years, there is still a large area to be explored, addressing the research gaps identified since the year 2012: development of empirical studies; analysis of supply chain integration; analysis of how ICT tools can influence decision making and management of environmental impacts; development of performance indicators; analysis of financial impacts with the insertion of green practices.

Besides the identified gaps, future research may address other databases as this work has been limited to only two (Scopus and Web of Science) and relevant studies elsewhere may have been excluded from the analysis, for example, in the gray literature. Still, future research can address green logistics in the context of sustainability, considering the theme as the environmental aspect of the sustainability tripod or triple bottom line (TBL).

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Chapter 105
Social Lab for Sustainable Logistics: Developing Learning Outcomes in Engineering Education

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Abstract A frequent problem in the education of engineering students refers to recognizing the relevance of learning outcomes beyond curriculum or academic content. This work explores students undertaking learning experiences within a Social Lab setting related to sustainable logistics to increase their appreciation and value of studies in the discipline.

Keywords Sustainable logistics · Social Lab · Engineering education

105.1 Introduction

This work refers to *Logistics and Supply Chain* (LSC) learning within a sustainability context where students often see no relevance in their studies and the impact they have on their career decisions and professional life. Learning might be addressed from a wide variety of aspects, such as the sufficiency of curriculum and contents, the design of learning activities, or how students participate in their learning processes.

The curriculum should encourage academics to look for meaningful and relevant applications and examples beyond textbooks and to consider the personal interests of students [22]. Additionally, the educational activities should promote the participation and interaction of students to engage in the development of their learning outcomes.

This work addresses the relevance of learning through the development of educational experiences by means of versatile and participatory spaces that recreate pertinent learning experiences about contemporary challenges and real-world situations. This refers to incorporating contextual situations and problem solving into purposeful activities to develop specific disciplinary and personal learning outcomes. The relevance of learning is approached in terms of highly important topics for humanity such as those of *sustainability* [24]. Nowadays, an alternative for the intervention of this type of issues is known as a *Social Lab* [13].

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Accordingly, this work proposes an adaptation of a Social Lab into a *learning space* to increase students' learning relevance in logistics and supply chain considering sustainability criteria. This proposition refers to a *Social Lab for Sustainable Logistics,* representing an incremental educational innovation because of the conjunction of ideas across different disciplines.

105.2 The Relevance of Education

Education is still in a state of crisis, because it has failed to respond to changing social needs, lagging behind rather than leading. The current crisis of education has no easy solution but rather calls for an educational reform that understands how students acquire information and convert knowledge into action [6]. Students have difficulty in recognizing the relevance of their studies, which is originated by a dissociation between their acquired knowledge and the requirements they anticipate facing in their future professions or careers [9]. However, this difficulty might result from wider causes, such as the prevailing traditional educational models.

The lack of educational relevance for students is not an isolated or sudden problem at the final stage of studies but generated throughout the educational processes that students carry out from their admission to graduation [8]. According to Gibbons [12], the relevance students give to their studies might be transferable to universities; that is, relevance depends on the ability to generate learning activities suitable for the education of students.

In the current context of globalized economies based on innovation and skills, students require higher education to meet their expectations of finding a job or undertaking appropriate professional activities after finishing their studies [18]. On average, graduates of higher education in countries of the Organization for Economic Cooperation and Development (OECD) develop skills to perform satisfactorily in the labour market. However, there is a significant minority who do not achieve an expected success in the labour market. This brings doubts and concerns about the quality and relevance of the acquired learning outcomes in higher education.

In the teaching literature for logistics and supply chain (LSC), some authors recognize that relevance might be achieved by defining an adequate curriculum, contents, materials, and teaching methods [15, 19]. Others highlight the development of critical thinking and problem-solving skills, the integration of knowledge, and the use of cooperative methods, workshops, gamification, field trips, and active learning [11, 16, 21]. Summarizing, relevance might be addressed in terms of answering *what to teach or learn?* or *how to teach or learn?*

This work emphasizes that the relevance of learning can be strengthened in terms of the engagement of students in their learning activities. That is, the way students are immersed, interact, and conduct their learning with other participants in a learning space within a specific context or situation. This refers to answering *how to teach or learn?* Therefore, the task of this work consists of creating a framework for (i) incorporating pertinent challenging situations into learning spaces and experiences and (ii) the conceptualization and design of purposeful learning spaces and experiences that contribute to the recognition of studies relevance in LSC. Accordingly, a guiding question for this work is proposed: What should be the type of learning space to recreate relevant experiences for students to face contemporary disciplinary challenges in LSC?

105.3 Developing Learning Spaces for Educational Relevance

Learning spaces might be understood as a meaningful way to insert students in the development of disciplinary and personal outcomes [17, 20]. A learning space is commonly referred in terms of physical spaces, such as classrooms or workshop laboratories containing educational resources such as computers, tables, chairs, and boards, among others [23]. However, this also refers to any type of physical, virtual, remote, or hybrid working environment, venue or location in which learning happens in a synchronous or asynchronous way [5]. This work proposes that a learning space consists of a domain of interaction in which instructors, mentors, evaluators, students, and other educational partners relate among themselves with a specific learning purpose, that is, recreating a common set of purposes and objectives, and grounding these onto activities and experiences within a specific structure of roles and resources [10]. This brings attention to the social purposes and interactions among people rather than just the required physical infrastructure or resources.

Accordingly, a learning space requires to (i) defining the educational purpose and objectives to achieve in students; (ii) determining the adequate contents to cover in learning; (iii) selecting the relevant disciplinary and personal learning outcomes or competencies to develop; (iv) defining highly significant situations for experiential learning in which relevant learning can take place; (v) designing learning challenges within relevant situations, incorporating objectives and contents, learning outcomes and activities, and evaluations; (vi) conforming learning spaces for the interaction of participants in relation to learning challenges; and (vii) executing learning experiences in specific situational contexts such that participants produce their learning outcomes.

Therefore, these ideas focus on learning spaces that promote participation for achieving educational purposes, engaging students in learning experiences for problem solving, and developing learning outcomes. An alternative way to work out this type of learning space can be found in *Social Labs* (SL) [13]. However, an adaptation of a Social Lab is required to create an educational space in LSC, which allows creating an incremental innovation for learning in the field as this involves a notion commonly used for different purposes.

105.4 The Social Lab for Sustainable Logistics

A SL is a space for the participation of multiple stakeholders with a focus on the intervention of complex challenges involving a systemic approach [13]. This type of laboratory is commonly used for research or consultancy, addressing social or community problems in relation to, for instance, education, health, well-being, or security issues. A SL focuses on addressing social challenges in specific contexts, providing stable supportive spaces for problem solving and decision making, and offering a set of practices for experimentation [14]. The impact of a SL can be measured in terms of the generation of different types of capital, that is, the case of intellectual, human, or social capital, among others that contribute to the environment, the commons, communities, and investors. A SL addresses challenges in terms of three elements, a social component of participants acting collectively; an experimental set of experiences and sustained efforts to prototype interventions in given contexts; and systemic solutions taking broad views of situations. To address challenges under the SL perspective, problem solving should consider the required resources, the people to address the challenge, and the strategic direction to be taken.

An adaptation of the SL notion as a learning space can contribute to learning relevance by generating engaging experiences that involve the collaboration of participants for discussion, problem solving, and decision making upon highly important, global and broad issues for humanity. One possibility is paying attention to *sustainability* in these terms [24], such that this refers to a product or process that constrains resource consumption and waste generation to an acceptable level, makes a positive contribution to the satisfaction of human needs, and provides enduring economic value to the business enterprise [3]. Sustainability incorporates environmental, social, technical, and economic aspects, at present or future time, and situated in close or distant locations. Nowadays, LSC activities face sustainability challenges related to full asset load and vehicles utilization, disposal and reduction/elimination of waste, reuse, and recycling of resources, carbon footprint and emissions reduction, energy consumption savings, land efficient use, and exploitation, supplies conservation, and integrity and legal compliance [2]. A SL for educational purposes stresses LSC challenges that go beyond technical efficiency and/or economic aspects to consider other aspects of sustainability. This type of SL is proposed in this work as a *Social Lab for Sustainable Logistics (SLSL)*, which involves the integration of LSC and sustainability education into a learning space. Hence, the SLSL results in the interaction of participants recreating learning experiences and developing their learning outcomes, carrying out problem solving in relation to a relevant challenging situation.

Participants in the SLSL play specific roles as stakeholders within the learning space. These roles mainly consist of students, mentors, instructors, evaluators, and other educational partners, interacting among themselves to execute their activities and achieve their learning purposes and objectives. This covers the social element of a SL referring to participants collectively acting.

A methodology is presented in Sect. 105.5 to address learning challenges within the SLSL as the process and systemic elements of a SL. Moreover, a model is presented in Sect. 105.6 covering the notion of sustainability in LSC operations to identify and conceptualize learning challenges and experiences in relevant situations.

The execution of some learning challenges under a SL concept led to the creation of the SLSL at Tecnologico de Monterrey in Mexico City. The challenges covered topics such as *Consumer Preferences in Nanostores, High-Calorie Products Retail, Supply Delivery Disruptions in Supermarkets, and Carbon Footprint Reduction in Supply Deliveries for Department Stores.* These learning challenges recreated experiences about urban logistics and operations retail regarding contemporary issues of LSC in Latin America. The evaluation of the learning relevance impact was positive in terms of the general comments obtained from students; however, a quantitative evaluation is still pending from further learning challenges in terms of outcomes development.

105.5 The SLSL Problem-Solving Methodology

A methodology is presented to define experimental set of experiences and sustained efforts to prototype interventions in learning challenges within the SLSL. This refers to an adaptation of the soft systems methodology (SSM) [7] as a framework for problem solving. SSM provides an interpretative approach, creating a structure for action research, by means of a seven-step intervention that results in a continuous problem-solving learning process. The SSM adaptation, as a SLSL problem-solving methodology, takes an iterative learning cycle perspective, incorporating the identification of participating stakeholders, the inclusion of sustainability criteria, an intervention problem-solving strategy, and selecting problem-solving methods, and tools (see Fig. 105.1). This methodology is divided in two main sections. One section refers to the real world in which the problem situation happens in daily life and peo-

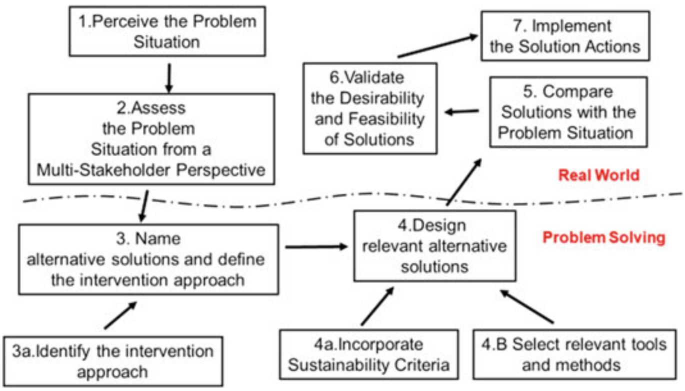

Fig. 105.1 Social lab for sustainable logistics problem-solving intervention methodology

ple reflect and take actions upon, for instance, in terms of SCL operations and their performance results and assessments. The other section is about problem solving, pointing to the use of engineering concepts, tools, and methods. The seven steps of the SLSL problem-solving methodology are described as follows.

Step 1 Perceive the problem situation: Exploring the problem situation involves unveiling the purposes and intentions of the participating stakeholders, their issues of concern and their multidimensional relations with other stakeholders. This involves collecting data and information about key performance indicators, processes, and operations, and their sustainability results and impact. An observational tool for these purposes is the model presented in Sect. 105.6. This step also refers to observing the operational context involved in the situation, that is, identifying and bringing those stakeholders setting context for the situation, those who are accountable for the operation, the potential problem solvers, those implementing possible changes and the beneficiaries. *Step 2 Assess the problem situation from a multi-stakeholder perspective*: This refers to structuring the problem situation, that is, describing the set of problems involved in the situation, establishing their relation and precedence, and their causality and/or dependence, all of this from a multi-perspective view of stakeholders that calls for the exploration of consensus or convergence of their viewpoints.

Step 3 Name alternative solutions and define the intervention approach: This is about identifying the alternative solutions from a specific disciplinary approach for each of the problems making up the problem situation. Each problem intervention demands defining a specific intervention approach. That is, interventions might be guided by problem-solving experts, facilitators using participatory discussions, or stakeholders using self-managed conversations. Finally, this also involves creating an adequate domain of social interaction for problem solving. This includes setting roles, relations, responsibilities, time and resources for undertaking actions. *Step 4 Design relevant alternative solutions*: This involves developing solutions for each problem using problem-solving methods and tools from the selected intervention approach considering sustainability criteria. Step 3 and 4 represent together the design of the problem solution.

Step 5 Compare solutions with the problem situation: This requires comparing the developed solutions with the real-life situation such that differences are identified, and an action plan can be worked out to produce a change in the situation. *Step 6 Validate the desirability and feasibility of solutions*. The proposed changes must be validated such that these are environmentally and socially desirable, and technically and economically feasible. *Step 7 Implement the solution actions*. Undertake the action plan setting the specific roles, activities, resources, time, and follow-up. This refers to creating the contextual change conditions and defining the necessary interactions and conversations to allow people to execute the necessary solution actions.

Therefore, this methodology helps defining the main elements of the SLSL in terms of a learning challenge, the engagement of stakeholders, building up capacity for problem-solving in participants, and creating social spaces for interaction.

105.6 A Model to Study LSC Situations

The SLSL also involves a working model to conceptualize stakeholder's involvement in sustainable LSC situations. That is, (i) to recognize manufacturers, distribution centers, retailers, customers, and transporters, besides materials and information flows in processes. And (ii) to identify the value-delivery impact, performance criteria, and sustainability issues of concern (see Fig. 105.2). This broad perspective covers the fundamental technical and economic aspects for a satisfactory logistic operation performance. However, this also considers value generation and innovation capacity in addition to social responsibility and environmental conservation. All these ideas make up a comprehensive framework for sustainability under the vision of valuable results and dynamic effects in the long term.

The model was created based on Ronald Ballou's model [4] on LSC and the 2030 Agenda for Sustainable Development [24]. This model can be used as a conversational tool (i) to identify relevant learning challenges in daily life situations of sustainable logistics operations and (ii) to guide participants of the SLSL in their observation and reflection upon their issues of concern. Accordingly, this is not a prescriptive model for conceptualizing logistics processes and systems, but a framework to reflect and explore relations between logistics and sustainability.

The model describes stakeholders in a logistics and supply chain setting, such as manufacturers, retailers, distributor centers, and customers who are the origin or destination of information and the physical transportation of products and goods. Sustainability issues and concerns are presented to cover ecological and environmental aspects of carbon footprint, energy saving or waste reduction; human well-being and health; community engagement, equality and social inclusion; responsible consumption and production; value generation and innovation; and the evolution of logistic systems to manifest the proliferation of their dynamic complexity over time. The model also pays attention to the type of results a logistic system produces referring to financial, operational, environmental, and social impacts. Results might be

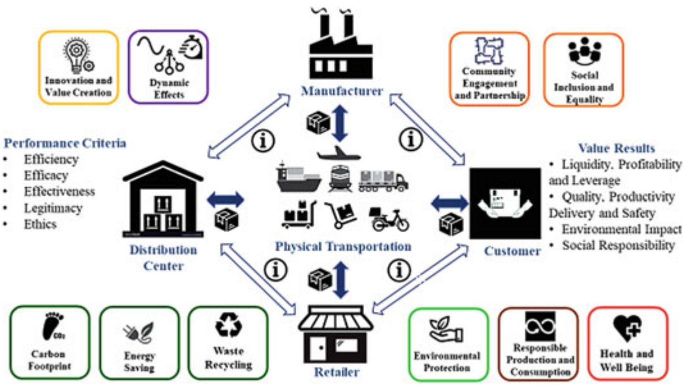

Fig. 105.2 Sustainable logistics and supply chain context

also assessed according to the performance criteria of technical efficiency, ethical behavior, and legitimacy requirements.

The first version of the model was presented and used to guide conversations with professionals of LSC in Puebla, Mexico, to explore their views about this research work over a 3-hour discussion panel this year. These people came from automotive manufacturing, parcel delivery, convenience stores, and food bank organizations. They shared ideas and interpretations upon sustainability in their logistic operations to answer questions about their understanding of sustainability within their LSC strategy and operations, their envisioned implications and the impact they had on their customers. The discussions resulted in obtaining feedback to enrich the model, for instance, technical and financial results, environmental protection, ethical integrity, social responsibility, and people well-being were unanimously considered fundamental for achieving sustainability in the long term. Moreover, innovation and value generation were identified as crucial to create response capacity against contemporary challenges. Accordingly, the model was recommended to be part of the SLSL to identify relevant learning challenges and to identify the necessary learning outcomes student's need for their professional careers.

The SLSL extent of success should be evaluated to include considering the challenge intervention methodology, the working model, and the learning activities for stakeholders' challenge intervention. This must be in terms of measuring the level of achievement students attain in their learning outcomes, the relevance students give to their studies and their opinions upon their experiences. Learning outcome evaluations should measure the progress students make in their ability to collect data, diagnose situations, solve problems, and to envision solutions under realistic constraints as proposed by ABET [1]. This evaluation can compare the initial and final level of average results that individual and group students exhibit in their learning outcomes, which might be related to the advancement of intellectual capital in a SL. Other instruments might be used such as the statistical and correlation analysis of satisfaction surveys and opinion questioners regarding learning relevance and applicability, and their relationship with learning activities and experiences. Results must be analyzed to identify contributions to educational relevance.

105.7 Conclusions

The development and operation of the *Social Lab for Sustainable Logistics* have been a process about a new way of conceptualizing learning in the discipline. This proposes a space for students that recreate learning experiences that increase the recognition of value and pertinence of their studies. This work allowed conceptualizing a learning space within the framework of educational objectives, student outcomes, experiential learning, and learning challenges, and experiences. Additionally, a working method was proposed to guide problem solving within the laboratory as an iterative learning process, incorporating criteria for the intervention of relevant situations from a participatory perspective, and sustainability criteria. This work also presents a model to converse about LSC and sustainability so to identify possible learning challenges and to explore situations with participants. The model sets a specific understanding of logistics and supply chain in terms of sustainability. Therefore, the development of the SLSL as a learning space is proposed to produce relevant learning not only in terms of disciplinary contents, but in relation to pertinent learning experiences immersed in real-life contexts set in authentic educational challenges. Determining the contribution, the SLSL makes to the recognition of learning relevance, demands measuring and assessing student's opinions, the evaluations they make upon their educational experiences and the progression of their learning outcomes in learning challenges. Accordingly, there is still pending work in terms of the quantitative evaluation of results and impact of the SLSL as a learning space, which demands the design of measurement instruments and their implementation in specific learning challenge instances in different contexts and situations, obtaining feedback, and extending the experience to other academics and students for their replication.

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Chapter 106
Analysis of the Application of Additive Manufacturing in the Circular Economy: An Integrative Literature Review

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Abstract Using the integrative literature review to identify and analyze research that links the applications of additive manufacturing with the concept of circular economy, this paper aims to highlight guidelines and parameters that can guide the paths to this integration.

Keywords Additive manufacturing · Circular economy · Integrative literature review

106.1 Introduction

The world's production system traditionally operates in a linear way, with excessive exploitation of raw materials and large accumulation of waste. Analyzing the report of the United Nations Environment Program—UNEP [15], raw material exploration between 1970 and 2010 has grown from 22 billion tonnes annually to 70 billion tonnes per year, four decades, almost tripled. The report says that in this trend the forecast of demand for raw materials by 2050 will be 180 billion tons per year. The accumulation of waste follows the same pattern of growth, World Bank, and UN report on solid waste (2012), describes that in 2012 was generated 1.3 billion tonnes per year of waste, and the expectation for 2025 is 2.2 billion of waste per year. It also predicts that by 2050 there will be an accumulation of waste on the order of 4 billion annually. It is noted that the two parameters are in a large scale of growth which causes harmful effects to the environment and society. The circular economy (CE), based on the maximization of reuse and minimization of resource extraction, plays an important role in the scenario described. In this sense, the additive manufacturing

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(AM) presents itself as productive means that press for the elimination of the waste and maximum use of the raw material. Denoting themselves at the first sight to be in the convergent sense, through an integrative literature review, this study seeks to answer two key questions:

- Is there evidence of AM being adopted in a CE?
- If so, are the applications in line with principles of sustainability?

This study is original and has three contributions: (i) to identify, in the literature, the researches that link two relevant and current topics (AM and CE), (ii) to highlight guidelines and parameters that make it combination possible in order to direct the paths to this integration and (iii) point out gaps that may direct future research.

The rest of the paper is structured as follows: Sect. 106.2 gives an overview of the existing literature of CE and AM. The methodology of this study is introduced in Sect. 106.3. Section 106.4 synthesizes in details the main findings (problems, applications, and research proposals) in the selected reviews. A discussion pointing out the main linked areas is proposed in Sect. 106.5. Section 106.6 summarizes and concludes this paper.

106.2 Background

106.2.1 Circular Economy

"*Inspired by the mechanisms of natural ecosystems, which generate long-term resources in a continuous process of re-absorption and recycling*", Ellen MacArthur Foundation [6] explains that today's "*extract, transform, discard*" economic model is reaching their physical limits. Circular economics is an attractive alternative that seeks to redefine the notion of growth, with a focus on benefits for the whole society. This involves dissociating economic activity from the consumption of finite resources and eliminating waste from the system on principle. Supported by a transition to renewable energy sources, the circular model builds economic, natural, and social capital. Thus, the CE is based on three principles, each one facing various challenges related to resources and systems that the industrial economy faces. These principles are:

- Preserving and increasing natural capital, controlling finite stocks, and balancing flows of renewable resources.
- Optimize the production of resources, circulating products, components, and materials at the highest level of utility all the time, both in the technical and in the biological cycle.
- To promote the effectiveness of the system, revealing the negative externalities, and excluding them from the projects.

In summary, a closed-loop schematic model proposed by CE is based on a scenario in which discarding is replaced by reuse and includes the following diagram: raw materials, design, production remanufacturing, distribution, consumption (use, reuse, and repair), collection, and recycling [7].

106.2.2 Additive Manufacturing

Defined as a "*Process of joining materials for the production of objects from data from a 3D model, usually through stacking layer upon layer, unlike subtractive manufacturing methodologies*" [1], AM, often referred to as 3D printing (3DP) is considered one of the most effective technologies, with the potential to provide the sector with adequate responses to the markets, with a sustainable long-term perspective. Layered manufacturing can lead to structural changes in both the economy and society and can fill the missing link to promote the dissemination of circular systems to realize effective circular economies [3].

Holmström et al. [9] suggest that the unique characteristics of AM produce the following benefits:

- No tooling is required, significantly reducing manufacturing time and production expenses with waste;
- Small production batches and simpler supply chains are viable and economical, with shorter lead times;
- Possibility of rapid change in design and customization of the project;
- Allows the product to be optimized for the function.

Through these benefits, additive manufacturing has recently gained importance with the development of new production technologies that cover a wider range of materials. These new technologies enable new applications in the industry, such as in aerospace, automotive, medical, and prototyping. There is a widespread interest in manufacturing that awaits a shift from linear systems to circular systems, where biological and technical safeguards are possible [16]. In this way, it is possible to identify a convergence of the AM in the context of the CE, emphasizing the importance of this study.

106.3 Methodology

We used an integrative literature review, with a search carried out on April 26, 2018, and used as descriptors the keywords: "*additive manufacturing*" and "*circular economy*" in the Scopus and Web of Science databases.

As Souza et al. [14], the integrative review is the broadest methodological approach to revisions, permitting the inclusion of experimental and non-experimental studies for a complete understanding of the phenomenon under review. It also combines data from the theoretical and empirical literature and incorporates a wide range of purposes: definition of concepts, revision of theories and evidences, and analysis of methodological problems of a particular topic. The broad sample, together with the multiplicity of proposals, should generate a consistent and comprehensible picture of complex concepts, theories, or relevant problems.

In the first step, 15 results were found (Scopus {11}, Web of Science {4}), limited to the English terms, coming from different countries. There was no need for limitations per year, since the results presented were after 2014, therefore within the scope of the approach of the last 5 years.

In the second step, when comparing the results presented in each base, it was verified that the four articles found in Web of Science were repeated in the eleven results of Scopus, thus allowing its exclusion.

Finally, in the third step, two results were excluded due to restricted access, among them an article published in congress and a book ("*3D printing with biomaterials: Towards a sustainable and circular economy*"). Therefore, after considering these inclusion and exclusion criteria, nine articles composed the sample of this research.

All steps in the review process are detailed in the following flowchart (Fig. 106.1).

106.4 Results

Table 106.1 presents a brief summary of the nine articles found, emphasizing their authors, year of publication, and the main information, highlighting the research questions/objectives, context/applications, and findings/implications in each article.

106.5 Discussion

From the analysis of the main results, four areas were highlighted as the major focus of research: biomaterials, design, remanufacturing, and recycling (Fig. 106.2).

Additionally, Despeisse et al. [5] recommend other areas of knowledge as the basis for new research, among which are: education; entrepreneurship; flows of information, and business models. Giurco et al. [8] also stress the importance of sustainable supply chains, taking into account the environmental impacts that arise along the supply chain, so that the consumer can be assured that the product has been acquired responsibly.

Moreover, it is important to emphasize the importance of quantitative and qualitative studies, also suggested by other authors, even based only on each isolated area, as presented in articles A3, A5, and A6. In this way, it is possible to identify the largest gaps and direct knowledge to more centralized issues, seeking new parameters as the basis for the guidelines that integrate additive manufacturing in a circular economy.

It is important to highlight the studies A6 and A8, which present successful applications in three different technologies of the additive manufacture, using biodegrad-

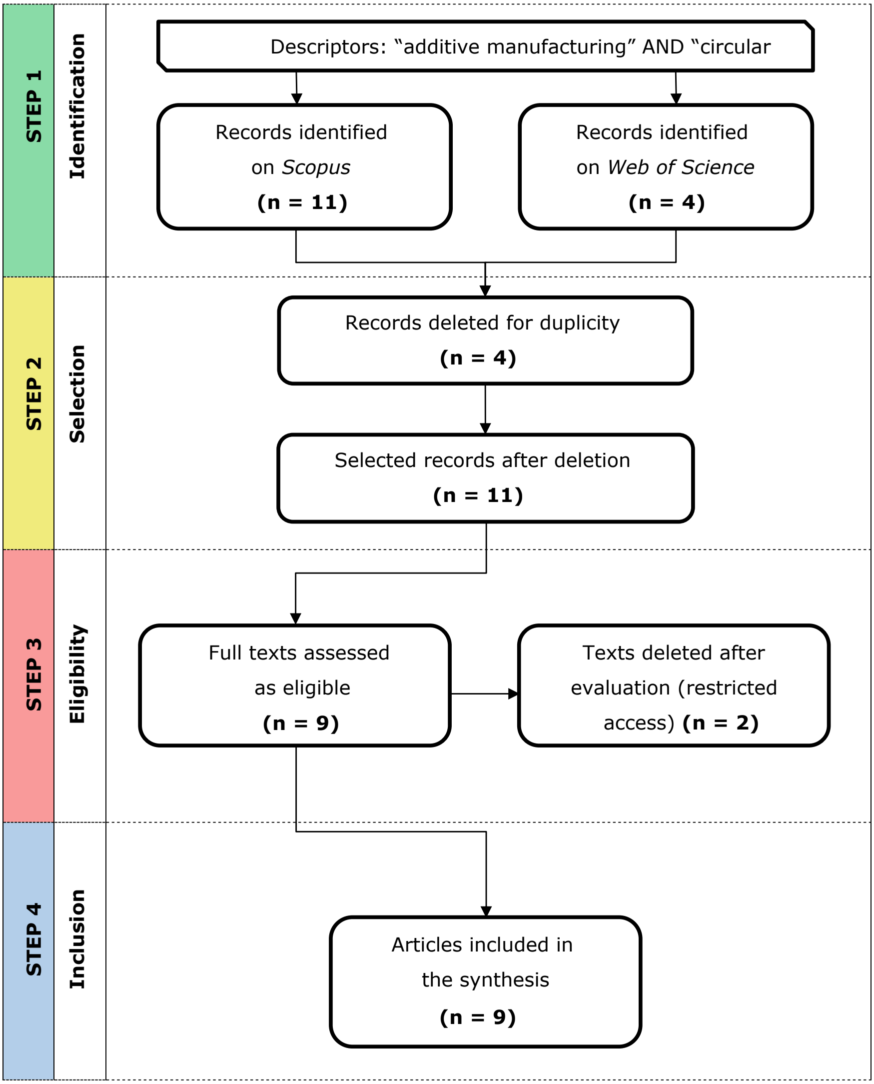

Fig. 106.1 Research steps. *Source* Adapted from Paixão et al. [12] and based on Liberati et al. [11]

able materials in their composition. Another relevant point is the validation of the proposed methods, through case studies, as presented in papers A5 and A9.

The justification for highlighting the four research areas is due to the direct relation with the process and principles of the CE described in Sect. 106.2.1. In addition, most of the authors point out that although additive manufacturing demonstrates concrete potential in some aspects, it is still necessary to understand how it can be a better

Table 106.1 Summary of the studies

Reference—author(s), year/main information
A1—Giurco et al. [8]
Research question(s)/objective(s): it proposes a discussion between two trends in the Australian scenario, about responsible supply chains of minerals and their role in additive manufacturing to metals recycling. **Context/applications**: it explores issues of environmental impacts along the supply chain as well as the social responsibility involved in the processes, based on the Australian context for trends in mining, manufacturing, disposal, collection, and recycling of metals. **Findings/implications**: significant future directions were identified in a prospective scenario and thus defined research agendas based on structured questions at different scales, so that their approach recognizes connections and dependencies between them. Metals such as for steel, gold, and aluminum are used to show the diversity of issues present.
A2—Angioletti et al. [3]
Research question(s)/Objective(s): it investigates how AM can be a better manufacturing solution in terms of efficiency and sustainability in the circular economy scenario **Context/applications**: Research on methodologies and quantitative models to verify how AM technology enables the reuse of materials, tools, and equipment in the framework of the change of linear systems for circular systems. **Findings/implications**: the AM allows the time between the design and the manufacturing, flexibility of shapes, reduction of the use of materials, resulting in a significant reduction in costs and in the amount of resources throughout the life cycle. This reduction in consumption allows the efficient use of the material, optimization of reconfiguration, and circular flows.
A3—Leino et al. [10]
Research question(s)/Objective(s): it identifies the current research results and the state of the art based on the use of AM in order to promote a circular economy, along with the environmental benefits expected in the processes of repair, reform, and remanufacturing of metallic products. **Context/applications**: the processes of repair, reconditioning, and remanufacturing are procedures that aim to return the value of the product during its life cycle. It is expected that AM will be an enabling technology in business models based on the circular economy. **Findings/implications**: further research should be done to identify and verify possible new applications and their technical performance of AM. At the same time, it is essential to ensure that new manufacturing routes reduce environmental impacts compared to conventional manufacturing routes by formulating evaluations from the full life-cycle perspective, rather than focusing only on the manufacturing phase.
A4—Despeisse et al. [5]
Research question(s)/Objective(s): it explores: (1) How can a 3DP-based manufacturing system create a CE? (2) What are the barriers to a circular 3DP economy? **Context/applications**: recycling materials (metal and plastics); due to the digital nature of the manufacturing process, designs can be modified and shared easily. By improving its technical performance, the potential to use 3DP as a direct manufacturing process is being gradually realized in sectors such as aerospace, automotive, construction, pharmaceuticals, and health care where personalization is key. **Findings/implications**: this paper derives a research agenda from a UK perspective by proposing six well-defined research areas—design, supply chains, information flows, entrepreneurship, business models, and education—to understand how 3DP can enable CE.

(continued)

Table 106.1 (continued)

Reference—author(s), year/main information
A5—Alghamdi et al. [2]
Research question(s)/Objective(s): it presents a theoretical framework to reduce stochastic and fuzzy nature of engineering attributes during remanufacturing process planning. **Context/applications**: it proposes a decision-making framework, supported by the quality function deployment (QFD) method, to aid the planning of remanufacturing engineering processes (REP). **Findings/implications**: the conceptual proposed model (also referred to as REP-QFD) can reduce dependence on subjective judgment and consider different stages of the product life cycle.
A6—Voet et al. [17]
Research question(s)/Objective(s): it presents the manufacturing of complex format prototypes from biologically based acrylate photopolymer resins, using a commercial stereolithography (SLA) 3DP. **Context/applications**: due to the ongoing global transition to a circular economy, the availability of renewable raw materials for additive manufacturing is becoming increasingly important. Thus, studies are needed that may facilitate the widespread application of bio-based resins for the manufacture of new sustainable products through stereolithographic 3D printing methods. **Findings/implications**: four different resins with a biologically based content were successfully developed, demonstrating a suitable viscosity in their formulation and were readily polymerizable by the UV laser-based SLA process. Another important factor to note was the increased bonding concentration within the resin, which resulted in more rigid and thermally resilient 3D printed products. High viscosity resins lead to high-resolution prototypes with complex microarchitecture and excellent surface finish, comparable to non-renewable commercial resins.
A7—Clemon and Zohdi [4]
Research question(s)/Objective(s): applications in complex geometries and conduct studies based on the finite element method. **Context/applications**: introduction of a blend of recycled granular materials into 3DP filament materials for less rigorous educational demonstrations; filling for bulk building materials with materials unsuitable for filament, minimizing the impact of transport; determine mixtures of these particulate materials with existing types of road pavement to rebuild road infrastructure; regardless of the end use of the materials, they can be compacted and/or packaged efficiently through milling and grinding and recycled as filler or insulation. **Findings/implications**: this new framework identifies and indicates variational trends from recycled material-enhanced composites that are less costly and faster and the approach could be useful where processes have a distribution of materials and rapid design iteration, enabling a more CE.
A8—Sauerwein and Doubrovski [13]
Research question(s)/Objective(s): it aims to define an approach that supports the search of local materials that are recyclable and suitable as raw material for AM, aiming to serve several product life cycles. **Context/applications**: since AM is pointed out as a potential facilitator for a sustainable process within a CE, even if this type of manufacturing is distributed, the materials used in the production can rarely be purchased locally. Thus, a process was presented to adapt mussel shell residues as input material for AM. **Findings/implications**: besides discussing the steps for developing a method that links locally available materials to AM processes, it presents significant applications to satisfy the circular economy, so that the result obtained is suitable for 3D printing by extrusion of material. It is also important to consider the recyclability of the material during the process, since they can be easily reused, dissolved in water, and reused as material input.

(continued)

Table 106.1 (continued)

Reference—author(s), year/main information
A9—Unruh [16]
Research question(s)/Objective(s): to guide managers and policy-makers through a 3D manufacturing strategy in search of a circular economy. **Context/applications**: the Biosphere Rules, in the context of a biomimetic model of industrial ecological inspiration, as a guideline to bring together the implementation of an EC in a production based on 3D printing. **Findings/implications**: technologies that are capable of guiding an additive manufacturing production system in the circular process are available. The Biosphere Rules can serve as a basis for this path of sustainable production.

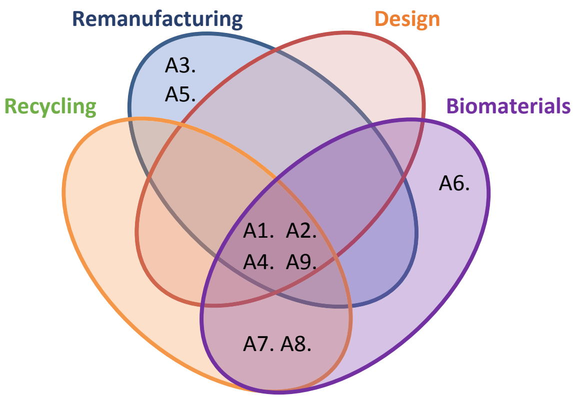

Fig. 106.2 Main links between the topics

alternative to other technologies, allowing an expected sustainable efficiency in the circular economy.

106.6 Conclusions

Although the synthesis of results proves the expected links between additive manufacturing and the concept of circular economy, there is still no consensus that it is a more environmentally sustainable technology than the conventional production system, since other authors point out some features that highlight the technology are leading to the opposite side: the variety of materials used as raw material and excessive production of customized products. Thus, it is necessary to ensure that the environmental impacts arising from the process are mitigated and to focus on the creation of standards that direct these new manufacturing routes toward sustainability.

Therefore, it is proposed that new studies be based on analysis of the entire product life cycle, through research focused both on the intersection of the four highlighted areas and on the individual cases isolated within each one, seeking alternatives to the sustainable scenario. In addition, other areas that make up the circular economy diagram should be highlighted, such as the transportation and supply chain as a whole. Finally, we suggest that new research focus on defining a core of guidelines for each area that are linked with the concept of CE in order to direct the processes of AM to sustainable production practices.

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Chapter 107
Sustainable Purchases in HEI: Sustainability Requirements in Cefet/RJ Public Contracts

Thiago da Silveira Carbonell, Aline Guimarães Monteiro Trigo, José Aires Trigo and Úrsula Maruyama

Abstract The purchase of goods and contracting services costs the public coffers more than 600 billion reais annually. This amount, spent by the federal government, refers to approximately 15% of the Brazilian GDP [16]. Through this scenario, one must analyze the importance of driving the purchasing power of the public sector to obtain goods and services, under the application of sustainability requirements in the generation of environmental improvements. In 2012, a standardization of criteria, guidelines, and practices was established as of the publication of Decree 7,746 to promote sustainable national development in contracting by public administration. Therefore, this qualitative and quantitative study, whose objectives are part of an exploratory research, has the purpose of evaluating the different sustainability requirements employed in the edicts and respective Terms of Reference developed and used by Cefet/RJ for the acquisition of goods and contracting services, in accordance with Normative Instruction 01/2010. The study showed, therefore, that the environmental requirements requested in the bidding instruments were gradually being incorporated during the year 2017; however, it is clear the need to implement changes in order to institutionalize the practice of sustainable public procurement in Cefet/RJ.

Keywords Sustainability requirements · Licitation · Public contracts

107.1 Introdução

Each year, more than 600 billion reais are spent on contracting services and purchasing goods from the federal government, which is approximately 15% of the Brazilian GDP [16]. Through this scenario, one must analyze the importance of driving the purchasing power of the public sector to obtain goods and services, under the application

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of sustainability requirements in the generation of environmental improvements, and promote and stimulate the market that provides goods and services, as well as raising awareness about consumption, the development of new technologies and products with less environmental impact in both production and disposal.

Sustainable requirements or specifications, which also include sustainability criteria, are parameters for the evaluation and comparison of public goods and services according to their environmental, social, and economic impact. The contemplation of these requirements in the bidding instrument can lead to energy efficiency, automation of building lighting, use of drainage water, reuse of wastewater, standardization and specification of sustainable materials, and use of recycled, non-toxic, and biodegradable materials in the administrative and operational activities of the educational institution.

It is expected that the sustainability requirements to be adopted in procurement and sustainable procurement by public institutions also encourage private companies and suppliers to seek and adapt to new standards in order to make processes and goods viable while maintaining product quality, affordable price, and reduced consumption of resources. Therefore, the objectives of this study are:

- To recognize the sustainable requirements and specifications used in the acquisition of goods and contracting services in the Terms of Reference.
- Raising and analyzing the edicts and their respective Terms of Reference for the acquisition of goods and contracting of services used by Cefet/RJ, regarding the presence or not of the sustainability requirements—sustainable criteria or Environmental Sustainability Declaration.
- To stimulate new models of Terms of Reference for acquisition of materials and contracting of services by Cefet/RJ with the presence of sustainable requirements or specifications, according to the Normative Instruction (IN) 01, dated January 19, 2010, which provides criteria environmental sustainability.

This research used a qualitative and quantitative approach. Regarding its nature, it is classified as descriptive, taking the form of exploratory research. The instruments used for data collection correspond to bibliographic research and documentary analysis. It is a case study [11] for conducting a survey of the edicts with their respective Terms of Reference of Cefet/RJ, noting the presence or not of the sustainability requirements—sustainable criteria or Environmental Sustainability Declaration during the acquisition of goods and contracting services.

107.2 Public Administration

The society demands of the public administration the correct use of the resources and services. In order to do so, the rules set forth in Law 8,666, dated June 21, 1993, the Law on Tenders and Contracts, which has undergone some updates to the promotion of sustainable national development (Article 3), must be respected.

> The bidding is intended to ensure compliance with the constitutional principle of isonomy, selection of the most advantageous proposal for the administration and promotion of sustainable national development (emphasis ours) and will be processed and judged in strict accordance with the basic principles of legality, of impersonality, of morality, of equality, of publicity, of administrative probity, of being bound to the convening instrument (Brazilian Law 12,349/2010).

Law 12,349, dated December 15, 2010, establishes that one of the instruments for managing sustainable public contracting is Normative Instruction 01/2010 of the Ministry of Planning, Budget and Management (MPOG), which “provides for sustainability criteria environmental services in the acquisition of goods, contracting services, or works by the federal public administration, autarchic and foundational.”

In the search for services and products, suppliers should be encouraged to offer environmentally responsible products and services at competitive prices or to consider the environmental impacts of delivery services, as well as to seek information on the environmental performance of products and services, accepting the policy of purchase of the organ and stimulating more sustainable alternatives.

Decree 9,178, dated October 23, 2017, amended Decree 7,746, dated October 5, 2012, which established criteria, practices, and guidelines for the participation of companies in hirings carried out by the public administration, with a view to promoting sustainable national development:

> – low impact on natural resources such as flora, fauna, air, soil, and water;
> – preference for materials, technologies, and raw materials of local origin;
> – greater efficiency in the use of natural resources such as water and energy;
> – higher generation of jobs, preferably with local labor;
> – longer useful life and lower cost of maintenance of the good and the work;
> – use of innovations that reduce pressure on natural resources;
> – sustainable origin of natural resources used in goods, services, and works;
> – use of timber and non-timber forest products originating from sustainable forest management or reforestation. (Article 4)
>
> … require in the instrument the call for the acquisition of goods that are made up of renewable, recycled, non-toxic, or biodegradable material, among other sustainability criteria. (Article 5)
>
> *The proof of the requirements presented in the convening instrument may be made by means of a certification issued or recognized by an official public institution or accredited institution or by another means defined in the convening instrument* (*our emphasis*, Article 8).

Among other conditions to be met by the suppliers, there are also the technical qualification requirements established in Article 30 of the Law on Tenders and Contracts, which, in section IV, determines that the supplier must prove “the fulfillment of requirements provided by law special, where appropriate.” The Environmental Sustainability Declaration is a kind of relevant attestation (s)/certificate (s) of the competent bodies (MPOG 2010, Article 6) and must be completed and presented by the bidder together with all the documentation and registration in the Federal Technical Registry of Potentially Pollution or Resource Users Activities of Normative Instruction No. 31, dated December 3, 2009, of IBAMA.

In this sense, it can be said that sustainable public procurement is a formal administrative procedure that contributes to the promotion of sustainable national development by inserting sustainable requirements/criteria in the procurement of goods, contracting of services, and execution of works.

107.2.1 National Guide to Sustainable Acquisitions

Due to the growing importance in the current Brazilian scenario of public procurement or procurement in a sustainable way, it has become necessary to develop manuals or guides that collaborate so that the public manager can incorporate sustainable criteria into the bidding instruments. The selection by the National Sustainable Bidding Guide (NSBG) is due to an important contribution, which is the orientation, presented in a didactic way to the manager, for the execution of sustainable bids, which begins with the evaluation of the need for contracting, planning of public procurement with the inclusion of sustainability criteria, practices and guidelines, to achieve the promotion of sustainable development through public procurement.

Next, based on the National Sustainable Bidding Guide, Table 107.1 was elaborated, which is a summary table of two public goods commonly requested and that present sustainable requirements to be incorporated in the Terms of Reference, when they are acquired by a public administration body, such as Cefet/RJ.

107.3 Cefet/RJ Case Study

The case study seeks to meet the specific objectives proposed from the following stages:

- Step 1: Analyze Terms of Reference elaborated by Cefet/RJ, during 2017 presentation and recognition of sustainable requirements and specification, which is a legal requirement for the promotion of sustainable national development, considering that is also one of the objectives of public contracting (Law 12.349/2010).
- Step 2: Develop a specific subchapter on sustainability in the Terms of Reference for acquisition of materials and contracting services by Cefet/RJ with the presence of sustainable requirements or specifications, according to Normative Instruction—IN 01, dated January 19, 2010, which provides the criteria of environmental sustainability.

Although 75% of the notices issued in 2017 (which total 45 of the 60 notices) still do not meet the sustainability requirements, it is noticed that the requirements are gradually being inserted in the Cefet/RJ notices, in addition to the Environmental Sustainability Declaration, thus revealing the fulfillment of a legal requirement with the incorporation of these two requirements: criteria and Environmental Sustainability Declaration in the future notices (Chart 107.1). Therefore, 15 edicts presented

Table 107.1 Brief presentation of the sustainability requirements of NSBG

Items	Sustainability requirements
General electric appliances	In the acquisition or location: (1) Insert in the REFERENCE TERM—item of description or technical specification of the product: “Only the XXXX product that has the National Energy Conservation Label—ENCE, in class (s) XXXX, according to INMETRO Regulation XXXX, which approves the Conformity Assessment Requirements—RAC of the product and deals with compulsory labeling” In the services: (1) Insert in the REFERENCE TERM—item of obligations of the contractor: “The product XXXX to be used in the execution of the services must have the National Energy Conservation Label—ENCE, in class (s) XXXX, in accordance with INMETRO Directive XXXX, which approves the Conformity Assessment Requirements—RAC of the product and deals with compulsory labeling”
Fluorescent lamps	In any case: (1) Insert in the REFERENCE TERM—item of obligations of the contractor: “The contractor shall arrange for the collection and proper disposal of the fluorescent lamps originating from the contracting, collecting them to the collection system set up by the respective manufacturer, distributor, importer, merchant or reseller, for the purpose of their final environmental disposal”

Source Advocacy of the Union [1]

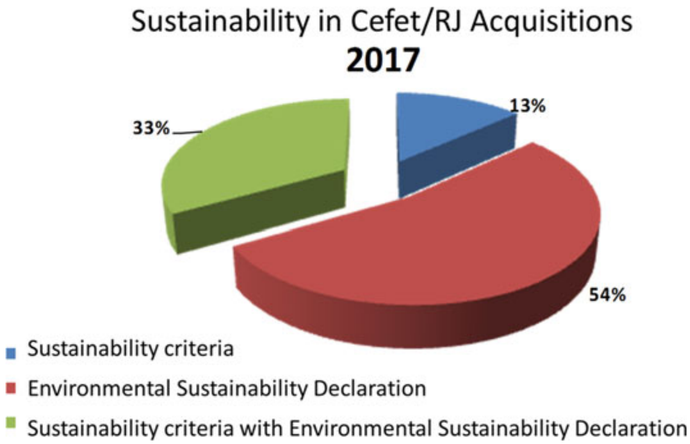


Chart 107.1 Cefet/RJ notices that present the various types of sustainable requirements in 2017. *Source* Own elaboration from Cefet/RJ (2018)

some type of criterion or the Environmental Sustainability Declaration, and about eight notices (54%) had only the presence of the Environmental Sustainability Declaration.

The sustainability criteria are described in chapter III of art. 5 of Normative Instruction 01/2010, of MPOG and presented in the edicts investigated at the Institution of Higher Education, as a subchapter of the Term of Reference, denominated sustainability:

> I - that the goods are constituted, in whole or in part, by recycled, non-toxic, biodegradable material, according to ABNT NBR - 15448-1 and 15448-2;
>
> II - that the environmental requirements for obtaining certification from the National Institute of Metrology, Standardization and Industrial Quality—INMETRO as sustainable products or of less environmental impact in relation to their counterparts are observed;
>
> III - that the goods should preferably be packed in suitable individual packaging with the smallest possible volume, using recyclable materials, in order to ensure maximum
>
> protection during transportation and storage; and
>
> IV - that the goods do not contain hazardous substances in a concentration above that recommended in Restriction of Hazardous Substances (RoHS), such as mercury (Hg), lead (Pb), hexavalent chromium (Cr VI), cadmium (Cd), biphenyl polybromates (PBBs), diphenyl-polybrominated ethers (PBDEs).

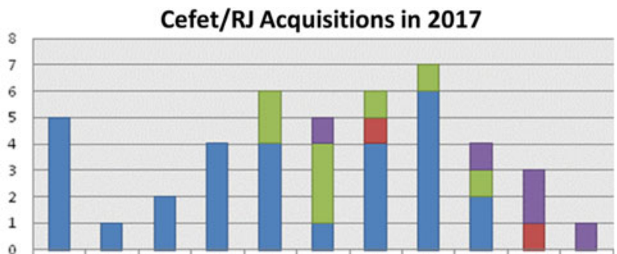
In addition to the criteria, another requirement observed in IN 01/2010 is the certification that is issued by an official public institution or accredited institution or by means of an evaluation that ensures that the good supplied meets the requirements of the public notice in question, also known as Declaration of Environmental Sustainability.

These requirements—sustainability criteria and Environmental Sustainability Declaration—express the concern that the public manager should have in the execution of sustainable bids, which begins in the evaluation of the need for contracting, passing through the planning of public contracting with the inclusion of criteria, practices, and guidelines, which are exemplified in Table 107.1.

The requirements were introduced in the Cefet/RJ notices, mainly after organized meetings, in the beginning of the second half of 2017 (Graph 107.2), by the Strategy Division for Institutional Environmental Sustainability (DISAI) with the Tenders and Contracts Division team (DILCO), in order to cooperate to comply with the legislation on sustainable biddings and to bring greater reliability to the work of public managers during the incorporation of the criteria in the procurement and sustainable biddings of public goods and services, with the use of the National Sustainable Bidding Guide (LNGS).

Therefore, it was possible to diagnose in Graph 107.2, since June, the presence of notices that incorporated not only the Environmental Sustainability Declaration (to Article 170 of CF/1988, to Article 3 of Law 8.666/1993 modified by Law 12,349/2010, Law 12,187/2009, and MPOG/SLTI IN 01/2010), but also the sustainability criteria (MPOG/SLTI IN 01/2010).

Despite the initial work at Cefet/RJ, it is understood the need for planning the insertion of sustainability requirements, highlighting, for a long time, federal institutions of higher education that have been seeking the application of sustainable



	Fev	Mar	Abr	Mai	Jun	Jul	Ago	Set	Out	Nov	Dez
D- Environmental Sustainability declaration and criteria						1			1	2	1
C- Environmental Sustainability declaration					2	3	1	1	1		
B- Environmental Sustainability criteria							1			1	
A- No criteria	5	1	2	4	4	1	4	6	2		

Graph 107.2 Cefet/RJ acquisitions during 2017, based on sustainable criteria. *Source* Own elaboration from Cefet/RJ (2018)

procurement as a rule and no exception in the federal agencies: State University of Pará, Federal University of Espírito Santo, Federal University of Rondônia, Federal Rural University of Bahia, Federal University of São Francisco Valley, Federal Institute of Southern Minas Gerais, University Federal University of Sergipe and Federal University of Santa Maria (CARDOSO 2016).

107.4 Final Considerations

This study evaluated the different sustainability requirements used in the acquisition of goods and contracting services in the edicts and respective Terms of Reference used by Cefet/RJ, in accordance with Normative Instruction 01/2010. The article was able to show the importance of inserting sustainability requirements used in the acquisition of public goods and contracting services to promote sustainable development through public procurement. The presence of the sustainable requirements, cited in the National Sustainable Bidding Guide and exemplified in Table 107.1, to be incorporated in the Terms of Reference, upon its acquisition by a public administration body, such as Cefet/RJ, demonstrates the concern and the socio-environmental responsibility that the organization must have to avoid possible negative impacts.

The sustainability requirements or specifications, which also include the sustainability criteria, are parameters for the evaluation and comparison of public goods and services according to their environmental, social, and economic impact. The contemplation of these requirements in the bidding instrument leads to energy efficiency, automation of building lighting, use of drainage water, reuse of wastewater, standardization and specification of sustainable materials, and use of recycled, non-toxic, and biodegradable materials in administrative and operational activities of the educational institution.

It is hoped that the sustainability criteria to be adopted in procurement and sustainable procurement by public institutions also encourage private companies and suppliers to seek and adapt to new standards in order to make processes and goods viable while maintaining product quality, affordable price, and reduced consumption of resources.

It was possible to verify, through this case study, that the number of edicts with sustainable criteria and Environmental Sustainability Declaration had increased, mainly from June 2018. This analysis also showed changes in the Terms of Reference with subchapter creation on sustainability in order to institutionalize the practice of sustainable procurement, especially after meetings organized at the second half of 2017 by Strategy Division for Institutional Environmental Sustainability (DISAI) with Tenders and Contracts Division team (DILCO).

The environmental requirement included in the notice, contrary to what may appear, not only allows greater efficiency, but also broad and total control by the administration and other bidders that the documents specific to each branch of activity (product/service) will be under the penalties of the law and the disqualification of the bidder.

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Chapter 108
System Infrastructure Maintenance Call: IT Collaboration for Environmental Sustainability in HEI

Matheus Mota, Enoch Silva, Aline Guimarães Monteiro Trigo, Carla Mota and Úrsula Maruyama

Abstract This IT contribution to environmental sustainability in HEI. For opening of occurrences, communication by QR code in each place. A drop-down shows the potential problems. For the maintenance area, it is possible to observe backlog with the call location, based on HTML, PHP, CSS, and also JQuery.

Keywords Sustainability · Green IT · Institutional resource optimization

108.1 Introduction

Human socioeconomic activities are based on a rhythm of incessant and ever-increasing production and consumption, fostering the increase of the productive processes that deplete the resources of nature, necessary for the maintenance of the Earth System. The collapse scenario in which the planet finds itself has as its pillar the industrialized world growth logic, whose practices, already crystallized in society, are manifested through consumption of superfluous, programmed obsolescence, and production of goods that cannot be repaired, as well as the waste and degradation of natural resources. "This logic has already left its legacy to the planet: an environ-

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mental degradation that culminated in the irreversible extinction of species and now threatens the survival of man".

Although this situation shows the lack of a global action, that is, both organized and agile, there are complexities in recognizing environmental crisis impacts on a global scale, since it manifests itself differently, according to each place reality. Thus, to be effective, solutions that aim at sustainability require the ability to articulate solutions that integrate interests, actors, effects, and expectations to minimize disputes over the appropriation of biodiversity resources. This does not mean that solutions applicable from a local perspective should be neglected. They are important because of their contribution to a common environmental awareness, as can be seen in the sustainable practices directed to the management of water resources, recommended in Brazil within the scope of the federal public administration.

During the last few years, sustainability has become a subject discussed extensively in the federal instance, leading to the recent requirement of sustainable use of water. Thus, awareness of resource imminent shortage due to its frequent mismanagement encouraged initiatives in public educational institutions, such as Celso Suckow da Fonseca Federal Center of Technological Education (Cefet-RJ) Maracanã campus.

The survey presented in Conscious Consumption of Water Project parcial report, produced by Division of Strategy for Institutional Environmental Sustainability (DISAI) coordinator, and Strategic Management Department (DIGES) published in April 2018, was an important step for the implementation of new practices related to Cefet/RJ's water-conscious use. The cited document describes the methodology used to Cefet/RJ environmental conditions survey, as well as its results, information extracted from these results, and actions that lead to conscious consumption of water.

It is from this document that the present project was prepared, aspiring both to public awareness of the institution in which it is developed and to the contribution to the formation of a collective environmental action. In addition, it is worth mentioning that it is a result of the participation of Cefet/RJ community, Maracanã campus, in initiatives to promote responsible citizenship from a socioenvironmental perspective.

108.2 Project Description

Due to the size of the institution, Cefet/RJ employees have difficulties communicating structural issues to the responsible sectors. From malfunctions in the bathrooms' hydraulics system to electrical problems and faulty equipment, these events significantly increase the expenditure of several types of institutional resources, be they human—due to recurrence of technical calls (a form of protocol record) requesting repairs with a lack of detailing; material—repeating replacement of parts due to imprecise technical diagnostics; or natural—such as leaks in drinking fountains, faucets, and toilets throughout the campus.

As a strategy of interest for the coordination of the Conscious Water Consumption Project of Cefet/RJ—Maracanã campus, water waste was the object of study of this project and the rationalization of its use, the objective. Thus, in order to reduce it, the initial demand for this project's elaboration was forwarded to the campus' Information Technology Department. The first request was a simple system, capable of simplifying communication between Cefet/RJ's public and campus Major, receiving notifications and directing technical crew (in accordance with problem nature) is one of its assignments. As such, the idea behind the system was that if an individual using a lavatory detected a leak, for an example, they could quickly register the issue, automatically generating a call for the sector responsible for the repairs.

Three were basic characteristics that the system should possess: the first was portability, that is, the possibility of being easily implemented in other institutions; the second, responsiveness, adapting to different devices, from desktops to mobiles; finally, the system should be user friendly, that is, usability ensured through an easy-to-understand interface. Its latest version also requires the user to be at Cefet/RJ and have Internet access, so that they can scan the QR code located in the area by mobile device's camera, redirecting user to its respective URL. Alternatively, it is possible to access it entering the URL in a browser.

Since other requirements related to the structure of the calls were brought forward, increasing the project's scope during its development, selecting the nature of the problem and identifying the location of the occurrence were not enough information in some cases. As a solution, an area to type in a brief description and the possibility of ending photographs were added (Figs. 108.1 and 108.2).

Subsequently, a routine issue was identified: the bureaucratic long procedures also contribute to waste of resources. Therefore, technical assistance could only be attended after it receives validation from campus Major; meanwhile, the waste remains unattended. Thus, to expedite the routine, two additional administrative screens were created, in which all the calls are accounted for and organized, allowing their closure and eventual reopening, if necessary.

108.3 Methodology

The project's development is comprised of two stages, each composed by steps, as described:

Phase I: System Planning and Development

Step 1—Collection of primary data for requirements survey, through an unstructured interview with the coordinator of the project "Conscious Consumption of Water—Campus Maracanã," by Strategic Institutional Environmental Sustainability chief and Systems Development and Maintenance Division chief, in August 2017.
Step 2—Development of the system during the period from August 2017 to January 2018, throughout several iterations and subsequent surveys of new requirements.

Fig. 108.1 Mobile call registering screen

Phase II: Evaluation, Testing and Implementation of the System

Step 1—System evaluation, recognizing possible safety faults to be corrected before the test period, and subsequent repair of the possible faults pointed out.
Step 2—Small-scale test evaluating the interaction of the public with the system, as well as identify possible system characteristics to be changed in order to make the use of the system simpler or more pleasant, and subsequent changes resulting from community feedback.
Step 3—Project submission to the appreciation of campus Major for validation. This stage also aims at the reception of recommendations and criticisms that may lead to the need for possible changes.

Fig. 108.2 Desktop call registering screen

Step 4—Final version implementation of system with full coverage of all environments within project scope, for further data collection related to resources economy.

108.4 Final Considerations

O presente projeto contempla recomendações do documento "Relatório Parcial do Projeto de Consumo Consciente de Água", publicado em Abril de 2018 pela Divisão de Estratégia para Sustentabilidade Ambiental Institucional (DISAI) do CEFET/RJ, que traz uma lista de ações de diversas categorias, que conduzem ao consumo consciente de água. Nele, são atendidos os seguintes pontos:

- Categoria 1 (Capacitação e Sensibilização), ação 6.

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Chapter 109
Ranking Precarious Housing: A MCDA Model Applied in a NGO Case in Brazil

Leonardo Antonio Monteiro Pessôa, Helder Gomes Costa, Marcos Pereira Estellita Lins and Aline Rocha

Abstract This paper presents a model for ranking attendance priority of low-income families, living in precarious housing. It was developed under the Community OR concept, and is based in a MCDA-based approach: the aggregation additive method. The model was applied to support a Brazilian Non-Governmental Organization (NGO).

Keywords MCDA · Precarious housing · NGO

109.1 Introduction

In this chapter, we present an application developed by a Brazilian Non-Governmental Organization (NGO) "Soluções Urbanas" (Urban Solutions) which is used to rank the priority of low-income families of Vital Brazil community in Niterói (Rio de Janeiro state, Brazil) registered under a project called "Arquiteto de Família" (Family Architect), comprehending safety, health, and comfort dimensions.

The paper describes the project achievements, and why such decision aid was needed. The ranking criteria developed by the NGO are formalized under multi-criteria decision analysis (MCDA) light. The formalization is desirable both for highlighting features which can be useful for MCDA research and to provide the NGO with a structured frame of its own method, showing its participants how the ranking is done, with an academic appreciation about its use.

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It is not only a matter of which unit would be attended first, but also of ensuring justice in the allocation of priorities, which is particularly relevant since applicants live in the same community. This is facilitated through the use of a structured methodology. Operations Research (OR) is not easily accessible to organizations or social groups that cannot afford the development of a paid project or hire OR consultants. Nevertheless, a methodological contribution can be obtained when a researcher gets in touch with different real problems that can bring new insights.

This reasoning is already observed in [11] regarding multimethodology applications, but we consider that rationale is also valid for isolationist methodology context, since it presents, at least, new problems and approaches to tackle them. In fact, the criteria structure empirically developed by the NGO is rich and can be used to similar problems. We present some similarities between the developed approach and classical MCDA methods and the developed structure could be a transferable model.

Next section provides a short theory background, covering Community OR, MCDA, and a context background about the project. Section 109.3 describes the MCDA model. A brief discussion and the conclusions are shown in Sect. 109.4.

109.2 Theory Background

Operations Research (OR) roots are related to social well-being [16]. Moreover, it has, as main purpose, the solution or mitigation of real-world problems. Molinero [14] presents a panorama of OR since its war applications, in which the HARD OR (Operations Research quantitative methods) was predominant until the advent of SOFT OR (Operations Research qualitative methods) and COMMUNTY OR (Operations Research for the community). The latter has its beginning with Ackoff [1] in a study focusing on an Afro-American community.

On the other hand, Parry and Mingers [16] argue that OR has its roots not only concerning profit but also related to social well-being. Moreover, they present three major elements for Community OR focus: organizations with limited resources, which represent people interests; enhancing of traditional OR, since it presents new problems or new types of clients; and it must be aimed at a society improvement.

Furthermore, Johnson and Smilowitz [13] present the differences between Community OR and Community-Based OR (CBOR). They show that CBOR has its focus on public sector problems, where which is desirable to optimize is not a proprietary benefit, with three characteristics which distinguish it from other OR areas: focus on humans; • focus on the less favored; and focus on the local. It strives to provide the local community needs.

Johnson [12] argues that CBOR can use both qualitative and quantitative methods. Additionally [17], detail characteristics of non-profit organizations, in which the studied NGO is comprehended, showing that they serve as economic and social forces turning possible to the less favored obtain services which they would not receive otherwise.

The approach developed by the NGO can be considered a quantitative approach, in order to solve a gamma problem (ordering) [19]. The model uses an additive aggregation method, which conceptually can put it near to MADM methods such as SAR and SAW [8, 9] as it uses the weighted sum of evaluations obtained by each alternative for each criterion.

So, mathematically, it can be described as the calculation of a global evaluation for each alternative. Following De Almeida [5] notation, the global evaluation of an alternative a $v(a)$ is:

$$v(a) = \sum_{j=1}^{n} k_j v_j(a) \tag{109.1}$$

where

j	represents the evaluated criterion, among n considered criteria.
$v_j(a)$	represents the evaluation of alternative a under criterion j.
k_j	represents a scaling constant which turns possible to compare the different. Ideally they should not be mere weights and should not be arbitrarily established.

109.2.1 Context Background

The project "Arquiteto de Família" (PAF) was initiated in 2001 and proposed an intervention methodology on houses built under no technical assessment, located into subnormal areas, striving to a requalification of these buildings so as to reduce health (and safety) risks [2, 3]. The first PAF experiment took place in 2002 on "Tavares Bastos" community in Rio de Janeiro, but was unsuccessful because of the lack of funding.

From 2009 until 2016, PAF helped Vital Brazil community in Niterói (Rio de Janeiro state, Brazil), with the support of "Instituto Vital Brazil" (IVB) under a technical partnership. The Vital Brazil community has 460 homes and approximately 2000 residents. And the PAF goals included the attendance of the families by interdisciplinary teams (architects, engineers, and social workers) aiming at design architecture projects; planning the implementation (under compatible budgets and scheduling); and supervising the building execution and helping the family's management.

Figure 109.1 depicts the Vital Brazil community (red) and the location of the Vital Brazil Institute (white).

Since 2009 until 2016, there were community mobilization and organization actions, a community center construction and 170 free professional technical assessments for housing improvement.

It should be noted that, although in possession of architecture projects, most of the participating families did not have the needed materials to carry out the improvements

Fig. 109.1 Instituto Vital Brazil and Vital Brazil Community

proposed by the PAF team. So, a set of strategies, based on Fair Trade (Solidarity Economy), capable of fostering such reforms took place. The first strategy was the "Feira de Trocas Solidárias" (a Community Economic Fair), in 2012, where it was possible to exchange recyclable materials (tetra-pack™) for a special social currency, used to buy construction materials that were donated to the NGO [7]. In fact, at least one project was completely done with only such financial resource [15]. In addition to providing those materials for incremental housing, in over 33 editions, the "Feira de Trocas Solidárias" removed from the nature 176,212 kilos of packaging [18].

Later, PAF provided a microcredit system in order to turn economically viable the implementation. An economic fund was created with resources donated by the American Planning Association. The objective of the fund was available to the families loans of up to R$ 1.200,00 without the formalities of the banks. Between 2013 and 2015, 45 families used interest-free loans and 59 projects were carried out.

In order to rank the habitability conditions of the houses, classifying them regarding risk, the PAF staff developed a set of criteria and indicators, done especially for houses built under no technical assessment. These criteria were organized into a matrix, examined on next section.

109.3 Model

The first issue is: why do they need a structured scheme for the priority of attendance? Indeed it is not only a matter of which unit would be attended first, but also, as the work is done into a local community, where all units are altogether, justify to one poor family that their neighbor shall be attended first, based on an honest and structured method. Following, we present the major elements of the MCDA problem, using [5] framework, so as to methodologically explicit it.

In the problem we are tackling, i.e., describe the approach used by the NGO to rank the priorities, and provide a computational aid to attribute scaling constants, there is just one actor. Decision-maker, client, and specialist are understood as the NGO "Soluções Urbanas" staff, which is responsible for "Arquiteto de Família" project.

Following MCDA terms, alternatives are the elements to be ordered, in the mentioned case, the houses whose attendance priority must be obtained accordingly to selected criteria. The criteria set, created by the NGO, comprehends two partitions, which are represented in the matrix by the columns and rows subsets. In order to better reference them, we propose to name them as follows.

Requirements Group (RG) is the subset that comprises elements corresponding to evaluation dimensions. Its elements are thermic, illumination, acoustic, mobility, revetment, humidity, conservation, dimensioning, and precariousness.

On the other hand, another subset, Project Type (PT), describes the nature of the work needed, whose elements are: architecture, electric, sanitary system, infrastructure, cover, foundations, superstructure, cliff, and base.

The empirically developed model constructs a composition matrix that will describe each criterion accordingly to its RG and its PT, as shown in Table 109.1.

It is noteworthy that some elements in that matrix do not correspond to a valid criterion, so they are represented by zeroes in the previous table. The mentioned partition is a key point for the model, and it was built this way as a structure to establish constraints for the scaling constants.

It is really remarkable how the criteria where organized, which resembles a hierarchical organization for each partition. It could be seen as a similarity to the Analytic Hierarchy Process (AHP) [20] structure. But, at the same time, it interconnects some elements of each partition through the criteria, which can be a similarity to Analytic Network Process (ANP) [22].

In additive aggregation models, the definition of the scaling constants, should be done by establishing the trade-offs among criteria. A good way to do it would be by pairwise comparisons, and some methods use this procedure such as FITradeoff [6] and Paprika [10]. Besides, pairwise evaluation is a key point to AHP [23].

In this case, there is an additional pitfall, due to conjuncture issues, and it is possible that the problem can get dynamic contours, where the scaling constants would have to be reevaluated (e.g., due to material type shortages, as they come also from donations), so a pairwise comparison, in this case, would not be just exhausting, but could became too complicated that could not be performed properly. Just for a simple evaluation, we have 46 criteria. A complete pairwise comparison would take more than 1000 comparisons. However, in fact, there would be much more than that, because some criteria have more than one indicator.

Another issue is related to the possibility of alternative inclusions/exclusions during the process. Some ranking methods are not adequate when you exclude or include alternatives, because they can produce a phenomenon called ranking reversal [21]. In the developed model, it would not occur if the scaling constants are preserved.

Table 109.1 Criteria composition matrix

	Architecture	Electric	Sanitary system	Infrastructure	Cover	Foundations	Superstructure	Cliff	Base
Thermic	TA	TE	0	0	0	0	0	0	0
Illumination	IA	IE	0	0	0	0	0	0	0
Acoustic	0	AE	0	0	0	0	0	0	0
Mobility	MA	ME	MH	MI	MC	0	0	0	0
Revetment	RA	RE	RH	RI	RC	0	0	0	0
Humidity	UA	UE	UH	UI	UC	0	0	0	0
Conservation	CA	CE	CH	CI	CC	CF	CS	CEn	0
Dimensioning	DA	DE	DH	DI	DC	DF	DS	DEn	DB
Precariousness	PA	PE	PH	PI	PC	PF	PS	PEn	PB

Since there are several alternatives, it is important to evaluate them quickly and consistently, so the NGO produced a scale pattern to preserve a standard of evaluations. That permits different people performing the evaluations in different locations at the same time and maintaining consistency. Table 109.2 presents the indicators' scale for criterion Thermic-Architecture (TA). Each indicator is evaluated on a discrete scale ranging from 0 to 2.

Figure 109.2 depicts a conceptual map of the problem.

The indicators are coherent, since there is always greater evaluation according to the more critical elements are present, and the same philosophy is used for all 46

Table 109.2 Thermic-architecture indicators

Indicator	0	1	2
Existence of room without window	All rooms have window	Its bathroom does not have window	There is bedroom, living room, or kitchen without window
Cross-ventilation	It has cross-ventilation in bedrooms and kitchen	It has cross-ventilation in rooms or living room or kitchen	All rooms have no cross-ventilation
Roof characteristics (roof is made from fibrocement and/or crawlspace or slab has no cover)	Coverage allows cross-ventilation	The roof is unlined or it has no roof slab (roof > 2.6 m)	Roof average height is under 2.6 m
Existence of a north face window without horizontal protection	It does not has north face window or it has north face window with horizontal protection	It has a partial north face window with protection (horizontal)	It has a north face window without horizontal protection
Existence of a north face window without horizontal protection	It does not has north face window or it has north face window with horizontal protection	It has a partial north face window with protection (horizontal)	It has a north face window without horizontal protection
Existence of a west-facing window without protection/shade in the rooms	It has not west-facing window or west-facing window has protection	It has face west window protection/partial shade	It has unprotected face west window/no partial shade
Existence of insufficient size spans from floor to ceiling	It has adequate living rooms and kitchen	It has bedrooms, living room, or kitchen with low span	It has insufficient span for bedrooms, kitchen, or living room
Air conditioning or ventilator requirements	There is no need	Yes, only on very hot days	Yes, most of the year

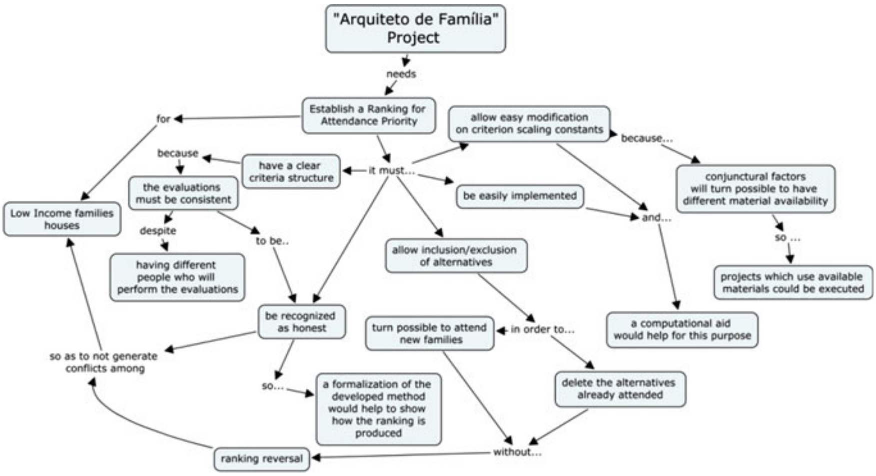

Fig. 109.2 Conceptual map

criteria. So the alternatives with greater overall evaluation present a higher attendance priority. There is, also, a concern to build the scale in a clear manner, so different analysts will be able to perform consistent evaluations. In a first analysis, it can be argued that the method used by the NGO is just an additive aggregation method and it would have a justifiable reason because there are possible inclusions/exclusions and besides, a pairwise comparison among many alternatives would be too complex to be manageable.

On the other hand, it also can be argued that the criteria structure have some similarities with an Analytic Hierarchy Process, since the criteria are grouped into partitions and also are composed by one or more indicators. But it also has similarities with the ANP method, because the criteria are not only linked to only one partition, so there is an interconnection of different partitions linking the criteria in a mesh.

But, when it comes to defining the different criteria scaling constants, the process takes an alternative path, putting it away from AHP and ANP. The method empirically developed by NGO uses the partitions in order to distribute the scaling constants among all criteria, using constraints to perform it. So, the trade-offs among partition elements are performed by this proxy.

It also must be highlighted that the people who developed it did not have any formal basis on linear programming. In spite of that, we can see that the scaling constant definition is based on a distribution of a total of 124 points among all criteria, using the aforementioned constraints for elements of RG and PT partitions (Table 109.3).

On the other hand, the process was done manually, without any decision aid support, and the scaling constants used were presented on Table 109.4.

Table 109.3 Constraint limits of the scaling constants

	Architecture	Electric	Sanitary system	Infrastructure	Cover	Foundations	Superstructure	Cliff	Base	Limit
Thermic	TA	TE	0	0	0	0	0	0	0	**11**
Illumination	IA	IE	0	0	0	0	0	0	0	**12**
Acoustic	0	AE	0	0	0	0	0	0	0	**3**
Mobility	MA	ME	MH	MI	MC	0	0	0	0	**15**
Revetment	RA	RE	RH	RI	RC	0	0	0	0	**15**
Humidity	UA	UE	UH	UI	UC	0	0	0	0	**15**
Conservation	CA	CE	CH	CI	CC	CF	CS	CEn	0	**8**
Dimensioning	DA	DE	DH	DI	DC	DF	DS	DEn	DB	**18**
Precariousness	PA	PE	PH	PI	PC	PF	PS	PEn	PB	**27**
Limits	**30**	**26**	**15**	**15**	**15**	**6**	**6**	**5**	**6**	**124**

Table 109.4 Scaling constants

	Architecture	Electric	Sanitary system	Infrastructure	Cover	Foundations	Superstructure	Cliff	Base	Limit
Thermic	9	2	0	0	0	0	0	0	0	**11**
Illumination	6	6	0	0	0	0	0	0	0	**12**
Acoustic	0	3	0	0	0	0	0	0	0	**3**
Mobility	3	3	3	3	3	0	0	0	0	**15**
Revetment	3	3	3	3	3	0	0	0	0	**15**
Humidity	3	3	3	3	3	0	0	0	0	**15**
Conservation	1	1	1	1	1	1	1	1	0	**8**
Dimensioning	2	2	2	2	2	2	2	2	2	**18**
Precariousness	3	3	3	3	3	3	3	3	3	**27**
Limits	**30**	**26**	**15**	**15**	**15**	**6**	**6**	**5**	**6**	**124**

109.4 Discussion and Conclusion

The approach was not carried out by MCDA experts but, as shown, it has some similarities with sophisticated methods (e.g., using an AHP hierarchy structure of criteria, it presents an interconnected structure of criteria as ANP, and uses constraints to define the scaling constants as FITradeoff and PAPRIKA). The way the developed approach presents a dual partition to organize the criteria is a useful perspective and can be further explored and used to different problems. Despite its simplicity, and imperfections (e.g., the scaling constants are not based in a pairwise comparison), it achieves the intended purpose satisfactorily.

As noted by Box and Draper [4]: “Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful.” So it reinforces the Community OR argument of the benefit OR can obtain through searching for new clients and new problems.

The paper formalizes an empirical method developed by the NGO “Soluções Urbanas” used to evaluate and prioritize the attendance of family houses owned by low-income families, for the project “Arquiteto de Família,” in a Brazilian local community. The formal description helped the NGO staff to reduce disputes regarding the ranking among these families. During the work, the facilitators helped to build a database and automated global evaluation support, which reduced the time spent in order to rank the alternatives.

This work is comprehended in a university extension principle, producing a real impact from academic knowledge. It presents similarities of the developed approach and MCDA methods, which can produce further extensions. A methodological contribution is presented, regarding a dual partition criteria structure, which is an unusual feature and helps to establish scaling constants through a mesh of constraints. Therefore, it also represents an academic knowledge gain from this real application study.

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Chapter 110
Interface Between Industry 4.0 and Sustainability: A Systematic Review

Lucas Conde Stocco and Luciana Oranges Cezarino

Abstract This paper explores the relationship between the concepts of industry 4.0 and sustainability as a contribution to the development of more sustainable production systems. A systematic review of literature shows the tendency of expansion of this research field as well as integration between sustainability and industry 4.0 emerging technologies.

Keywords Cleaner production · Smart manufacturing · Smart factories

110.1 Introduction

Economic development through the strengthening of the industrial sector and the consequent exploitation of natural resources has led to the greater concern of both governments and society in the search for new ways of achieving sustainable development. For sustainable development to be achieved, it is necessary that all the stakeholders involved contribute to the transformation of the processes involved along the productive chains. In this way, we can understand sustainable development as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs [3]. The central role that businesses must take on as they have to seek greater cooperation with their suppliers, customers, and other stakeholders [6] is directly linked to how new sustainable business models generate positive impacts and reduce negatives to the environment and society that contribute to the solution of an environmental or social problem [15].

The technological advance made possible improvements in the production process through the integration of intelligent and automated mechanisms in the industrial environment. A new perspective for the business world is brought with the advent of Industry 4.0, which is based on the establishment of intelligent factories through network used between devices that streamline production. These new spaces can be interpreted as cyber-physical systems (CBS) that operate in a self-organized and

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decentralized way, because they use connected devices and sensors that can influence physical processes [15]. Through the use of some mechanisms such as cloud computing, big data analytics, Internet of Things (IoT), augmented reality, and vertical and horizontal integration of processes [17, 19], there may be greater integration among stakeholders, which makes innovative business possible along the value chain.

Industry 4.0 and sustainability can be seen as trends in production systems [8], which show the relevance of the theme to the planning of a systematic review of this research field. The papers developed in this theme often point to more technical sides, considering only one and not all dimensions of the triple bottom line [12] mainly the environmental dimension [4]. Therefore, it is evident the need to analyze how the new productive strategies enabled by these technological advances from the Industry 4.0 movement, contribute to the adoption of practices by the organizations that lead to economic, social and environmental sustainability.

The aim of this paper is to analyze the trends of scientific production through a systematic review to ascertain the interface between the concepts of Industry 4.0 and sustainability. For that, a bibliometric survey was made on the Scopus platform of articles that cited these two terms. As a result, a certain level of integration between concepts through the use of new technologies and greater digitalization and interconnection of industrial processes, contributing to the development of the three dimensions of sustainability can be seen.

110.2 Industry 4.0 and Sustainability

Industrial processes have changed over time and today one can observe the way in which technology is present in all production systems. More specifically, the interior of the industries has been an environment conducive to a series of changes that have been taking place from the adoption of more integrated systems through the available technologies. This movement leads to a series of sustainable manufacturing possibilities from the use of these technologies [15]. Systems such as Internet of Things (IoT), cyber-physical system (CPS) extend production efficiency and flexibility [10] as well as more efficient allocation of resources such as materials, water, energy, and products from sharing between agents in the production chain [8].

The work of Stock and Seliger [15] contributes to this field of analysis by clearly stating the possibilities of contribution of Industry 4.0 to more sustainable manufactures from the macro-perspectives as those related to new business models and creation networks of value, as well as those related to micro-perspective at organizational level, related to equipment, human factor, organization, process and product, as shown in Table 110.1.

Lom et al. [11] present how the concepts of Internet of Things (IoT), Internet of Energy (IoE), and Internet of Services (IoS) contribute to the connection between the concept of Smart cities and Industry 4.0, leading to the development of intelligent and integrated logistics system that lead to greater operational efficiency, demand orientation, and sustainable development of society. This gain in operational efficiency

Table 110.1 Sustainable manufacturing opportunities from a macro and micro-perspective

Opportunities of sustainable manufacturing for the macro-perspective	
Business models	In Industry 4.0, new evolving business models are highly driven by the use of smart data for offering new services. This development has to be exploited for anchoring new sustainable business models. Sustainable business models significantly create positive or reduce negative impacts for the environment or society or they can even fundamentally contribute to solving an environmental or social problem
Value creation networks	The cross-linking of value creation networks in Industry 4.0 offers new opportunities for realizing closed-loop product life cycles and industrial symbiosis. It allows the efficient coordination of the product, material, energy, and water flows throughout the product life cycles as well as between different factories
Opportunities of sustainable manufacturing for the micro-perspective	
Equipment	The manufacturing equipment in factories often is a capital good with a long use phase of up to 20 or more years. Retrofitting enables an easy and cost-efficient way of upgrading existing manufacturing equipment with sensor and actuator systems as well as with the related control logics in order to overcome the heterogeneity of equipment in factories. Retrofitting can thus be used as an approach for realizing a CPS throughout a value creation module, such as a factory, with already existing manufacturing equipment
Human	Humans will still be the organizers of value creation in Industry 4.0. Three different sustainable approaches can be used for coping with the social challenge in Industry 4.0. Increasing the training efficiency of workers by combining new ICT technologies. Increasing the intrinsic motivation and fostering creativity by establishing new CPS-based approaches of work organization and design. Increasing the extrinsic motivation by implementing individual incentive systems for the worker
Organization	A sustainable-oriented decentralized organization in a smart factory focuses on the efficient allocation of products, materials, energy, and water by taking into account the dynamic constraints of the CPS
Process	The sustainable design of processes addresses the holistic resource efficiency approach of Industry 4.0 by designing appropriate manufacturing process chains or by using new technologies such as internally cooled tools
Product	The approach for the sustainable design of products in Industry 4.0 focuses on the realization of closed-loop life cycles for products by enabling the reuse and remanufacturing of the specific product or by applying cradle-to-cradle principles

Source Stock and Seliger [15]

and the creation of an intelligent logistics network may incur new organizational structures and business models that adapt more rapidly to changing environmental conditions [13]. Yue et al. [20] show that cyber-physical system technology will help these new businesses to meet customers' demand from the monitoring of each part of production through real-time logistics for product delivery and complete customer service.

It should be considered not only how these technologies operate or are used, but also how the principles developed by Industry 4.0 can lead organizations to sustainable operations. The principles of interoperability, decentralization, virtualization, real-time capability, modularity, and service orientation [5, 11] enable practical organizations to contribute to new approaches such as sustainable products through closed-loop life cycles and use of identification mechanisms in order to ensure a better quality of customer service [4].

Since these new technologies are implanted in the organization, it is necessary that workers will be able to operate the devices and have the capability to interact with the new reality of the organizational environment. For the production area that requires labor-intensive flexible deployment of workers will play an increasingly important role in thinking of responsive supply chains and self-regulated material cycle, which makes it necessary to adjust the capabilities of these workers [2]. These new requirements of worker's capacities cause new areas to be opened up as Internet of Things (IoT) specific jobs as well as the creation of technical assistance spaces to release employees from routine work [10]. The new educational dynamics such as serious games contribute to the specialization of this workforce either at a tactical, strategic, or operational level, from the development of an organizational reality in a virtual environment [5].

110.3 Methodology

The approach used for this study was the bibliometric survey with a subsequent systematic review of the content found in the Scopus platform when considering works that seek to understand possible contributions of the Industry 4.0 to sustainability. The bibliographic study is thus justified because it is a method by which one can understand the development of discipline by counting and analyzing the various facets of written communication [14]. Another factor that explains the use of bibliometrics is related to its contribution to analyze the trends and growth of knowledge and of certain areas and the emergence of new themes [18] as well as to understand the production indexes and their dissemination [1].

The systematic review as a research method allows the researcher to map and evaluate the field of knowledge when defining a research proposal which contributes to the development of a given area [16]. Thus, by clearly defining a research question, the researcher can find relevant studies and present the results found [9]. Based on this reasoning, the study was structured from the considerations of Tranfield et al. [16]

according to which a systematic review can be carried out in three stages: planning the review, conducting a review, and reporting and dissemination.

Initially, exploratory research was done on the Scopus platform to observe the publications on the theme. Scopus appears as a significant search tool for this type of research since it comprises a wide range of journals and scientific production worldwide having more than 5000 publishers and approximately 69 million records from journals, books and book series, conference proceedings, and trade publications [7].

It was defined for all the searches carried out in the platform that would be considered only papers that contained Document Type "conference paper" and "article" because they have greater ease of access to the content for analysis. For this research were considered papers published in "journals" and "conference proceedings".

110.4 Results

From the search by applying these job classification steps, the term "Industry 4.0" returned a number of 2669 jobs. Because it is a global trend and contributes to the dynamization of industrial production processes, and a second search was made that related the terms "Industry 4.0" and "Manufact*" to observe this specific field, thus returning 1286 jobs. However, because the objective of this work is to understand the interface between the terms Industry 4.0 and sustainability, a search was made to highlight the contribution of this work to the scientific field and observation of trends in this field. In this way, the search for the terms "Industry 4.0" and "Sustainab*" in Article Title, Abstract and Keywords, considering the research limitation tools mentioned above, returned a number of 141 documents.

Publications covering the concepts of Industry 4.0 and sustainability started in 2014. The period 2014–2018 shows a significant evolution in the number of publications. In 2014, three papers initiated this new research trend. The total number of annual publications increased significantly from three works in 2014 to six in 2015, 11 in 2016, and 55 in 2017. If we consider the year 2018 the number of publications up to the conclusion of this research had 66 publications, however it is likely that the number of publications will increase by the end of the year.

For this research, from the terms used were considered all subjects areas of which the most significant in number of works were engineering (97), computer science (57), and management and business (28). Figure 110.1 shows the list of publications by area. It is an observed predominance of works in the areas of engineering (33.2%), computer science (19.5%), and business and management (9.6%). The use of published works in all areas is justified since the phenomenon of Industry 4.0 comprises a series of changes in all research fields, as it involves the development and application of technologies that contribute to dynamize activities in various areas.

The number of papers published by country of origins shows that Germany is the most relevant country with 22 papers, followed by Italy with 11 and China with 6. The institutions with the largest number of publications are Politecnico de Milano (3),

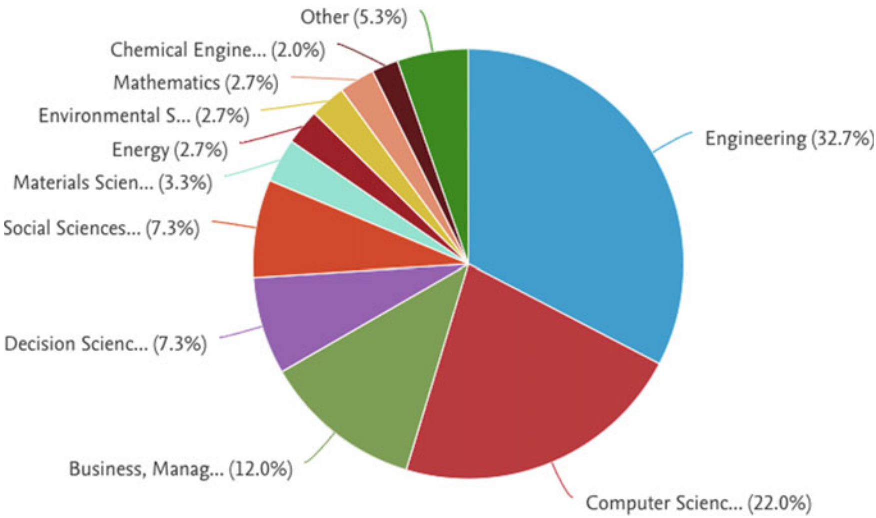

Fig. 110.1 Documents by subject area. *Source* Scopus

Universitat degli Studi di Modena and Reggio Emilia (2), and Technical University of Berlin (2).

Another significant observation is citations analysis that allows the researcher to identify and describe a series of standards in the production of scientific knowledge when surveying the most cited authors, the type of document most used, the average age of the literature used, the most cited journals, among other factors [1]. Table 110.2 shows the 10 most cited works. Because it is a new field of research development, the published works present a not so high number of citations. With the development of new researches and strengthening of this thematic area, the number of citations tends to increase, especially considering that the total number of publications had a significant increase and presents a trend of continuity of this growth, as explained previously.

Keyword analysis is another factor that contributes to drawing perspectives for the development of researches. Thus, after observing the main research trends developed, the number of publications based on geographic and institutional location, it is possible to observe which are the main keywords used in published works that make the relationship between the two terms. For the definition of the keywords for analysis, those used as a search term in the Scopus platform were excluded, namely, the terms Industry 4.0 and sustainability or sustainable. This grouping allows observing the share of published works. Table 110.3 shows that, despite the fact that there are studies that relate the terms Industry 4.0 and sustainability, the keywords used show a little predominance of terms related to sustainability. Most of these words are related to the technologies employed by manufacturing industries such as manufacture (17%), Internet of Things (16%) and big data (12%).

Table 110.2 Most cited articles

Title	Citations	Authors	Year	Journal/conference
Smart factories in Industry 4.0: a review of the concept and of energy management approached in production based on the Internet of Things paradigm	107	Shrouf, F., Ordieres, J., Miragliotta, G.	2014	IEEE International Conference on Industrial Engineering and Engineering Management
Opportunities of sustainable manufacturing in Industry 4.0	99	Stock, T., Seliger, G.	2016	Procedia CIRP
Cloud-assisted industrial cyber-physical systems: an insight	35	Yue, X., Cai, H., Yan, H., Zou, C., Zhou, K.	2015	Microprocessors and Microsystems
Industry 4.0 as a part of smart cities	19	Lom, M., Pribyl, O., Svitek, M.	2016	2016 Smart Cities Symposium Prague, SCSP 2016
Sustainable business models and structures for Industry 4.0	19	Prause, G.	2015	Journal of Security and Sustainability Issues
Toward an operator 4.0 typology: a human-centric perspective on the fourth industrial revolution technologies	18	Romero, D., Stahre, J., Wuest, T., (…), Fast-Berglund, Å., Gorecky, D.	2016	CIE 2016: 46th International Conferences on Computers and Industrial Engineering
From sensor networks to Internet of Things. Bluetooth low energy, a standard for this evolution	15	Hortelano, D., Olivares, T., Ruiz, M.C., Garrido-Hidalgo, C., López, V.	2017	Sensors (Switzerland)
Transforming to a hyper-connected society and economy—toward an "Industry 4.0"	14	Bauer, W., Hämmerle, M., Schlund, S., Vocke, C.	2015	Procedia Manufacturing
When titans meet—Can Industry 4.0 revolutionize the environmentally-sustainable manufacturing wave? The role of critical success factors	12	de Sousa Jabbour, A.B.L., Jabbour, C.J.C., Foropon, C., Filho, M.G.	2018	Technological Forecasting and Social Change
Advanced technologies in life-cycle engineering	11	Stark, R., Grosser, H., Beckmann-Dobrev, B., Kind, S.	2014	Procedia CIRP

Source Scopus

Table 110.3 Keyword analysis

Keyword	*n*	%
Manufacture	24	17
Internet of things	22	16
Big data	17	12
Embedded systems	14	10
Industrial research	14	10
Industrial revolutions	13	9
Cyber-physical system	11	8
Information management	10	7
Automation	8	6
Engineering education	8	6
Total	141	100

Source Scopus

110.5 Conclusion

The evolution of the industrial system allowed a series of transformations in the society from productive mechanisms developed from technological innovations. At the present time, a series of new technologies have been emerging as Internet of Things (IoT), cyber-physical system (CPS), and cloud computing and being applied in the productive systems in what we could qualify as the fourth industrial revolution or as commonly it has been called Industry 4.0. Because it is a movement that has brought a series of innovations in production systems based on these technologies, Industry 4.0 contributes to achieving organizational sustainability with a significant impact on the environment as a whole. It is necessary that organizations, researchers, consumers, and society pay attention to the way in which the economic, social, and environmental dimensions are being affected by these changes and what the possible contributions of this new industrial wave to reduce these impacts.

The productive systems are constantly evolving and undergoing changes based on the technological advances that have been achieved. These new technologies applied to the industry contribute to the dynamization of the value chains and new business models emerge from these transformations. Therefore, it is evident the need to monitor how this area of research will evolve as the concepts of Industry 4.0 and sustainability gain increasing importance in the scientific field.

As can be observed, studies that seek to understand how Industry 4.0 can contribute to sustainability as well as how these two concepts relation are in their initial stage. However, this field of research is promising given the significant numbers of publications that have been contributing to stabilize an interface between these concepts.

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Chapter 111
Is Circular Economy a New Driver to Sustainability?

Lorena Gamboa Abadia and Marly Monteiro de Carvalho

Abstract As an emerging topic, circular economy is said by several authors to be a new driver to sustainability, while others claim its just a new concept within the sustainability spectrum. This study aims to analyse the relation between the constructs of circular economy and sustainability, supported by a literature review.

Keywords Circular economy · Sustainability · Environmental sciences

111.1 Introduction

Society presently finds itself in many dilemmas and conflicts based basically on one hand in the waste generation *versus* resource scarcity and on the other hand in the impacts of pollution and environmental degradation against the carrying capacity and regeneration ability of natural ecosystems. Many crises and disasters were necessary to get society's attention and understanding on the seriousness of these problems and the necessity of changing some attitudes. Now, in the last decades, consumers, industries and companies from capitalist society have been adapting its activities little by little, as reconnecting to natural ecosystems and reabsorbing or resignifying knowledge previously used by ancient cultures.

There is not a specific time for when the concept of sustainability started being used, as there are still many definitions on the literature used for this idea. Brown et al. [5] claim that sustainability was becoming a popular term in the environmental policy and research ground, along with other terms such as "sustainable development", "sustained use of the biosphere" and "ecological sustainability", that were also being increasingly used by institutions and individuals concerned with the relationships between humans and the environment. In the same year, the Brundtland report was released by the World Commission on Environment and Development —WCED, presenting the established definition for sustainable development as "the

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development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [33, p. 41].

Since then, many concepts and definitions were presented in the sustainability or environmental field, and many practices have been developing over the years. Despite that, the way businesses think and operate still needs to change considerably to address the systemic challenges related to the environmental conditions [3], especially considering the position of the corporate world in impacting the global economy [4]. Governments seem unable to instigate changes against the will of the corporate world, hidden under the threat of continued economic growth [25]. But the corporate world seems to have decided to address the hierarchy of the 3R's "reduce, reuse, recycle" in the reverse direction [24].

A new concept that has been gaining attention is the circular economy. The proposition is an economic model that follows the energy circulation pattern from ecology [7] as a way to face the challenge of resource scarcity and waste disposal in a win-win approach, with economic and value perspective [19]. The concept is probably gaining attention for presenting "a clear angle of attack to help solving environmental problems" [28, p. 55]. In the Brazilian scenario is possible to say that it already brings many opportunities for the economy and industry, as a more resilient and sustainable way to aggregate and recover value [10].

As the concept gains prominence and strength, some questions arise: is the circular economy really capable of solving all or, at least, most of the environmental issues we encounter today? Can it drive us towards a relevant impact? Is it more viable and practical than other suggested paths?

This article intends to present a contribution to that discussion, as it is part of a research that seeks to answer this and other questions related to sustainability and circular economy practices as a way of reducing environmental impacts in businesses. Evidences and discussions presented in this paper are mostly based on the present sustainability and circular economy areas literature and related topics.

111.2 Sustainability

Sustainability means, literally, the ability to sustain, or "the quality of being able to continue over a period of time" [6]. The concept is being used for many years now, and it is uncertain to say when it started being used in the environmental sciences context. A search conducted in September 2018 on the Web of Science database shows that is possible to find publications on sustainability related to environmental sciences dating from 1987, such as [5, 11, 26, 34].

The most well-known and used definition on sustainability is probably the triple bottom line principle of "people, planet, profit", presented by Elkington [12]. That definition got widespread and included on reporting documents [9], evolving into a popular shortening for both the win-win and firm-level sustainability assumptions within the corporate sustainability discourse [20]. Because of that, and also the use of the term in association with greenwashing activities from corporations and governments, it generated a vulgarization of the term and its guidelines in the corporate world, leading to the emergence of prejudices against the idea of sustainability and sustainable development [28].

As a result, some discussions and definitions such as weak and strong sustainability emerged. Where weak sustainability means a more flexibility, such as proposing that natural capital can be at least partially substituted, allowing a given level of production to be maintained with the input of fewer natural capital each time and progressively more manufactured capital [28]. While strong sustainability emphasizes not just an efficient allocation of resources over time, but also a fair distribution of resources and opportunities between the current generation and between the present and future generations [22].

Other results from this vulgarization of those terms divide into two opinions: either the association of the concept of sustainability with little relevant changes and initiatives or the establishment of it as a utopia.

111.3 Circular Economy

According to the literature, the concept of circular economy was first introduced by British environmental economists Pearce and Turner, in 1989 [16, 17, 19, 30]. But it seems that the interest on the concept only returned on the beginning of the 2000s. In the most relevant databases for scientific studies, the publications found on the subject date only from 2003 to 2004. This resurgence of publications on the subject may be associated with the approval of the "circular economy law" in China, 2002. Such legislation addresses the encouragement of the circular economy as a new development strategy, with the objective of maintaining economic growth and at the same time reducing environmental impacts [35].

Nowadays, the concept is undoubtedly gaining attention, not only in the academic world, but also on the policies, businesses and industrial operations spheres [4, 16, 19].

It arises as an opposition to the traditional linear approach, where, from raw material extraction to final waste disposal, environmental impacts are ignored and energy potential returns to Earth and is lost through pollution [28]. Excessive waste generation represents a loss of valuable material that has the potential of being reused or reintroduced into production systems [23]. However, a linear system can be converted to a circular one when it made the connection between the use of resources and waste generation [1].

Based on that awareness, the circular economy is proposed through the creation of closed loops in which resources flow in circular movements within a system of production and consumption, where integrated combinations of industrial activities act synergistically to feed and nourish each other [28]. It can be seen as cycles of continuous positive development that preserve and enhance natural capital, optimize resource incomes and minimize system risks through the management of finite reserves and renewable flows [13].

The definitions of the concept may seem so perfect that some people might even call it a “dreamy” vision of the future [24]. But, the concept is not entirely new [16]. It is mostly a new construct, but inspired by several schools and lines of thought that already existed in the sustainability spectrum and have built the basis for the debate on sustainable development [10], such as cradle-to-cradle [21], reverse logistics [27], industrial ecology [18], industrial symbiosis [8]. It is also flowing in a way that encompasses other concepts and practices that are recently rising, such as the sharing economy [13, 15] and product service systems [31, 32]. For example, both cradle-to-cradle and circular economy are concepts within industrial ecology that can be considered leading principles for eco-innovation, in which wastes are used as raw materials for new products and applications [23].

111.4 Discussion

The world where we live today is fastly and continuously changing. Innovation is a necessity and a challenge at the same time. The circular economy, for example, is a great opportunity for value creation [14]. It represents a new paradigm that requires novel concepts and tools to describe and support it [2, p. 309]. The transition to a more circular economy requires changes along the value chains, from product design to new business models, from new ways of transforming waste into resources to new consumer behaviour modes [19, 29]. But most companies seem to have trouble adapting to society wishes. Perhaps because of the lack of guidance, the general complexity of the problems presented or the fact that alternative business models may not feel sufficiently reliable [25].

That is why the challenges associated with this dynamic context make it essential to aim at more comprehensive and multidisciplinary visions, enabling a more cohesive view of the situations, as well as the ability to avoid, reduce or mitigate problems that arise [28]. By promoting systemic thinking, both sustainability and circular economy can present different inter- and trans-disciplinary perspectives that juxtapose with the implementation of sustainable business [25].

That way, both the sustainability and the circular economy concepts present benefits. Deciding which concept encompasses the other, may depend on the definition adopted, as both concepts also present its own limitation, due to the definition or to the way it is seen by most people. If considering sustainability as the triple bottom line adapted to the corporate context, it may seem like a less functional term and the circular economy as a more clear practice/solution. On the other side, the circular economy encompasses many concepts and initiatives that were already on the sustainability and environmental sciences spectrum, placing it as just a new terminology.

For the arguments presented, we consider that the idea of sustainability is a much more complex one, contemplating a search for less and less negative impacts and environmental degradation, passing through the basis of economic development with environmental protection and social justice proposed by the triple bottom line, but in more rigorous parameters. The great highlight brought by the circular economy may be the incorporation of the circular economy into the economic mainstream, not as a "saviour" of the planet and of the human species, but as a "saviour" of the economy itself, with beneficial consequences for the planet and humanity [10]. That way solving the problem of the sustainability and sustainable development terms prejudice.

In any event, the main point is that all of these concepts are different, but they all share an important factor: all of them widely aim to address environmental problems [28]. For that, technological advances are needed, and also advances towards government support and incentives to initiatives for sustainability and reduction of impacts to the environment. The Brazilian scenario is still a bit limited to the transfer of responsibility, with little considering on complementary policies that could promote technological innovation and preventive solutions.

The Brazilian National Confederation of Industry indicates the opportunities identified for the Brazilian industrial sector through new business models and material recovery. It also highlights the potential of the electronics industry, with the recovery of materials and new services; plastics, with great reduction and recovery opportunities; along with the civil construction, with the reduction of waste generation; and the textile sector, with new materials and circular value chains [10].

That way, in order of the circular economy and other sustainable initiatives in general to scale up and realize its full potential, it is necessary to create enabling conditions, such as better quality education, specific public policies, circularity infrastructure and innovative technologies.

111.5 Conclusion

As mentioned, this article is part of a bigger research in course that seeks to analyse questions related to sustainability and circular economy practices as a way of reducing environmental impacts in businesses. Evidences and discussions presented in this paper are mostly based on the present sustainability and circular economy areas literature and related topics. Empirical studies are also being made in the context of the research, and further results are expected.

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Chapter 112
Sustainable Practices and the Relationship with Suppliers in SSCM: A Case Study in Wholesale

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Abstract This research aims to describe and analyze the sustainable practices of a focal company as well as its relationship with the supply chain in order to identify if the sustainable practices of the suppliers affect their sustainability. For that, a case study was carried out in a large wholesale reference company in the country and located in the city of Uberlândia. The results showed that the sustainability of the focal company is directly related to the sustainability of the members of its supply chain. In addition, sustainable supply chains, in addition to minimizing the negative impacts of organizational activities on the environment and society, reduce costs, improve the company's image, promote innovation, and lead to stronger and more lasting relationships with members of the supply chain. The limitations are the number of interviews performed, given the size of the company, and the fact that the research addresses only the vision of the study's focal company.

Keywords Sustainable practices · Suppliers · Wholesale

112.1 Introduction

Pagell and Shevchenko [12] comment that true sustainability must be present as an aspiration for the organization. Being "sustainable" requires a change in how supply chains are managed. Sustainability is an essential competency on how the company can survive in the future. Most existing supply chains will not survive unless they change their practices and business models so as to cause less negative social and environmental impacts.

More recent studies on the SSCM indicate that much research on the subject is heavily involved in the manufacturing, food, and automotive industries [2]. In the study conducted by Ansari and Kant [2], the logistics sector occupies the fifth place as the branch selected in the main chain sustainability studies. Considering this fact and the importance of the management that applies the concepts of sustainability in

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the supply chain as a strategy for the permanence of a company in the market, and that according to Pagell and Wu [13] for a company to be considered sustainable, all their suppliers must also be sustainable; this research aims to describe and analyze the sustainable practices of a focal company as well as its relationship with the supply chain in order to identify if the sustainable practices of the suppliers affect their sustainability.

Thus, the present study will focus on sustainability in the focal company, as well as on the sustainability implications of SC in its business, distinguishing itself from studies such as Evangelista et al. [8] and Abbasi and Nilsson [1], who considered only the company practices that the research focused on; the research will also be able to confirm if sustainability can bring cost reduction to companies, as was done in the survey of Sureeyatanapas et al. [18], but in the context of a wholesaler–distributor located in Brazil.

To reach the objective, a case study was carried out at a large wholesale institution in Uberlandia, a city known as a logistics hub, whose strategic location allows the movement of goods between the north and south of the country. The research allowed the definition of categories that are determinant for the evaluation of sustainability in the company.

112.2 Literature Review

According to Barbieri and Da Silva [3, 4], the concept of sustainability has become broader, being used and interpreted according to the interests of each group. In 1992, Eco-92 was held in Rio de Janeiro, Brazil, where Agenda 21 was implemented by the governments, in which 179 leaders from "developed" and "developing" countries committed themselves to goals for sustainable development, which has consolidated sustainability as a global concern.

With the advancement of sustainable development in business and global social demand for quality, safety, concern for the environment and social issues, an even greater number of companies realize the urgent need to change their activities to fulfill their responsibilities with the environment which is inserted [9], and then the triple bottom line (TBL) concept emerges. The process of management by the TBL is made around three dimensions: economic, social and environmental, and the business performance according to these dimensions is disclosed to the stakeholders' knowledge in the companies involved. There are accounting firms that offer the service to measure, report, and audit their TBL actions [11]. According to Lima [9], organizations that use TBL have better relationships with their suppliers and customers, as well as passing a good image of the company to society.

With the advancement in the SCM studies and in the sustainability issue, there were major external pressures (legislation and stakeholders) for organizations to implement the TBL concept in their processes, modifying the traditional vision of just increasing profitability and efficiency. In this sense, in order to meet these requirements, the management of the sustainable supply chain arises, which is the main theme of this work. Sustainable supply chain management (SSCM) consists of integrating the SCM concept with practices that lead to sustainability (TBL); that is, the supply chain as a whole must minimize its damages to the environment and society and generate profits [13].

Seuring and Müller [17] define SSCM as the management of the flow of information, material, capital, and also cooperation among members of the supply chain, with the objective of performing well in all three dimensions of the triple bottom line. The authors also point out that all members of the chain must follow established sustainability criteria so that they can remain in the chain. By this point, SSCM offers a competitive advantage over traditional supply chain management.

Some of the behavioral characteristics of the companies differentiate SSCM from SCM, such as: integration and cooperation among all members of the supply chain (both direct and indirect suppliers and customers) and also with stakeholders (government, NGOs, investors, society, employees, among others); the effort to maintain a "supplier base" with long-term relationships and to present transparency, traceability, certifications, and supplier development actions; and a greater number of performance objectives to include TBL [13, 17].

Pagell and Wu [13] also argue that in addition to the focal organization, all members of the supply chain need to contribute to sustainable practices in a proactive and engaged way. That is, economic, environmental, and social practices must be aligned along the supply chain. According to Beamon [5], company networks using SSCM should evaluate the sustainability of all processes at all stages of a given product (collection, remanufacturing, reuse, recycling, and final disposal).

112.3 Method

In order to achieve the objective, a large wholesale company was selected in the city of Uberlândia, Minas Gerais, to collect data. The choice of the sector and the city is justified because it is a major wholesale hub in Brazil, where large industries are located in the logistics sector, whose activity has a significant impact on the economy of the state and the country. Wholesale companies play a central role in the supply chain, mediating between a large number of members who are in SC (factories/industries) and downstream (retailers) directions, allowing the proposed case study to reach the objective of the research, portraying the reality of the whole, even in a dynamic context [7].

The sources used to carry out the data collection were: physical documents made available by the company; institutional Web site of the wholesaler and its social institute; and semi-structured interviews with four leaders from areas relevant to the development of the research: purchasing director, logistics leader, risk and environment management leader, and the person responsible for the actions of the company's social institute. The interviews were conducted between December 2017 and February 2018, at the company's administrative headquarters, lasting approximately one and a half hours each, and were recorded for later transcription. The triangulation of data from several sources of evidence, relating it to theory, increases the reliability and validity of the research [7, 20].

The data collection instrument was elaborated from the theoretical discussion proposed in item 2 of this article, considering the studies of Coral [6], Vachon and Klassen [19], Pullman et al. [15], Pagell and Wu [13], and Paulraj [14]. From this bibliographic research were the questions related to the socio-environmental practices carried out by the company, relationship with the supply chain and the impact of sustainability on the actions carried out by the company and its main suppliers, which contributed to the formulation of the interview script. Data analysis was performed using the content analysis method in order to better understand the meaning of the message.

With the information collected by the interviews, and using the content analysis method, it was possible to establish some categories resulting from the process of data interpretation, such as internal sustainable practices, social practices, influence of legislation, impact on company image, suppliers, evaluation, and sustainability of suppliers. Thus, the results were analyzed in the last phase in comparison with results obtained in other published researches on the subject.

112.4 The Main Results

The Company Y is a distributor wholesaler that serves all the cities of the national territory, with its central located in the city of Uberlândia-MG and storage units in numerous federal units. It is a large company that operates in the market for over 60 years, owning a fleet of its own with around a thousand vehicles and also has 33 outsourced carriers to carry out the delivery of the orders. The company has 600 suppliers and serves more than 400 thousand retailers. The annual turnover of company Y in 2016 was R $ 5 billion.

The results found in research demonstrate some categories that are describe in Table 112.1. Each category was created by content analysis of the information collected in the interviews with logistics and risk management responsible.

112.5 Discussion

It is observed that the wholesaler has sustainable practices in its operational processes, in order to reduce the costs and the impact of its activities on the environment, mainly in relation to the waste generated in the process—cardboard box and ribbon—and the emission of pollutants into the atmosphere by its own fleet [13]. One of the important facts about the insertion of sustainability as an element in the operations was the creation of the risk and environment cell in 2003 and the W Institute in 2005, which took place in the near future and soon after the end of the Brazilian Agenda 21 in 2002 and the beginning of its implementation in 2003, when sustainability and

Table 112.1 Sustainable practices in wholesale

Category	Main results
Operational processes	Use of reusable plastic boxes in order separation Reuse of carton boxes from suppliers to send orders Reverse logistics with cardboard boxes (customer company), being reused when they are not damaged It has a supplier of recycled boxes if extra boxes are needed to pack the orders Recycling or correct disposal of the waste (plastic tapes for lashing and damaged boxes)
Internal actions	Use of LED lamps Control of the consumption of electric energy, aiming at its reduction Control of paper consumption (printing) Periodic maintenance of the fleet to avoid the increase of emission of pollutants, adherence to the Arla 32 system, and vehicles with a seal of commitment to the environment Donation of products with expiration date close to expiration or correct disposal Recreational activities for the employees promoted by the human resources area, the accomplishment of gymnastics, the provision of gymnasium, project for the conclusion of secondary education for operational employees, work safety, among others Certifications like great place to work (GPTW); hiring companies to audit the statements; A rating by Fitch Ratings Creation of University Z
Actions taken by the W	Socio-environmental projects such as “ZAPe” which aims to spread entrepreneurship for young people, VemSer that mobilizes the company’s own employees to carry out various social actions for the community, and numerous partnerships that allow the institute to have an impact on the national environment, such as FAS—Amazonas Sustainable Foundation
Influence of legislation	Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) requirements for the transportation of products with high risk, such as payment of fees and specific documentation Driver training Development of the cargo box as an innovation on the initiative of the company Support in the process of developing new regulations

(continued)

Table 112.1 (continued)

Category	Main results
Impact on company image	Image as the company's largest equity Sustainability is directly linked to the organization's image Sustainability as a means to remain competitive in the environment Creation of the W Institute and the Department of Risk and Environment The company requires certifications from suppliers and customers
Practices of suppliers	Have certifications; long-term contracts; good relationship between company and supplier; "win-win" relationship; top-to-top meetings
Suppliers evaluation	They are constantly evaluated as to the quality of service, ease of contact with the company's president, delivery of the product according to the combination, flexibility in face of instabilities in the market, and its sustainability. If sustainability requirements are not met, business with the supplier is discontinued. They have a software evaluation tool
Actions in conjunction with the supply chain	Partnerships for preservation of the environment, correct destination of damaged products, community actions, reverse logistics, customer support or future projects of the W Institute

Source Data research

sustainable development gained more space in the country [10]. In this way, company Y seeks to improve its processes to minimize its impacts on the environment, such as the reuse of cardboard boxes from suppliers, the use of reusable plastic boxes in the product separation process, and the purchase of recycled boxes.

Another process that has undergone modifications was the periodic maintenance in the vehicle's own dealership, through the maintenance contract, which guarantees the quality of the fleet, avoiding unforeseen during the delivery of the orders, increasing the useful life of the fleet and above all avoiding the increase of the emission of pollutants into the atmosphere due to the wear of the vehicle. In addition, the company performs environmental practices that corroborate with the suggestions of Vachon and Klassen [19] and with the business sustainability model proposed by Coral [6], such as the constant renewal of the fleet aiming at joining the Arla 32 system, which decreases the emission of pollutants from vehicles, following the regulations; the vehicles that are currently purchased have a "seal" of environmental commitment; and as for the third-party fleet, the company also guarantees the quality of the vehicles through contracts.

The company is in compliance with the environmental practices suggested by Vachon and Klassen [19], Coral [6], and Paulraj [14], because it uses LED lamps in the new units built and in the older ones it performs the gradual replacement; there is the control of energy consumption, aiming at its reduction. There are projects that aim to reduce the amount of paper consumed in the company; and products returned by customers for malfunctioning, the correct disposal is performed. In addition, the wholesaler has a partnership with Chão Brasil, where food is shipped with date close to expiration is donated for charity intuitions, and this practice can be considered social in terms of aid to charities and also environmental, by preventing the product from expelling the expiration date and being discarded, thereby reducing food waste.

Knowing that the institute depends on its maintainers (company Y and bank Z), the fact that the budget is always growing, even in crisis periods, and the fact that the company's own employees make up the assembly, the deliberative council and the board of the institute W demonstrate the commitment of the whole company to the cause of the entity, and the projects developed are always in the process of improvement and expansion. In addition, company Y encourages internships and young apprentice programs and has created W University to assist the retailer in their business. In this way, the company contributes to the growth of society [6, 15].

Still in the social scope, but in relation to the practices carried out internally by the area of human resources, the wholesaler develops actions that aim at the safety of the work, the well-being of the employees and to offer good physical and mental conditions to the collaborators. Among the actions taken are the gymnastics before the beginning of activities; provision of in-company academy for employees; and the promotion of recreational activities. These actions are in accordance with internal social practices recommended by Pullman et al. [15] and Paulraj [14].

As for the economic scope of the TBL, the wholesaler hires specialized and recognized companies to audit its statements, alternating them every four years in order to guarantee impartiality and convey greater confidence to stakeholders [11]. As a wholesaler–distributor, the largest number of environmental legal requirements for company Y is in the transportation and storage of high hazard products. It is observed that the regulations are one of the factors that impel the company to adopt sustainable practices, which shows that the government exerts pressure for the adherence of environmentally responsible attitudes, according to Rieskti [16]. However, the wholesaler recognizes the importance of the existence of regulations and complies with them not only because of the risk of assessment, but also to avoid damages to the environment and to community.

It is also noticed that the company Y presents significant involvement with its suppliers. The company always seeks to establish long-term contracts, allowing the formation of a supplier base, according to Seuring and Muller [17], being one of the factors that differentiate SCM from SSCM. Long-term relationships allow for greater interaction between the parties, thus developing trust, for example. The company's suppliers, in their totality, present certifications, which are also a characteristic of the sustainable supply chain [17], being a requirement in the supplier selection process. The certifications are extremely relevant because they indicate if the supplier meets the expectations regarding the quality of its products, legal requirements, and the company's own sustainability. According to Rieskti (2012), some certifications are required by law for the operation of the company; however, non-mandatory certifications can be a differential, as in company Y in relation to its suppliers.

Cooperation and integration between the focal company and the members of the chain are perceived [13]. Regarding cooperation, the company carries out practices in conjunction with its suppliers according to the "sustainability tripod." In the social sphere, the company reaches this dimension by developing projects for society carried out through the institute of the company itself, such as the purchase of school supplies. In the environmental field, it is realized through the preservation of native forests. Regarding the economic dimension the disclosure of balance sheets and other statements audited by specialized companies, in addition to sharing the resale value of the products [11].

Still on the evaluation method, the company constantly evaluates its suppliers, with weekly, monthly, half-yearly, and annual meetings. The main aspects evaluated are quality of care, ease of contact, flexibility, and sustainability. Beamon [5] and Vachon and Klassen [19] point out the relevance of the continuous evaluation of the suppliers in the fulfillment of the commitments made especially with regard to the three areas of TBL. T2T meetings together with information technology allow even greater integration of company Y with the rest of the supply chain and above all align sustainable practices throughout the SC. This type of meeting facilitates direct communication between the parties, involving the CEOs.

It can be seen that company Y is aware of the importance of belonging to a sustainable supply chain, since "unsustainable" suppliers can jeopardize its business and SC's business as a whole, as well as negatively affect its own image [9], valuing sustainable practices that go beyond what is legally required. And even though it is a wholesaler, the company is concerned with the satisfaction of the final consumer and not only with that of its direct customers (retailers), opting for the purchase of quality products from certified suppliers and that for the most part are renowned in the market national and international, being recognized for adopting sustainable practices in their processes.

The results of this research diverge, in part, from the results found in the study by Evangelista et al. [8], as it showed that the distributor–wholesaler is well aware of the importance of sustainability for business, society, and the environment doing more than is legally required. Although sustainability is not among the values of the company, it is part of its culture, even if it still has some factors to be improved. This research also showed, in addition to the authors' research, that there is a direct relationship between the sustainability of SC members and the sustainability of the focal company.

As the Sureeyatanapas et al. [18] study, this research has shown that it is possible to simultaneously adopt sustainable practices in processes and obtain cost savings, and it has also shown that efforts to improve or adopt new sustainable practices may result in innovations that optimize the operational process, such as the development of the Cargo Box.

For the "degree of importance" given to economic, environmental, and social factors, according to the Abbasi and Nilsson [1] survey, the wholesaler showed a stronger tendency for the economic side, such as making a "good purchase" for a greater margin of contribution and a better price for customers, however, not too distant in order of importance, unlike what the authors' research showed, are the environmental and social factors that have been present throughout the wholesaler's history and confirmed by the "punishments" to suppliers who break the established sustainable commitments. This demonstrates the concern with the issue of image and increasingly seeking to meet the social and environmental demands of stakeholders.

112.6 Conclusions

It is well-marked that the good relationship of the company Y with the other members of the supply chain always emphasizes respect and trust. There is also an evident flow of products, information and services among the "network of organizations" in order to generate value, with a management that involves the dimensions of the triple bottom line in its business, that minimizes impacts on society and in the environment, setting up sustainable supply chain management.

However, from the information gathered in the interviews, it is observed that sustainability is not considered as an institutional value for the company as a whole. The area of risk and environment management was created a short time ago, and there are actions planned to increase the focus on sustainability in company practices, but the incorporation of value appears a little outside the integrated network of companies that forms the institution studied.

The association of sustainability as an element that has a positive or negative impact on the company's image is evident. Nevertheless, there is no defined action protocol for selecting suppliers for their sustainable practices, and even requiring and worrying about these practices in their supply chain, it is not possible to determine at what level the sustainability of supplier actions, or its absence, affects the level of sustainability of the company surveyed.

This study has limitations. As it is a large company, the number of interviews could have been greater, since even if the company that is the target of the case study plays a central role in the SC that is inserted, the study was limited to the company's vision. Interviews could also have been conducted with other members of the supply chain, or even questionnaires. Future researchers could focus on suppliers, or even conduct a study of multiple cases in the wholesale-distributor sector.

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Chapter 113
A Sustainable Operations Proposal Framework for Improving the Healthcare Institution and Community Relationships

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Abstract The sustainable operations allow the scope of the work and the corporative social responsibility. The researchers developed the study from April to June 2018 and analyzed the healthcare institution and local community relationships through educational actions. The research presents the sustainable operations proposal framework. The four groups of the healthcare professionals are selected in this study: the infection prevention and control, the solid waste manager, the continuing educational, and the nutritionist. In the results and discussion section, four steps integrate the framework: "the identification of needs," "the action planning," "the slums engagement," and "the action maintenance and assessment." The conclusion reinforces the stimulus for the corporate social responsibility, the worship of citizenship, and the educational program. The partnership between the healthcare institution and the community can be improved by the sustainable operations proposal framework.

Keywords Corporate social responsibility · Healthcare · Sustainable operations

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113.1 Introduction

The sustainable operations are discussed by many studies [4, 5, 10] especially by the economically emerging countries [13, 17, 18] like Brazil. As a member of BRICS (Brazil, Russia, India, China, and South Africa) and target of the present study, Brazil is placed on G20 group, nominated like this by the United Nations Organization. The opportunities are observed either for the sustainable practices as for the implementation of the corporate social responsibility [1, 6] on Brazilian healthcare institutions.

The crisis period through which the country is going by many aspects, like the environmental, the social, the ethical, the political, and the economic, opens space for the reassessment of the possible changes. These possibilities favor Brazilian collaborative economic and allows the most homogeneity possible. Achieving homogeneity of these aspects has as a challenge the continental dimensions of the territory and the cultural diversity. The stimulus for the social responsibility practices in company contributes not only to the strengthening of brands, but to the maintenance of the ethical pattern. Companies search the fortification of this ethical pattern as a differential on their market, if compared to another companies and as a protection factor for their brands. Emerging countries have been the target of many studies involving the sustainability aspects and establish proposals for a sustainable supply chain [8, 21].

The green production [1, 3] is a concern that is part of the corporative scenario, since it aims to bring value and stimulate attitudes that might help to transform actions in order to have a more sustainable life. The social responsibility is discussed and stimulated on the corporative ambiance by the opportunities offered by the state of Rio de Janeiro. This state is the target of the present study. The opportunities given lead to the achievement of the social actions in slums and non-governmental organizations.

The state of Rio de Janeiro presents difficulties in many levels, but it is beneficial to promote the share of the experience with the information trade between the healthcare professionals and the community agents. This action leads to the improvement of standards and quality of life for the people who live in the slums. Especially for this study, the search for sharing knowledge in slums located close to healthcare institution is a way to strength the corporative role of the healthcare institution in society.

The exercise of citizenship is highlighted in the activities of the members of the healthcare staff. The exchange of experiences, either life and academic related, enables the participants to have new ways to look over work and their own lives. Therefore, the framework proposal, based on sustainable operations and the relationship between healthcare institutions and slums, is presented and suggested by the present study. The following section, “materials and methods,” presents the design of the study done and the contributions of the framework proposal. The “results” and “discussion” section provides a detailed scheme of the steps and activities of each professional on the framework proposal. The contributions given by the study are described on the "conclusions" section.

113.2 Materials and Methods

The researchers developed the study from April to June 2018, and highlights four groups of professionals related to healthcare activities: who work with infection prevention and control, who work with solid waste management, who develop continuing education, and who work with nourishment practices. The co-working of these professionals, the interdisciplinarity, and partnership with the community agents may stimulate sustainable and healthy practices toward the slums.

The present research aims to suggest a framework proposal for the improvement of the sustainable operations and the relationship with the slums and the healthcare institutions. The actions of the healthcare institution, beyond its physical space, can contribute to a better quality of life. The United Nations established 17 Sustainable Development Goals in 2015 [19]. These goals should be implemented until 2030, and the healthcare institutions can contribute to the achievement.

The prevention of sicknesses, the practice of the healthy feeding, and improvement on familiar income are relevant factors for the improvement of the lives of the citizens. In order to build the present framework proposal, four themes were chosen to be approached during the activities: the food integral utilization, the composting techniques, the recycling materials, and the hands hygiene habits. As a part of this structure, four phases are identified for the framework: the identification of needs, the planning actions, the slums engagement, and maintenance and the assessment of actions. All the phases involve the healthcare professionals and the community agents to create the actions.

The waste involving food brings real concern like the hunger, the improvement of the triple bottom line, and the waste reduction. Khalid et al. [9] approach the food waste and reminds that a billion people all over the world suffer the consequences of starvation and malnutrition. It also affirms that avoiding waste enables cost reduction and brings the environment benefits, since it improves human health and prevents diseases.

Figure 113.1 represents the framework proposal, in which the healthcare institutions and the slums are the pillars of the sustainable operation structure. The four professionals of the healthcare institution and the community agents lead the responsibilities on the four stages of the process. The beneficiaries, the healthcare institutions and the slums, are placed on the basis of the inverted pyramid of the framework.

The healthcare institution wins by the social responsibility and the strengthening of the brand. The slum wins by the possibility of improving the citizen's quality of life. The lines dividing the pyramid get stronger as it gets the target public of the framework. The representation by thicker lines shows the fortification of relationship between the healthcare institutions and the slums.

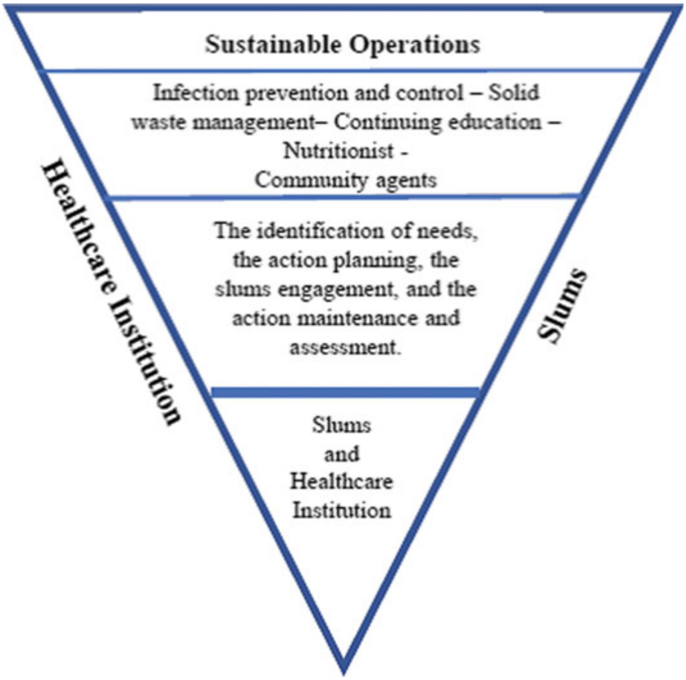

Fig. 113.1 A sustainable operations proposal framework

The section "results and discussion" present a detailed scheme of the actions proposed by the framework with actions to be developed by the professionals involved, as well as the final result for the healthcare institution and the slums. This section is divided into four subsections: the identification of needs, the action planning, the slums engagement, and the action maintenance and assessment.

113.3 Results and Discussion

Some steps are necessary for the implementation of the sustainable operations proposal framework. These steps are highlighted as subsections and are part of the themes established and activities to be performed by the professionals, either by the healthcare institution as for the community agents.

113.3.1 The Identification of Needs

The first action will identify and understand the needs of the slums, so that the project can be implemented regarding the goals proposed. The community agent makes a mapping by searching for people who want to take part on the project, inside the slum. Through this mapping, the professionals search for the previous history of these people and the sustainable activities that are made and that they want to share. The four subjects chosen, "the food integral utilization," "the composting techniques," "the recycling materials," and "the hands hygiene habits," are offered to the citizens who live in slums, and they can choose which are more interesting for them. The stimulus for an effective participation of this population might be possible by the dissemination in local radio stations, displays, and invitations given to the families that attend the activities. The "mouth-to-mouth" communication enables to elucidate doubts and promote which activities are going to be made. Studies involving the material recycling [7, 16], the reduction of waste [11, 15], and the composting techniques [2, 12] can have its frameworks adapted for the healthcare sector.

113.3.2 The Action Planning

All the actions of the data collection, the mapping, and the dissemination should have a schedule established with the place and time for the planning meetings. These meetings are made by the healthcare staff and the community agents. The materials to be used should be previously listed for the purchasing of it. Having the materials allows the theoretical knowledge to be given and the skills to be developed by the practice. The staff involved on the project do the data collection for material and food necessary. The healthcare institution invests for the purchase of the materials. Some examples of these materials are the purchase of food for the reuse theme, soap, and paper towels for hands hygiene. The recycling materials [7, 16] are also taken as a way to exemplify.

Each member of the healthcare staff attends specific themes. The hand hygiene is approached by those who work with the infection prevention and control, the composting techniques and the food integral utilization by nutritionists, and the material recycling is taught by those who work with solid waste management. The professionals of the continuing education coordinate all the activities, in collaboration with all the staff involved. By the time each course is concluded, a celebration can be a positive way to build social relationships with the citizens who live in slums.

113.3.3 The Slums Engagement

In this stage, the history of the citizens who live in slums is known, for example, people who already do the whole usage of food and those who already use composting techniques or recycling. These people are invited to share their knowledge with the aim of worshiping their attitudes. Sharing these practices strengths, the ethical values of each participant contributes to the improvement of the quality people life. From the example, participants may get more confident about these practices feasibility. The learning process structured by the experiences trade enables to build opportunities that used to be seen as challenges or obstacles. The selective collection can be stimulated [20] during meetings, and the healthcare institution can add value to the investment things like collector boxes identified by symbols. Besides, the creation of a cooperative for the selective residues' collection brings new job opportunities and reduces the amount of waste without discard specifications.

113.3.4 The Action Maintenance and Assessment

All the actions developed should have a schedule for the maintenance of meetings and speeches with a variety of the themes and the subjects. In each meeting, an assessment may allow new needs of improvement. This assessment brings the possibility to closer cooperation between the healthcare institution and the slum. With the aim to achieve a better level of the opinions and the perceptions, three kinds of assessment can be used: during the meetings and at the end of them, written on a sheet of paper and by individual conversation with professionals of the healthcare institution and the community agents. The authors of the study do not aim to bring a formal status to this evaluation through the written assessment. Some ground of informality is expected so that the slum citizens feel free to express ideas and expectations.

Another relevant aspect of the three kinds of assessment is not to promote exclusion because some of them might do not know how to read or write, since the framework proposal should be inclusive. The corporate social responsibility is connected to the triple bottom line (environment, society, and economy) all the time [14]. The environment preservation, the slum engagement on the social aspect, and the possibilities of the family income improvement represent the triple bottom line. Therefore, considering the opinion the citizens who live in slums, the healthcare professionals and the community agents assess and align future actions with this group.

Figure 113.2 shows the work development by the healthcare professionals and the community agents with the slum citizens' participation.

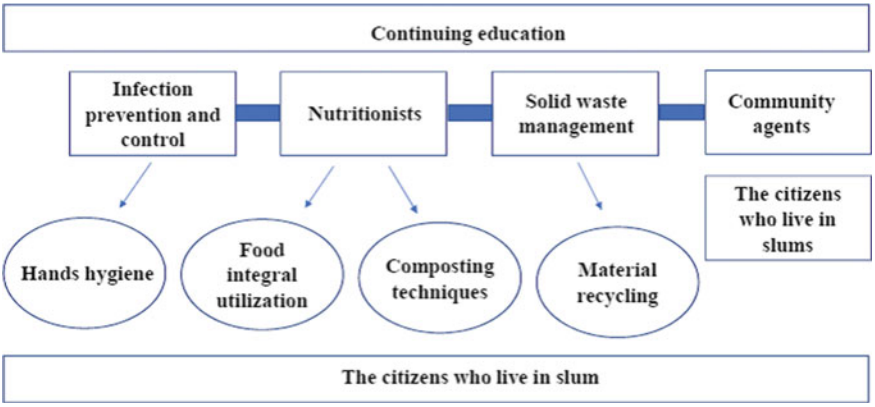

Fig. 113.2 Work development by the healthcare professionals and the community agents with the slum citizens' participation

113.4 Conclusions

The sustainable operations and the corporate social responsibility are two themes that widen the world discussion of these issues, especially concerning emerging countries like Brazil. To establish and improve the relationship between the healthcare institutions and the local communities enable the materialization of these themes. The present study brings the sustainable operations proposal framework, focusing on this relationship. The four groups of the healthcare professionals like the infections prevention and control, the solid waste management, the nutritionists, and the continuing education were chosen to approach specific themes. All the staff involved developed the job together with the community agents. The authors of the study chose the whole use the composting techniques, the recycling materials and the hands hygiene habits, since those are emerging themes and that enable full attention to the triple bottom line. These professionals aim to establish the sustainable operation proposal framework by the use of the four stages. The actions are divided into "the identification of needs," "the planning actions," "the slum engagement," and "the action maintenance and assessment." Each of these stages is designed through a partnership between the healthcare professionals and the community agents, aiming not only to bring information about the themes chosen, but also to strengthen up the sustainable practices and the corporate social responsibility.

So, the authors of the present study conclude that establishing a sustainable operations framework brings possibilities to improve the relationships between the healthcare institutions and the slums. The inclusive proposals that stimulate social responsibility of companies bring the worship of citizenship and ethics. The worship of citizenship is an exercise to be practiced by the healthcare institutions and the slums.

The themes chosen to aim to attend not only educational proposes involved on the present proposal framework, but also the family income improvement and a better quality of life. Future studies like sustainable proposes, including the corporate social responsibility in the different fields of action, either health or industrial, promote the sharing of the new experiences. The experiences sustained by social relationship and that may bring contributions for the many aspects that involve the academic scene with reflections on the practical one. The proposal framework enables the implementation of the actions and the possibility to promote adaptations in many fields of the society. One of the limitations of the present study lies on the low number of studies involving the health sector and the slums.

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Chapter 114
Job Satisfaction Diagnostic Instrument Based on Self-awareness and Engagement Metrics

Ricardo Luiz Fernandes Bella and Oswaldo Luiz Gonçalves Quelhas

Abstract This article investigate workplace spirituality literature to modeling a diagnostic instrument that map which factor can promote job satisfaction toward self-awareness and engagement metrics. The result was an instrument that can support managers to perform actions focused on job satisfaction.

Keywords Job satisfaction · Engagement · Diagnostic instrument

114.1 Introduction

This article aims to present an approach for job satisfaction through a meaningful work experience that can be understood by a spiritual drive, not religion, but a deep connection with your self among self-awareness and engagement toward a bigger purpose alignment. It may be noted that it is about a tendency of last generation to seek meaningful work to job satisfaction [5].

However, job satisfaction can be measured by many metrics; this research takes the preview literature about workplace spirituality to finding the main factors that support this new perspective for job satisfaction based on self-awareness and engagement [12]. At this point, the connection of the theme with sustainable operations can be perceived by the maintenance of a good and health conditions at work keeping workers motivated and productive in long terms [8].

For this, a literature review was done to identify the key work attributes to develop a job satisfaction diagnostic instrument. The diagnostic instrument was designed with Kano's model perspective, which maps the workers' satisfaction level related to the work attributes. It is expected that the instrument would contribute to the

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organizational efforts of developing more great places to work based on this new job satisfaction expectations.

114.1.1 *Literature Review*

114.1.1.1 Job Satisfaction

From the worker's point of view, job satisfaction stands out for quality at work. The relationship between job satisfaction and quality at work was discussed at first time by authors of management school at the beginning of twentieth century. In the main theory of this school, Maslow identified several sources of workers' needs that came from physiological and social matters [10]. The evolution of the job satisfaction theories shows a tendency to consider more and more complexity in workers' expectations. In Table 114.1, these theories are presented.

Table 114.1 Job satisfaction theories

Author	Study emphasis	Job satisfaction perspective
Taylor (1903)	Fatigue	Start with material matters
Mayo (1933)	Psychology	Added the importance of informal groups
Hoppock (1935)	Effectiveness	Discussed multiple factors (supervision, monotony, etc.)
Herzberg et al. (1959)	Psychology	Grouped factors into motivational and hygienic ones
Vromm (1964)	Situation and personality	Added employee expectation achievement matter
Porter (1968)	Altruism	Added autorealization and well being theme
Hackman and Oldham (1974)	Work characteristics	Added five critical factors: variety, identity, significance, task autonomy, and feedback
Locke (1976)	Affectiveness	Added the work experience perspective
Orpen (1981)	Values	Discussed the importance of individual values
Quarstein et al. (1992)	Balance	Discussed situational characteristics and occurrences

114.1.1.2 Self-awareness and Engagement Metrics

The self-awareness and engagement had been discussed on literature as a spiritual matter that remains to a human-centered view based on three aspects: inner life, purpose, and community. These aspects are defining new paradigms for work relationships and impacting the work environments [15]. These new paradigms are related to the search of meaningful work by last generation of workers. In fact, there are already some reviews about workplace spirituality; the most cited one organize the topic by these three dimensions: first, the inner life dimension that remains to self-centered matters such as identity and values; second, the sense of purpose dimension that refers to work significance perception; at last, the sense of community dimension that remains to connection and engagement. So, the research starts from these dimensions to find out which work attribute that can increase job satisfaction.

For example, human beings are animals that seek meaning and consequently seek meaning in their work activities [4]. Humans also are sociable; it means that people have concern with belonging to social groups [6]. These two aspects—meaning and belonging—reflect anxieties that develop within an internal life [7]. So spirituality in the workplace is about meeting the needs of inner life, purpose, and community. On the other hand, the company's role is to recognize that employees have an inner life that nourishes and is nourished by meaningful work in the context of a community [1].

Based on the latest literature on the matter, twelve factors can be elected as drivers that lead organizations to a job satisfaction experience. Bella et al. [2] pointed out these factors as: identity, belonging, values, inner life, purpose, coherence, cohesion, meaning, climate, community, connection, and environment. On this article, these factors were as components of the job satisfaction diagnostic instrument.

114.1.2 Methods

The Kano's model was used to orient the questions and answer scale of diagnostic design. This model consists of the relationship between two variables: consumer satisfaction/dissatisfaction and functionality/dysfunctionality of a product's attribute. The model has the purpose of explaining the behavioral tendency of the level of consumer satisfaction of a product in relation to the functional performance of any attribute of this product [9].

It is interesting to note that dissatisfaction is not the same as not be satisfied, but represents a negative aspect of satisfaction. Thus, the satisfaction denotes a "pleasure coming from the realization of what is expected" [11]; dissatisfaction is marked by displeasure, that is, a negative feeling.

So based on the relationship between these two variables: satisfaction and attribute functionality, the model can explain the tendency of satisfaction of an attribute by some categories previous mapped as [9], also illustrated on Fig. 114.1:

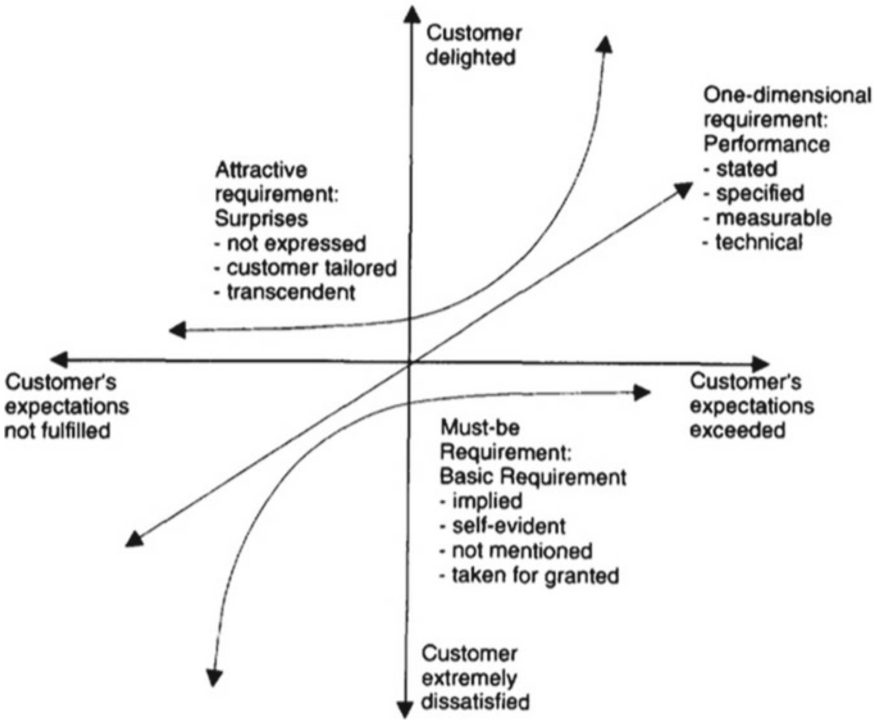

Fig. 114.1 Job satisfaction evolution on Kano's model

- Attractive (A): The attribute falling in this category generates absolutely positive satisfaction while customers will not be dissatisfied at all when it is not fulfilled;
- One-dimensional (O): The presence of the attribute in this category will increase satisfaction level, while its absence will proportionally decrease satisfaction level;
- Must-be (M): The attribute classified in this category consists of the basic criteria, and it will be extremely dissatisfied if it is not fulfilled. However, its fulfillment does not increase satisfaction level because it was taken by granted.

To classify the attributes in these categories, the Kano model proposes the measurement of the satisfaction given the functionality of the attribute using a qualitative scale of five points. It is interesting to note that the classification of attributes is done through the perception of consumers through an instrument, usually a questionnaire. Thus, in order to obtain the final classification of an attribute it is necessary to consolidate the answers of the various respondents consulted. For this, several resources can be used to aggregate the data as probabilistic models and fuzzy logic, among others [14].

114.2 Results

For each attribute was presented a couple of questions that the participants can answer in five different ways. The first question is concerned with the reaction of participants when the attribute is present (functional form). The second question is concerned with the reaction of participants when the attribute is absent (dysfunctional form). By combining the responses, it can determine the category of the analyzed attribute. In Table 114.2, the different results from the answers combination are presented.

To consolidate the answers of the various respondents consulted, two coefficients can be used - the Satisfaction Coefficient and the Dissatisfaction Coefficient—which combined results in the final attribute classification [3]. The great advantage of this methodological choice is given by the predefined parameters of the coefficients, as well as the validation of this in other previous studies [13].

For evaluation of work attributes, a group of two questions for each attribute based on Kano's model logic was proposed (i.e., one question functional and another one dysfunctional). The questions were elaborated based on the work attributes' descriptions. On Table 114.3, the functional questions are organized by each attribute [2]. To turn a functional question into a dysfunctional one, just put "no" in the sentence.

The classification of the attributes must be extracted for each interviewee, tabulated and compiled. The compilation of the answers was made based on the customer satisfaction coefficient [3]. The CSC indicates the percentage of respondents who were satisfied with the existence of an attribute and the percentage of respondents who are dissatisfied with the absence. The CSC is determined through two indexes, the satisfaction coefficient (SC) and the dissatisfaction coefficient (DC), calculated as follows:

$$\mathrm{SC} = \frac{\%\mathrm{A} + \%\mathrm{O}}{\%\mathrm{A} + \%\mathrm{O} + \%\mathrm{M} + \%\mathrm{N}}$$

$$\mathrm{DC} = \frac{\%\mathrm{O} + \%\mathrm{M}}{\%\mathrm{A} + \%\mathrm{O} + \%\mathrm{M} + \%\mathrm{N}}$$

The CSC is interpreted graphically through the formation of quadrants referring to the categories of the Kano model. The position of the lines separating the quad-

Table 114.2 Possible results by Kano's answer scale

Functional answer	Dysfunctional answer				
	Like	Must-be	Neutral	Live-with	Dislike
Like	Questionable	Attractive	Attractive	Attractive	One-dimensional
Must-be	Reverse	Indifferent	Indifferent	Indifferent	Must-be
Neutral	Reverse	Indifferent	Indifferent	Indifferent	Must-be
Live-with	Reverse	Indifferent	Indifferent	Indifferent	Must-be
Dislike	Reverse	Reverse	Reverse	Reverse	Questionable

Table 114.3 Diagnostic instrument questions based on the twelve factors of literature

Dimension	Attribute	Question
Inner life and identity	Identity	How do you feel when you can find identity at work?
	Belonging	How do you feel when you can find belonging at work?
	Values	How do you feel when you can find values at work?
	Inner life	How do you feel when you can find inner life at work?
Purpose and meaning	Coherence	How do you feel when you can find coherence at work?
	Cohesion	How do you feel when you can find cohesion at work?
	Purpose	How do you feel when you can find purpose at work?
	Meaning	How do you feel when you can find meaning at work?
Community and connection	Climate	How do you feel when you can find good climate at work?
	Community	How do you feel when you can find community sense at work?
	Connection	How do you feel when you can find connection at work?
	Environment	How do you feel when you can find good environment at work?

rants is arbitrary, varying according to purpose. In our case, the percentage of 50% of unsatisfied respondents was considered too high for the separation between an attractive and one-dimensional attribute, so the separation line of these quadrants was reallocated to 0.30. The line separating the neutral and attractive quadrants was reallocated to 0.70. Thus, the classification of attributes can be arranged according to the following quadrants shown in Fig. 114.2.

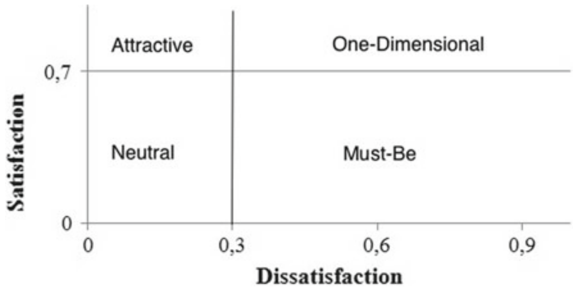

Fig. 114.2 Graphic analysis based on satisfaction coefficient

114.3 Conclusion

This article brings an upcoming topic that has been discussed on business and economic centered journals. This topic is a tendency of last workers generation that has influenced organizational changes on workplace. For these new workers, the job satisfaction cannot be measured by just financial returns and growth opportunities. The newest paradigm on workplace brings other attachments that have a human-centred perspective. These attachments can be understood by three dimensions of spirituality: inner life space; sense of purpose; and sense of community. This research proposes an instrument based on Kano's model that can map the worker satisfaction level behavior related to attributes of these spiritual dimensions. The worker satisfaction level was analysed by four categories established in Kano's perspective: attractive; one-dimensional, must-be and neutral; allowing managers to perform strategic attitudes to fit workplaces into the newest workers' expectations.

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