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João Reis
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Industrial Engineering and Operations Management I

XXIV IJCIEOM, Lisbon, Portugal, July 18–20

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Nuno Melão
Editors

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Preface

Industrial engineering and operations management (IE&OM) are enabling enterprises around the world to adapt and survive to turbulent environments. IE&OM are becoming more and more relevant to overcome complex situations in a digital era, where innovation cycles are increasingly shorter.

As IE&OM are playing a pivotal role, the series of International Joint Conference on Industrial Engineering and Operations Management (IJCIEOM) is offering to researchers the opportunity to share their current research, to establish new partnerships and to publish their articles. This joint conference is a result of an agreement between ABEPRO (Associação Brasileira de Engenharia de Produção), ADINGOR (Asociación para el Desarrollo de la Ingeniería de Organización), IISE (Institute of Industrial and Systems Engineers), AIM (European Academy for Industrial Management) and ASEM (American Society for Engineering Management) with the objective of promoting relationships between researchers and practitioners from different branches, and to enhance an interdisciplinary perspective of industrial engineering and management.

The International Joint Conference on Industrial Engineering and Operations Management was the twenty-fourth conference in the IJCIEOM series. It was hosted by the Military Academy of Portugal, during 18th and 20th of July 2018. It included five relevant topics: Business models and Service science; Education; Logistics, production and product management; Quality and product management; and Operations management.

As the IJCIEOM18 call for papers attracted scientists from all over the world, the conference organizing committee received up to 200 submissions from 20 countries, out of which the scientific committee selected 49 top-quality papers. All the papers were reviewed by at least two scholars from the scientific committee, composed of renowned scientists specialized on the aforementioned topics. This Springer book is the first of two volumes and contains the first 24 chapters. Inside you can find papers that explore real-life phenomena under the IE&OM scope, thus, providing various perspectives in the fields of modelling, simulation, logistics, innovation, sustainability, healthcare, supply chain, lean manufacturing, operations

management, quality and digital. All these papers put forward novel approaches and relevant findings that shed new light to IE&OM.

We would like to mention a special thanks to the IJCIEOM referees for their great work in reviewing all the papers and to the keynote speakers for their contributions to push this field of science forward.

Amadora, Portugal — João Reis
Amadora, Portugal — Sandra Pinelas
Viseu, Portugal — Nuno Melão
October 2018

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Simulating Performance for One-Dedicated-Lane Light Rail System—A Case Study

Yasser Dessouky, Gladis Valladares, Carmen Valladares, Minnie H. Patel and H.-S. Jacob Tsao

Abstract This paper develops a study of the concept of a one-dedicated-lane light rail system with real world data from the Valley Transit Authority (VTA) two-dedicated-lane rail system using a simulation model. The model analyzed 14 train stations in the San Jose area that included the downtown plaza. The results showed that a one-dedicated-lane is feasible even at the different service time periods that the VTA light rail encounters throughout a weekday. Statistical analysis (ANOVA) was performed on the two different track configurations, different headways, and service-time periods to determine the effect they have on train speed. From the analysis, the results showed that headway has a significant effect on train speed. Our results demonstrated a promising potential of the concept of a one-dedicated-lane Bus Rapid Transit (BRT) or light-rail system for efficient operation, as an end-state or as an intermediate state of a two-dedicated-lane, space-efficient system, i.e. 150–250 words.

Keywords Simulation · One-dedicated lane transit systems · ProModel

1 Introduction

Traffic congestion remains a big problem in many urban areas. Light-rail or subway system is the classical and conventional mass transit system used in most developed countries while the Bus Rapid Transit (BRT) is a new mass transit system that has been adopted by both developed countries, such as the U.S., and emerging economies, such as China and Brazil [1–4].

In many urban or suburban commute corridors, right-of-way sufficient for a two-dedicated-lane BRT or light-rail system simply does not exist. For example, portions of the Eugene-Springfield BRT, named "EmX Green Line", in Oregon, U.S are implemented with only one dedicated lane [5]. To developing countries such as China, the

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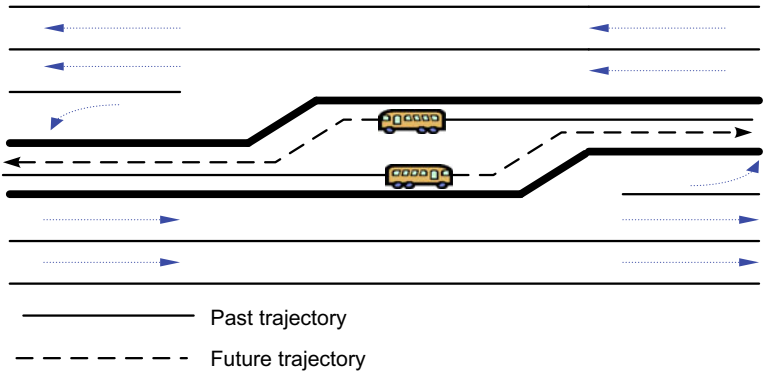

Fig. 1 Slanting of the dedicated lane and the crossing operation

construction and development of BRT or light-rail system requires significant amount of investment, which sometimes is a big hurdle to the development of an efficient mass transit system. These "chicken-and-egg", right-of-way and cost problems motivated Tsao et al. [6] to develop the concept of one-dedicated-lane BRT or light-rail train (LRT) system, which effectively requires only one dedicated but dynamically reversible lane in the median of an arterial serving a busy commute corridor with regular provision of left-turn lanes and significantly reduces the requirement of land and funding.

Conceptual design options and geometric-configuration sketches for the bus stop and crossing space have been reported in Tsao et al. [7]. for the dedicated lane and the crossing operation. Figure 1 illustrates the slanted geometric design of the dedicated lane and crossing operation. For busy commute corridors that have sufficient right-of-way but do not have sufficient demand to warrant dedication of two mixed-use lanes to public transportation, the proposed system could be very useful as an intermediate step toward a two-dedicated-lane system because of its potential for facilitating transit-oriented development. When the demand increases to such an extent that a two-dedicated-lane system is warranted, the one-dedicated-lane system can be expanded easily to a two-dedicated-lanes system proposed in Tsao and Pratama [8].

Computer simulation proves to be a very powerful tool for analyzing complex dynamical problems such as congested roads as shown in [9]. A potential use of the simulation framework to model the dynamics of a BRT system was presented in [10]. An overview of literature on the available analytic models for performance analysis of BRT systems along with a new dynamic microsimulation model implemented using Arena Rockwell Software to simulate and evaluate different BRT system configurations are given in [11]. Commercial speed is one of main parameters to evaluate public transport service performance. A simulation model is developed in [12] for one-dedicated lane BRT/light rail systems with different speed control rules to absorb the impact of stochastic demand on the performance of a closed system (with the

surrounding traffic ignored or its effect negated) based on the commercial simulation software ProModel.

The objective of this paper is to build on the operating rules already developed in [12] and use real world data to simulate a real case scenario of a one-dedicated-lane light rail system to test the feasibility of a one-dedicated-lane light rail system. The demand of passengers alighting the trains was considered and the real-world data used for this project was obtained by the Santa Clara Valley Transportation Authority (VTA). The VTA is an independent special district that provides transportation options throughout the Santa Clara county. One of the transportation options offered by the VTA is light rail services. This light rail service system used a dual-track. Light rail services are offered seven days a week for San Jose, Santa Clara, Mountain View, Sunnyvale, and Campbell [13]. A section of downtown San Jose light rail system, starting from the Convention Center station and ends at the Tasman station, is the focus of this case study. Real world data was used to simulate a 24-h weekday in September 2015 on the light rail route 902. For this purpose, in Sect. 2 ProModel simulation model of [12] along with the necessary modifications is presented followed by input data modeling in Sect. 3. In Sect. 4 simulation results are analyzed along with statistical comparison of two-dedicated lanes system with the one-dedicated lane system. Finally, conclusions are presented in Sect. 5.

2 Simulation Model

This real case study follows route 902 and only focusing on the stations starting from the Convention Center to Tasman (see Fig. 2). This path was chosen because it is a straight path and included the downtown area of San Jose.

The system has fourteen passing nodes connected by thirteen links. The backbone the single-track train and passenger system in the ProModel software is use of location objects. These location objects serve the function of allowing a space for the entities to arrive, exit, route, and interact. Two types of locations were used: “Benches” and “Train stops”. Two types of entities were used: “People” and “Train”. The people entities are also known as the passengers entering the system by arriving at a train stationX then move onto a pre-selected destination and finally exiting the system upon arrival to their desired station. The train entities that can only travel between train stops along the predefined bidirectional path network at variable speeds. A path network is used to represent the path that the trains use to travel between locations. The distance between locations in the path network was obtained from data from the VTA and was converted to feet. This study focuses on which train station the trains are crossing (i.e., passing), how frequently and how this affects the headway goal. This network will ignore the effects of traffic signaling and private car interference on the model. Signal priority given to public transportation is assumed and should minimize the effect of traffic signaling on the model. Speed was adjusted by the simulation but final speed results will be compared to trains speed limitations in the real world. Arrivals of people occur at the fourteen train stops and one train arrives at TSI Convention Center location and one arrives at TS14 Tasman location at the

Fig. 2 Section of route 902

start of the simulation. These two train stations are located at the beginning and the end of the route path respectively. Attributes, global variables, and passenger arrival distributions are appropriately defined to simulate the single-tracked system using as much real world data possible.

Past LRT/BRT performance analysis and studies focus on developing models to estimate the average train speed in the system and use it as a parameter to evaluate a LRT's service performance [11]. In general, LRT system has variables such as signal priority, vehicle technologies, fleet size, and schedule design that can affect train speed. The overall structure of this ProModel simulation integrates both a LRT model and a passenger model. This model was developed to analyze LRT system downtown San Jose assuming signal priority, and with no private car interference.

3 Input Data Modeling

Table 1 summarizes various types of inputs used by the model. Details of each type of input is given next. Data for the selected route for 2015 measured an average ridership of 34,935 on a weekday [13]. The section of route 902 consists of 14 train stations. From this ridership data, the arrival patterns of passengers at each station were analyzed.

Data from the month of September was used to get enough information regarding the interarrival times of passengers boarding the light rail at each station during the four services time periods (5:00 AM to 9:00 AM Peak AM; 9:00 AM to 3:00 PM Midday, 3:00 PM to 7:00 PM Peak PM, and 7:00 PM to 5:00 AM off peak). The

Table 1 Inputs for ProModel

Limits	Demand	Trains	Traffic control	Service goals
Distances between train stations (excluding traffic lights)	Passenger's arrival/demand distribution at every train station	Train distance length for every segment	Not applied in this study	Scheduled departure headways

daily interarrival times of each weekday were averaged at each station and for each service time period. These average interarrival times were used to estimate statistical distributions of interarrival times at each station for each service time.

Distance between stations strongly affects the train speed. In this case study, each road segment between train stations has its own unique value. The distances between train stations were measured using Google Maps and verified with documentation from VTA Facts of the Current LRT System Data. Total Route being analyzed is 6.7 miles.

VTA LRT specifications were considered in the simulation. VTA has 100 vehicles currently operating. Length of each train is 90 feet. Capacity per cart is 66 seated and 105 standing passengers for a maximum capacity of 171 passengers per cart. Trains usually travel with two carts allowing for a total capacity of 342. VTA LRT do not stop at a station if no passengers are waiting to load/unload but for this project the LRT will stop at each station.

Currently the VTA LRT System has implemented a speed and safety program where they have identified low-speed zones along the route 901/902. The LRT operates at 35 mph (3080 fpm) from TS1 Convention Center to TS14 Tasman except between the three stations TS2 San Antonio and TS4 Saint James in the downtown area where the LRT travels at 10 mph (880 fpm). Maximum speed in freeway median is 55 mph (4840 fpm).

Headway is the time between consecutive services. For example, if you catch a train that "comes every half hour," then the service you catch has a headway of 30 min.

VTA LRT route 902 runs for 20 h on a weekday with trains arriving at 15, 30, 60 min depending on the time of the day. The earliest train leaves at 5:08 AM and the last train drops off the last passenger at 12:41 AM. Headway encompasses travel train speed, distance length, passenger boarding and alighting time. A relationship between a headway and the required average transit-vehicle speed has been previously developed, given the values of some important operational parameters. All LRTs in model are assumed to have an identical acceleration rate and an identical deceleration rate, but they may have a different travel speed. The travel speed of a train, after acceleration at the common constant rate but for a varying required duration, varies to accommodate the difference in section length and the difference in passenger boarding and alighting counts. This study looked at 2–3 min headways used by VTA LRT system train schedule to determine the needed train speed to ensure passengers did not wait longer than 15 min for the next train.

4 Results and Discussion

The simulation was run for 4 different service time periods. To model a weekday, the peak service periods the simulations were run for 4 h and the midday and off peak periods of the simulation were run for 6 h. Eight hours of warm up time was added to the beginning of the simulation run-time to ensure we reach a steady state.

The average time that a passenger spent in the system was about 29 min. From the VTA schedule the average time for a passenger to go from station 1 (Convention Center) to station 14 (Tasman) would be about 30 min. Our results showed a realistic time for the passengers to be in the system.

The Peak service periods had less passengers exit the system which is expected since the simulation was run for 4 h instead of 6 h and therefore passengers had more time to exit the system in the Midday and Off Peak periods. The one-lane simulation could handle even the most demanding time of day which is the morning Peak time. The total number of passengers that went through the system was 17,919. This number is consistent with the average ridership from the VTA data. The time that passengers waited for a train was about 15 min which once again is consistent with VTA data since trains are scheduled to arrive at a station every 15 min.

The results show the averaged steady state of the number of passengers on the LRT while in motion. The VTA LRT capacities state that that each cart can hold up to 171 passengers a combination of 66 seating and 105 standing. Usually two carts per LRT are dispatched on route so our total LRT capacity is 342 passengers. In this simulation, there are two LRTs running at a time on the track and going in different directions, increasing our total capacity for passengers on to 684. The maximum number of passengers the two trains carried were 531.20, 534.80, 391.00, 641.60 for the service periods Peak AM, Midday, Peak PM, and Off Peak respectively. None exceeded the LRT's passenger capacity.

From the VTA Data there is a 2 or 3-min travel time between stations. Train speed experiments were done using the simulation by changing the headway from ± 1 min in increments of 30 s to determine the speed of the trains to get to the next station on time. Combination numbers (1, 2), (1.5, 2.5), (2, 3), (2.5, 3.5), and (3, 4) were assigned to the headway pairs (Headway2, Headway3). For example, combination 1 assigned Headway2 segment a value of 1 min and Headway3 segment a value of 2 min. These headway experiments were done for all four service times. As the headway was decreased the train speed increased to compensate. Inversely when the headway time was increased the required train speed was lower (see Eq. (1)). This is because of the function that is used to calculate train speed.

The attribute "aTrainSpeed" is a real number and is equal to the speed the train must travel to reach the next station. The speed is determined by several global variables as defined in the following equation:

$$aTrainSpeed = \frac{PathDistanceX}{(HalfHeadwayZmin - X)} \tag{1}$$

PathDistanceX is the distance between locations and HalfHeadwayZmin is the time it takes a train to load/unload and travel to the next train station. The variable X works to compensate for the time that the train spends at the train station loading/unloading passengers. This model assumed that the train will stop at each station regardless if there are passengers waiting to load/unload.

From the simulation results for the average train speeds at all the path segments for the service time Peak AM, we conclude that there is not much opportunity for further improvements on the headway when going from a two-track system to a one-track system. Looking at the train speeds it is not possible for the LRTs to ever function using the combination 1 headways. As mentioned before the maximum LRTs speed in a freeway median is 55 mph (4840 fpm) and the trains exceed that value in almost all the path segments in this combination.

For the one track and using headway combination 3, the global variable "vTrain-SpeedXtoY" showed that the train speed was the slowest at a speed of 5 mph (453 fpm) on the path segment from station 2 to station 3. The fastest speed the trains travelled were at a speed of 27 mph (2474 fpm) on the path segment from station 9 to station 10. Some path segments showed an increase in speed as opposed to others because the time to load/unload passengers might have resulted in less time to get to the next station. These speeds fall within our real case scenario requirements. The Downtown San Jose transit mall has a maximum light rail speed of 10 mph. Stations 2–4 are part of Downtown and the simulation showed the speed at both these path segment to be right under 10 mph.

A three-way ANOVA was run to examine the effect of the factors, service time (A), headway (B), and the number of tracks (C) had on train speed. The number of tracks used were single and dual. The data was analyzed in Minitab. All the interactions (AB, AC, BC, ABC) showed no significance since the F-value < F-critical and the P-value > 0.05. Only the factor headway showed a significant effect on train speed since the F-value = 35.59 > F-critical = 2.389 and the P-value = 0 < 0.05. Thus, different headway combinations produce a significantly different train speed.

5 Conclusion

A real-world simulation study of the concept of a one-dedicated-lane light rail system with real world data from the VTA two-dedicated-lane rail system was presented. The model showed only one instance when the trains had to wait at train station 7 to pass each other and the wait was about 20 min. Further changes to scheduling can be done to optimize the headway to decrease the model's WaitXCtr time. The results showed that a one-dedicated-lane is feasible even at the different service time periods that the VTA light rail encounters throughout a weekday. Statistical analysis (ANOVA) results showed that headway has a significant effect on train speed. Our results demonstrated a promising potential of the concept of a one-dedicated-lane BRT or light-rail system for efficient operation, as an end-state or as an intermediate state of a two-dedicated-lane, space-efficient system.

Traffic signal logic can be added to improve the model's real-world simulation of the San Jose downtown area. As of this study there are 34 traffic lights along the path of the route. To add more realism to this scenario the model can be adjusted with actual data used by the VTA for signal prioritization of light rail trains. VTA gives some LRT signal priority at certain areas along the system. More research will be needed to denote which of the 34 traffic lights give signal priority to the LRT versus those that do not. This will greatly affect the train headway and train speed. Traffic demand patterns for the areas surrounding the light railways would also add another layer to the realism of this model.

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Risk Assessment in Fluid Penetrant Inspection (FPI) of Critical Parts via Bayesian Belief Networks and Analytic Hierarchy Process

J. C. Pereira, G. B. A. Lima, A. D. F. Figueiredo and T. H. G. Frinzi

Abstract This paper discusses the framework for identifying high risks in the Fluid Penetrant Inspection (FPI) of critical parts, based on Analytic Hierarchy Process (AHP) and Bayesian Belief Network (BBN). This topic is very important because the inspection of critical parts with Fluid Penetrant (FP) in the industry is very critical. The correct selection and use of an adequate analysis method is key to the success of the inspection. If risks are not identified and proper responses are not provided, catastrophic accidents can happen. In this study, potential risks factors and typical scenarios pertaining to FPI have been investigated based on the most current literature on the subject and validated by process experts. The combination of probability and the impact identified the most significant risks. As a result, the method revealed that the most significant risks in the FPI of critical parts are Negative Organizational Factors, Unfavorable Control/Environment and Operator Failure. The conclusion is that the proposed method is an invaluable source for safety engineers and decision makers in companies, in the sense that it augments their information and help to identify critical risks in FPI of critical factors and implement actions to avoid critical parts failure and improve the safety in the inspection of critical parts.

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Keywords Risk assessment · Bayesian belief network · Analytic hierarchy process · Critical parts · Fluid penetrant inspection

1 Introduction

This paper aims to present a methodology to identify risks of undesired events during the FPI of critical hardware. The inspection of critical hardware with Fluid Penetrant Inspection (FPI) has been widely used in manufacturing industry for many years. While the process gives satisfactory results, it presents a variety of risks capable of compromising the viability of an organization. So it is very critical to identify and control these risks. FPI is a very detailed and critical process, has many process variables and depends on the performance of Hardware, Human Beings, Software and the Environment. Dangers, risks, and many critical elements are present in the several activities necessary to inspect a critical part with FPI. In order to identify risks and risk factors, a qualitative and quantitative risk analysis is critical.

This study is very important and is an invaluable source for maintenance professionals, safety engineers and decision makers in companies, in the sense that it augments their information and help to identify critical risks in FPI of critical factors. It can avoid critical parts failure and improve the safety in the inspection of critical parts. As far as the authors are aware and based on literature researched, AHP and BBN has not being used yet to identify risks in the FPI. In critical applications, the risk factors that affect the sensitivity of the inspection need to be known and addressed [1]. Capillarity Effect Analysis for Alternative Liquid Penetrant Chemicals in inspection process and the influencing factors was presented [2]. a. Risks can be avoided, shared, transferred, minimized or mitigated with suitable strategies [3].

The main contribution of the study is the increase of knowledge concerning the relationship between risk factors and failure in the FPI of critical parts. It also provides a method to assess the risk factors related to FPI failure, based on an in-depth analysis of current literature about the process and knowledge from experts. The study can help operational managers in the industry by providing knowledge about risks of FPI failure and respective responses to improve the quality and safety of the inspection process. In order to attain the research objective, the following research questions are answered:

Research Question 1. What are the major risk factors related to FPI of critical parts?

Research Question 2. What are the risk responses to improve the process and prevent FPI failure?

In this study, Sect. 2 presents Risk Probability estimation with BBN (Bayesian Belief Network), Sect. 3 describes Risk Effect (Impact) Analysis with Analytic Hierarchy Process (AHP), Sect. 4 the Method, Sect. 5 the results and finally Sect. 6 presents the Conclusion.

2 Risk Probability Estimation with BBN (Bayesian Belief Network)

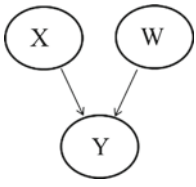
Bayesian Networks (BNs), also called Bayesian Belief Networks (BBNs) has been used to gain deeper insight into risks mainly in high-risk industry, such as the construction industry. An organization with a good safety program can have safety performance as a competitive advantage [4]. Bayesian networks have also been used for structural system reliability reassessment, with the incorporation of multiple failure sequences, and correlations between component-level limit states [5]. Bayesian approach has been used to aggregate expert estimates on human error probabilities to build a computable model using information from aggregate expert judgments [6–8].

BN can be used by HRA professionals and can be modified to incorporate data and information to address many of the shortcomings of human reliability analysis [9]. Human factors always affect operations performance, and systems availability and reliability. BBN has also been applied in the study of human reliability in the maintenance tasks in order to understand better how human factors influence maintenance performance [10]. None of the above previous studies deals with the application of BBN in FPI. In this study BBN is used to obtain the combined probability of risk factors. BBN was applied to this study with success. BBN has been widely used in the industry to estimate risks. The objective of Bayesian Network methodology is to allow easier predictions of risk events; it is a structure representing arguments when uncertainty exists. The nodes represent the variables and the arcs the direct dependency between those. As an example, Fig. 1 represents a BN, being node Y the consequence from causes X and W. In Fig. 1, nodes W and X are fathers of H and are called ancestral of Y.

Considering Software Reliability analysis, for example, the nodes X and W represent software failure conditions and node Y represents software error probability conditioned to software performance conditions X and W. A conditional probability table represent variables in each node. The Eq. (1) represents the probability of occurrence of variable Y based on the occurrence of nodes X and W.

$$p(Y) = \sum_{i=0}^{1} \sum_{j=0}^{1} p(Y = 1/W = i, X = j)p(W = i)p(X = j) \tag{1}$$

Fig. 1 Bayesian network



For example, Eq. (2) shows the probability of variable Y being true, depending on the variables X and W being true or false.

$$\begin{aligned} &p(Y = true) = \\ &p(Y = true/X = true, W = true)p(X = true)p(W = true)+ \\ &p(Y = true/X = true, W = false)p(X = true)p(W = false)+ \\ &p(Y = true/X = false, W = true)p(X = false)p(W = true)+ \\ &p(Y = true/X = false, W = false)p(X = false)p(W = false) \end{aligned} \quad (2)$$

3 Risk Effect (Impact) Analysis with Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP), introduced by Thomas Saaty (1980), is an important tool to help in the decision making process, and may be used by decision makers to define priorities and make good decisions [11]. Previous studies addressing the application of AHP are for example the one related to the combination of Bayesian Belief Networks to select the most significant risks in manufacturing process. This combination allowed decision makers to identify critical risks, aiming at allocating resources to improve the quality and safety [12]. The author proposed the use of pairwise comparison to evaluate alternatives. The method has been used extensively to solve complex decision problems. It divides a difficult problem into smaller parts aiming at ranking them hierarchically. Thus, relative importance of alternatives is weighted accordingly. None of previous studies related to the AHP deals with its application in FPI. In this paper, AHP is utilized to weight/prioritize the key risks affecting the stacking process. The AHP is an excellent tool to provide weight for the different risk levels; the first phase is to create a pairwise evaluation matrix (A) by utilizing the relative importance scale shown in Table 1.

The matrix A represents a pairwise evaluation matrix where each element a_{ij} ($i, j = 1, 2, \ldots n$) represents the proportional importance of two compared elements (i and j). The higher its value, the stronger the preference of first element (i) over the second (j). The matrix is shown in Eq. 3.

Table 1 Relative importance scale

Importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Absolute extreme importance
2, 4, 6, 8	Intermediate values

Table 2 Random consistency index

n	1	2	3	4	5	6	7	8	9
RCI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix}, a_{ii} = 1, \quad a_{ji} = \frac{1}{a_{ij}}, \; a_{ij} \neq 0 \tag{3}$$

Subsequently, the priority weights of each criterion are established with the next equation:

$$w_i = \frac{1}{n}\left(\sum_{j=1}^{n} a_{ij}\right) \Bigg/ \left(\sum_{k=1}^{n} a_{kj}\right) \tag{4}$$

The succeeding step in the AHP method is to demonstrate reliability of data. A basic equation was suggested to check if the evaluation pairwise matrix is reliable. The consistency index (CI) is calculated as follows:

$$CI = (\lambda_{max} - n)/(n-1) \tag{5}$$

where n is the order of the matrix A and $\lambda_{\max}$ is its dominant Eigenvector, which satisfies the following equation:

$$\sum_{j=1}^{n} a_{ij} w_j = \lambda_{max} w_i \tag{6}$$

Consistency ratio (CR) estimation is then needed to verify the sensible consistency. The CR value can be estimated by Eq. (7). The CR value needs to be equal or smaller than 0.10 if not the expert elicitation needs be revised to get a reliable result. In the equation, CRI represents the random consistency index (RCI).

$$CR = CI/RCI \tag{7}$$

The RCI assessment table is obtained from Table 2.

4 Methods

In this paper BBN is used in conjunction with AHP to find out these major risks in the FPI of critical hardware. All relevant risk factors were gathered from the most current literature on FPI of critical parts and were classified by the authors into six categories named: Manpower, Material, Method, Machine, Environment and Organization. These were validated by experts, who also estimated the probabilities of risk occurrence. In the probability elicitation process, the experts were asked to validate the probability level (very likely, likely, possible, unlikely or very unlikely) for each risk factor contributing to FPI failure when processing critical parts. The probability levels were converted to probability level scores and loaded into BBN to obtain the final risk probabilities. The reliability of the information was ensured by selecting experts having experience with FPI, involvement with operational side, academic training, familiarization and knowledge of the several different aspects of the subject. The same experts evaluated the impact of the risks by pairwise comparisons using AHP. Although these methods have been used is several different applications, as far as the authors are aware, the adoption of AHP in the FPI inspection of critical parts has not been reported yet and this seems to be the first time this approach is being used in this case.

5 Results

All relevant risk factors gathered from the most current literature on FPI of critical parts were classified by the authors into six categories named: Manpower (Man), Material (Mat), Method (Met), Machine (Mac), Environment (Env) and Organization (Org). The classification identified 12 factors related to Manpower (Man1–Man12), 12 related to Material (Mat1–Mat12), 12 related to Method (Met1–Met12), 12 related to Machine (Mac1–Mac12), 12 related to Environment (Env1–Env12) and 12 related to Organization (Org1–Org12). The risk factors were classified on probability levels based on Table 3 and listed in Table 4.

Table 4 shows the risk categories and the associated risk factors.

Table 3 Probability level scores

Probability score	Probability level	Probability
5	Very likely	More than 0.8
4	Likely	0.5–0.8
3	Possible	0.31–0.50
2	Unlikely	0.11–0.30
1	Very unlikely	Below 0.10

Table 4 Probability level scores

Event	Risk factors	Probability level
Man1	Operators not trained properly and lack of knowledge of defects	2
Man2	Operator lack of attention	2
Man3	Operator distraction	1
Man4	On the job training not performed	1
Man5	Training material poor	1
Man6	Horizontal communication poor	1
Man7	Preventive maintenance operator error	1
Man8	Operator skill and experience	2
Man9	Operator fatigue	1
Man10	Visual acuity, color vision	1
Man11	Inspectors attitude and motivation	2
Man12	Eyewear	3
Mat1	Unsuitable penetrant	1
Mat2	Unsuitable emulsifier	1
Mat3	Unsuitable developer	1
Mat4	Unsuitable cleaning solvent	2
Mat5	Penetrant not tested for effectiveness	1
Mat6	Emulsifier not tested for effectiveness	1
Mat7	Developer not tested for effectiveness	1
Mat8	Surface condition of part	2
Mat9	Complexity of part	2
Mat10	Defect type	1
Mat11	Defect dimensions	1
Mat12	Loading condition of part	1
Met1	Cleaning and etching procedure not defined	1
Met2	Cleaning and etching procedure wrongly defined	1
Met3	Penetrant application method not defined	1
Met4	Penetrant application method wrongly defined	1
Met5	Dwell time and emulsification time not defined	1
Met6	Dwell time and emulsification wrongly defined	1
Met7	Emulsification concentration not defined	1
Met8	Emulsification concentration wrongly defined	1
Met9	Developing time and application method wrongly defined	1
Met10	Developing time and application method not defined	1
Met11	Water pressure and air pressure wrongly defined	1
Met12	Water pressure and air pressure not defined	1

(continued)

Table 4 (continued)

Event	Risk factors	Probability level
Mac1	Timer failure	1
Mac2	Temperature indicator failure	1
Mac3	Calipers unserviceable	1
Mac4	Pressure meters failure	1
Mac5	UV light meter failure	2
Mac6	Refractometer failure	1
Mac7	Error in equipment calibration	1
Mac8	Calibration not performed	1
Mac9	Equipment missing	1
Mac10	Unserviceable equipment used	1
Mac11	Fluorometer failure	1
Mac12	Borescope inspection equipment failure	1
Env1	Inadequate water temperature and pressure	2
Env2	Inadequate materials temperature	1
Env3	Inadequate inspection booth white light intensity	1
Env4	Perceived pressure or haste	2
Env5	Space restrictions, illumination	1
Env6	Improper production planning	2
Env7	Time constraint	2
Env8	Unrealistic targets	2
Env9	Ergonomics - Man/machine interface	1
Env10	Inadequate oven temperature	1
Env11	Inspection variables (lighting) and inspection environment	2
Env12	Materials contamination (penetrant/emulsifier/developer)	1
Org1	Quality system ineffective	1
Org2	Preventive maintenance program ineffective	1
Org3	Lack of management oversight, control e monitoring	3
Org4	Training program poor	3
Org5	Incompatible goals	1
Org6	Poor production planning	2
Org7	Lack of materials	1
Org8	Inadequate safety culture	1
Org9	Inexistence of employee recognition program	1
Org10	Lack of equipment	1
Org11	Headcount inadequate	1
Org12	Lack of proper facilities	1

Table 5 Risk scoring matrix

Risk	Probability	Impact	Probability scoring	Impact scoring	Risk scoring
Operator failure	0.27	0.32	2	5	10
Improper material	0.15	0.16	2	4	8
Uncorrected method	0.20	0.21	2	4	8
Equipment/instrument failure	0.12	0.08	2	4	8
Unfavorable control/environment	0.49	0.11	3	5	12
Negative organizational factors	0.37	0.07	3	5	15

The risk factors listed in Table 4 were combined utilizing BBN to determine the probability scoring for each Risk, which are listed in Table 5. The impact of each risk was determined by pairwise comparison utilizing AHP and is listed also in Table 5.

In this study the proposed methodology on FPI process, the intolerable risks with the highest global scores were operator failure, unfavourable control and environment and negative organizational factors. Table 2 presents a summary of results obtained with the application of the methodology.

Important conclusions can be drawn from this application. If operator fails in the preparation of a critical parts surface before penetrant application, the driving force for the capillary are affected. Since the radius of the crack opening would be decreased by the presence of debris and oxides, the penetrant wet surface would be more than 90° and the height of penetrant above the free surface would be inadequate. This condition would not allow the penetrant to be drawn into surface breaking crack and so the sensitivity of the inspection would be affected and the crack would be missed, which is likely to result in a hazardous engine effect. If a crack is present on the surface of the hardware is missed in the FPI and the hardware is not removed from service, it will fail in operation with serious consequences. The use of an uncorrected method, such as wrong etching and cleaning of the part's surface, incorrect penetrant application, insufficient dwell and emulsification time, wrong emulsifier concentration, insufficient developing time and wrong application method, water and air pressure in excess, would not allow the penetrant to be drawn into surface breaking crack and so the sensitivity of the inspection would be affected. Penetration time is strongly dependent on the defect geometry, penetrant application procedure and by several others factors. The use of an incorrect method may lead to the failure of a critical part inspection and the missing of a crack, which is also likely to result in a hazardous effect. The specification of the correct method with the proper definition of all operating parameters is crucial for a reliable inspection. Operator failure and the availability of a wrong method can play a major role in the failure when all other variables are under control.

The method being proposed offers parameters and makes the decision makers more aware about the impact and probability scale of each risk. It ensures the scale is self-consistent and that the evaluation factors, which allow a quantitative assessment and evaluation judgements about alternatives, although subjective, are consistent. However, the method does not lead to an automated decision process, as the decision maker is still asked to express an opinion and is left with full responsibility of establishing a subjective priority among decision factors.

Unfavourable control and environment and negative organizational factors are very critical. Inadequate water and materials temperature and pressure, inadequate inspection booth white light intensity, perceived pressure or haste, space restrictions, illumination, improper production planning, time constraint, unrealistic targets, poor ergonomics in man/machine interface, inadequate oven temperature, inspection variables (lighting) and inspection environment, materials contamination (penetrant/emulsifier/developer) would also affect the sensitivity of the inspection. The unfavourable control and environment may lead to the failure of a critical part inspection and the missing of a crack, which is also likely to result in a hazardous effect. All the necessary controls and an adequate environment must be in place to ensure a reliable inspection.

The method ensures that the decision parameters, the priorities and the judgements are explicit and consistent. It is easy to implement and allows a quick rating of alternatives. Nevertheless, the method also has some limitations and does not eliminate the need to express subjective judgements. In particular, the adequacy of the choice of the risk to be responded is left to the decision maker, and the expression of the pair-wise preference between any two alternatives is left to a personal judgement.

6 Conclusion

The proposed method is important for several reasons. First, risk assessment using AHP is gaining importance in the industry and the adoption of multi criteria decision-making in the failure of critical parts in FPI has not been reported yet. In this study the methodology has been applied successfully in identifying the critical risk factors in the FPI of critical parts. Second, this study combines two approaches, the BBN and AHP and considers the risk of FPI failure as decision-making criteria. Third, the paper shows that the risk factors identified in this study are critical and must be controlled to avoid critical parts failure. The probability and impact of risks associated with FPI of critical parts were predicted quantitatively showing that preventive actions can be planned to minimize the downtime of the inspection process in production.

Operators are responsible to make sure the management of critical parts is effective to ensure parts are inspected periodically and removed from service, as per requirements defined in manufacturer approved technical data. They are also responsible for risk assessment in FPI inspection to ensure full compliance to manufacturer requirements in order to avoid accidents and loss of lives.

In response to the first research question, the method proposed in this paper identified the most critical risks in the FPI inspection of critical parts and can be used to plan risk responses to make the inspection more effective and safe. It is noteworthy here that it is not possible to infer these significant risks from a specialist's opinion only. The Bayesian Belief Network and Analytic Hierarchy Process (AHP) tools are very important in this process. As a by-product of the results, it is suggested that these methods should be used by companies to identify the critical risks in FPI of critical hardware.

In response to the second research question, the result of the study shows that actions to the significant risks should be taken, such as the definition of the criteria for training the FPI process operator theoretically and hands on (on the job training), the issuance of a detailed user friendly instructions for the operators and for the control of all variables of the FPI process. Awareness training of the production leadership and the people involved with production planning would also be very important.

In conclusion, this paper conceptualizes and demonstrates a new methodology illustrated with an application on the FPI on critical parts. The proposed new risk assessment method is very important to identify the most significant risks impacting FPI process and opened up some new research avenues for future and can be applied similarly in magnetic particle inspection, ultrasonic inspection, x-ray and eddy current. Further research is recommended to define a method to implement Six Sigma based projects aimed at avoiding the occurrence of the major risks identified in this study.

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The Team Process Capability Model: A Sociotechnical Theoretical Framework for Understanding How Teams Interact with Their Environment

Frederick S. Sexe

Abstract Numerous examples exist where teams and organizations perform at a high level only to see performance decrease over time. This phenomenon can be observed in manufacturing and engineering organizations where teams provide value to organizations through the use of tools, processes, and procedures to address customer needs. The rapid acceleration of digital innovations aimed at making teams more effective have actually compounded these problems by increasing the complexity of a task while ignoring the capability of the team to harness these new tools. The aim of this paper is to provide managers with a theoretical analysis of how sociotechnical interactions influence team and organizational performance within a larger context of environmental demands. This paper will propose a team process capability model to explain how dynamic social and technical interactions coupled with organizational decision-making influence team and organizational performance. The model will illustrate how team social and technical system interactions are influenced by managerial decisions which subsequently influences its performance. The concept of requisite process capability will be introduced to the reader within the context of resiliency factors such as dynamic capability and environmental uncertainty. Academic readers can benefit from this paper through applying the concepts within this paper to future research related to sociotechnical and organizational interactions. Managers can use the information shared in this paper to improve his or her understanding of how team performance is influenced by such systemic changes as digital and technical innovations or system complexity.

Keywords Dynamic capability · Organizational resilience · Operational performance

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1 Introduction

Examples exist in most every industry where a company begins with high performance levels but then suddenly experience a decline in capability. Companies such as airlines begin with high quality but experience slowly degrading quality until customers become disenfranchised and take their business elsewhere. Toyota, a company famous for its quality, saw its quality and reputation diminish between 1999 and 2010 when quality-related issues plagued vehicle designs which subsequently resulted in a decrease in customer satisfaction [2]. North American automobile manufacturers faced a similar dilemma in the 1990s and 2000s when management decisions contributed to the need for the 2009 automobile industry bailout. In all of these cases operational decisions were made without an understanding of how these decisions influenced the sustainability of the processes required to provide value.

A sociotechnical process capability model can explain this phenomenon by illustrating systemic interactions between the work domain and the environment. The work domain itself represents many factors relevant to the resilient capability of the team or organization to absorb and adapt to dynamic environmental elements (also called dynamic capability) [4]. An effective work domain design aligns social and technical system (also referred to as the sociotechnical system) interactions towards environmental factors based on organizational strategic objectives. Competency-based models are effective at explaining the maturity of an organization's process in relation to the work domain but fail to address the organization's ability to react to dynamic forces and absorb systemic variation at the point of failure. The ability to understand organizational process capability is critical in not only highlighting organizational shortcomings identified by competency-based models but also in developing organizational capabilities which in turn improve the organization's operational resilience [4]. The adaptation of organizational capabilities towards a more resilient work domain provides the organization with a sustainable competitive advantage within that particular environment [4]. The process capability model proposed in this paper provides a strategic overview of cognitive system elements in relation to the environment. The model also provides a template for applying such tools as competency maturity models, process mapping and cognitive work analysis within a larger systemic framework.

The process capability framework can provide valuable insights on how the cognitive system (defined by [5] as the ability of the sociotechnical system to *self-organize* and adapt to external variation) interacts both internally and in relation to the environment. The design of feedback mechanisms can also be designed to aid managers in detecting team performance issues before long-term team and organizational performance is negatively impacted. The sociotechnical model suggests that healthy organizations function when social and technical interactions are optimized towards an overall environmental requirement [7]. These interactions can begin to break down and lose effectiveness when demands placed upon them increase beyond a sustainable limit [6]. Prolonged operation of sociotechnical interactions beyond its sustainable limits can result in damaging long-term effects similar to the

dysfunctions observed in declining companies whose performance decline for no apparent reason. An underlying symptom in these scenarios are the lack of resilience present within the organizational design which prevents organizational entities from evolving social and technical interactions as required to address this dynamic complexity. In some instances, management actions (such as standardizing team-level work processes most vulnerable to dynamic environmental forces) can work to reduce a team's resilience and subsequently hastening the breakdown of the team.

A framework model can be developed with these factors of optimizing interactions from a social system and technical system perspective. The designed framework can provide valuable insights on how these cognitive system elements relate to both each other and the environment while also aiding in the design of feedback mechanisms to aid managers in detecting team performance issues before long-term damage to team performance occurs.

2 Sociotechnical System Overview

The sociotechnical system used in this model consists of three main elements. The social system (consisting of the individuals and interpersonal interactions within a team) represents the team members and the team's ability to leverage the competencies and expertise within it towards the team's goals. The technical system consists of processes, procedures, and tools assigned to and utilized by the team to exploit environmental elements identified by the work domain. The work domain subsequently represents the physical and purposive environment of the work environment the sociotechnical system is designed to address [6]. It is important to remember that the work domain is defined by the management function which defines the goals and purpose of the team and the environmental elements the team is designed to exploit [8].

A simple example of a defined work domain would be a menu designed by a restaurant. The menu would represent the work domain (i.e. which industry or niche that restaurant management decides to exploit) while restaurant employees hired to provide the menu items to customers would represent the social system. The recipes, utensils, and equipment used to create and serve the food would be the technical system. The demand upon the sociotechnical system would be that portion of the market that is addressed by what is defined within the work domain. An example of the work domain within an engineering or manufacturing context would be managerial decisions to design specific types of products to address a certain market niche while ignoring other potential markets. This act of deciding which products to make directly defines which part of the environment the sociotechnical team is designed to address. Note that decisions such as this can have ripple effects depending on the vulnerability of other sociotechnical systems within the same organization to environmental effects. For example, the decision to design and manufacture a certain product may indirectly influence the ability to support the product once it has been sold to the customer. A similar example can be made in most any other industry

where a team is designed and given resources to exploit a certain segment of an environment defined by management through the use of a work domain.

This emphasis on the sociotechnical system in process capability is important as the ecological elements of the system constrain the ability of an organization to exploit its environment [6]. The technical system can subsequently limit the social system through insufficient or ill-designed resources as they relate to the work domain. Therefore, any improvements made to the technical system require may require attention given to the social system (through such actions as providing training and assigning expertise to the team) for the full benefits of the improvements to be realized. Furthermore, prolonged design of a technical system without addressing the needs of the social system can result in team designs that are constrained by the technical system [5].

3 Sociotechnical Process Capability Model Elements

A team's process capability is depicted by social and technical system interactions (which are themselves individual subsystems within the sociotechnical system). The team process capability reflects a team's ability to absorb demands placed upon it by the environment through the work domain. Note that team process capacity and the work domain continuously change in size depending on a variety of factors. For example, team members can be replaced with newer team members resulting in both a change in social system size (the social system relies not only on the number of people within the system but the effectiveness of the interactions between team members) and team process capability (the newer team members may not be proficient in the technical system elements and would subsequently have less efficient interactions with the technical system and which may divert other team member interactions to train the newer team members). These changes can have drastic effects on the management and coordination of these elements if the feedback mechanisms used by decision-makers are delayed. These factors are illustrated in the sociotechnical team process model shown in Fig. 1.

The work domain is influenced by environmental demands related to the sociotechnical system design and subsequently changes in size relative to this demand. These demands create two scenarios where work domain demands affect team process capability differently. Team process undercapacity is a condition where the sociotechnical system interactions (represented as team process capability) is less than the demands placed by the work domain. Examples of the causes of undercapacity are a lack of social and technical system investment by the organization or an increase in work domain demand placed upon the sociotechnical system by the environment (e.g. an increase in the number of customers purchasing a product which subsequently increases the amount of interactions required meet the new demand for the product). Overcapacity in contrast can be caused by an overinvestment in social and technical elements or a reduction in the demands on the work domain (e.g. demand for a particular product has decreased). The effectiveness of a team

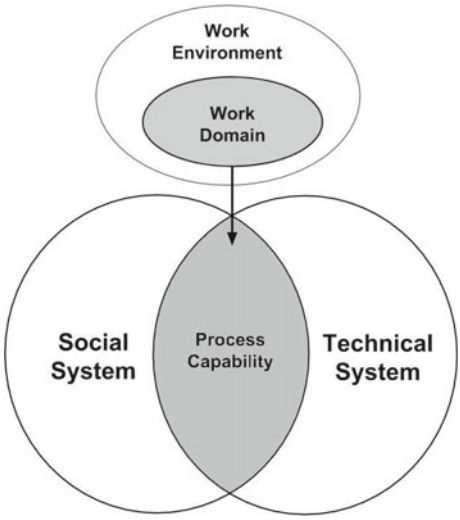

Fig. 1 The sociotechnical team process model illustrating relationships between the social system, technical system, work domain, and the work environment

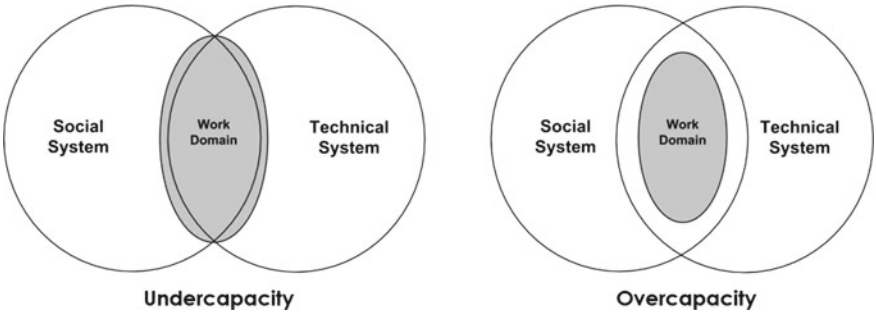

Fig. 2 Graphical depiction of the relationship between process capability and work domain demands

to absorb environmental demands via the work domain is illustrated by Fig. 2. It is important to remember that the work domain and team process capability are independent of each other; team process capability represents team capability to absorb work domain demands whereas the work domain represents the demands of the environment on the sociotechnical system design.

It is important to remember that sociotechnical system elements and the work domain continuously change in size. The social system can increase or decrease in size if team members or the interactions between team members change by such factors as the addition of new team members (resulting in a disruption in existing relationship patterns) or improved team member synergy. In the example of assigning or removing team members within a social system the social system can actually

shrink even though the number of team members may ultimately increase. This reduction in social system size stems from the fact that the effectiveness of a social system is defined by not only the number of team members within the social system but the ability of team members to exploit the strengths of other team members. The technical system changes in size if any of the elements within it are modified or replaced (e.g. a company moves to a new manufacturing resource planning (MRP) system). Note that a change in the technical system results in a corresponding shift in the relationship between the social and technical systems as the social system adapts to technical system changes.

The social system can shift leftward or rightward as social system element proficiency with technical system elements change due to experience or other similar factors. Note that this shift is relative to social system ability to use technical system elements as it pertains to the defined work domain. An example of a rightward shift would be a team that has overcome the "learning curve" associated with the use of new equipment or increased team proficiency after taking a training course on a new MRP system.

The technical system changes in size based on the amount of resources assigned to it and the relative ability of technical system elements to address work domain demands. The technical system can expand, for example, if additional resources related to the work domain are assigned to the system. A decrease in the size of the technical system can be caused by such factors as equipment wear and tear or a change in the work domain definition causing parts of the technical system to be obsolete. Note that the relative size of the technical domain is a reflection of the work domain itself and not the social system interactions aimed at the work domain. This distinction highlights the main difference between the technical system and both the social system and work domain.

The work domain expands and contracts based on two factors. The size of the work domain is initially influenced by how sociotechnical elements are aligned to address environmental factors. The work domain within this context can be referred to as a product mix of sorts that the social and technical systems are designed to work towards. This alignment typically stems from management decisions related to the purpose of the team purpose and the environmental elements the team is designed to exploit. The work domain is subsequently affected by the amount of environmental interactions related to the purpose of the sociotechnical system it has to absorb. An example of these interactions is an expansion of the work domain if demand for a product or service by the environment increases. Note that in the first factor the size of the work domain is influenced by managerial decisions whereas in the second factor the size of the work domain is influenced by customer-based decisions.

It is important to understand that the work domain and process capability area continuously evolves as managerial decision-making influences sociotechnical interactions between the work domain and the corresponding environmental elements. Management decision-making is based on feedback from important indicators of team performance models based on organizational goals and objectives. Figure 3 illustrates these resultant reactions by the sociotechnical system on these decisions. For example, managerial decisions changing the product mix (defined as the physical

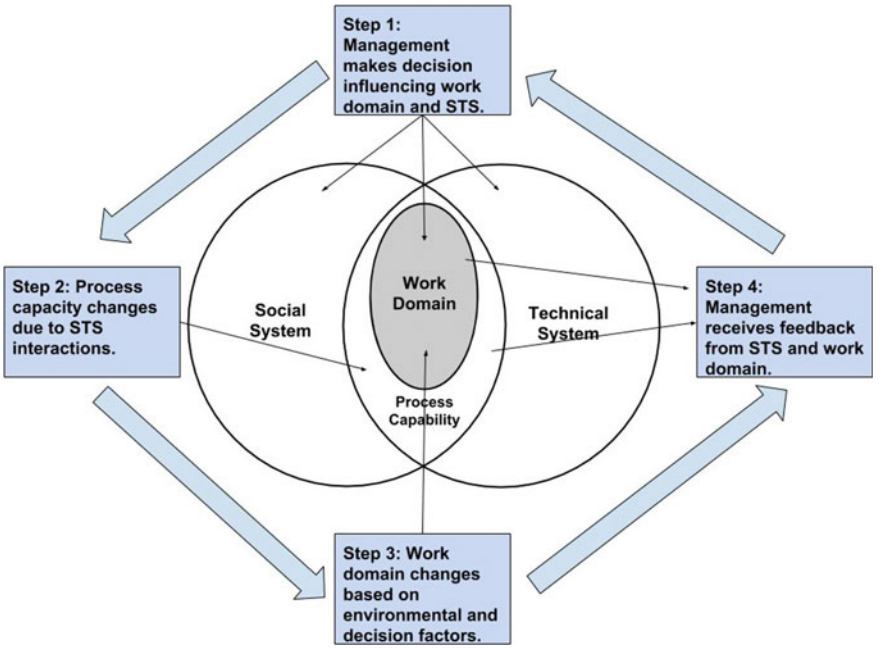

Fig. 3 Graphical illustration of work domain expansion

or tangible environmental items defined by the work domain) causes a corresponding change in the work domain (step 1). Decisions resulting in changes to elements of the sociotechnical system trigger changes in the interactions between the two systems which subsequently change the process capacity size (step 2).

The work domain changes in size due to the effects of managerial decisions upon the environmental elements the decisions are aimed at exploiting (step 3). The sociotechnical system begins absorbing environmental demands based on the work domain definition whereupon feedback signals representing sociotechnical system performance relative to the environment (market) are received by management (step 4). Environmental feedback can be from either the work domain (how much revenue has been made from work domain demands on the environment?) or the environment itself (what percentage of the market does the organization "own"?). The feedback received from the sociotechnical system (or process capability measures) and work domain (and/or environment) results in managerial decisions aimed at improving sociotechnical system performance or changing how it exploits its environment. Conversely, a change in environmental demands upon the sociotechnical system (e.g. change in demand for a particular product) may cause managerial decision-making aimed at realigning sociotechnical system elements towards other potentially more lucrative environmental factors (or a perceived increase in the ability to exploit the existing product mix).

4 The Team Process Capability Model

The team process capability model incorporates the sociotechnical team process model into a graph to illustrate the relationship between team sociotechnical interactions and environmental demands. The x-axis represents the output a particular sociotechnical system interaction and is denoted as the process output (P_o) (note that this can be an individual, team, process SIPOC (supplier, input, process, output, customer) cycle, or a string of numerous SIPOC interactions). The y-axis represents the process demand (P_d) placed upon the sociotechnical system elements responsible for the process output as defined by the work domain. The process demand in this context represents the work domain which subsequently increases or decreases based on the number of environmental factors it absorbs.

The diagonal line moving from bottom left to top right represents the point where P_o and P_d are equal ($P_o = P_d$). This reference point illustrates the point in the process capability model where the capability of the sociotechnical system (as represented by the team process capability) equals the demands of the work domain. Marginal process capability (Pm) represents the point where interactions between process output and process demand are maximized. Requisite process demand (P_r) is the point along the diagonal line where the team can sustainably meet the demands of the work domain. This location on the diagonal line can be considered the optimum operating capacity (homeostatic or harmonic balance) between the team's capabilities and demands of the work domain. Requisite process demand (P_r) should not be confused with the maximum team output; rather this is the point on the diagonal line in which the team can perform over the long term.

Marginal process capability (the highest point along the diagonal line where $P_o = P_d$) represents the highest point along the diagonal line where the team is able to match the work domain demands. Any rightward shift along this diagonal line (or a corresponding leftward decline in a team's process output (P_o)) results in a scenario in which the team is no longer able to adapt effectively to the work domain and therefore begins to suffer negative effects associated with undercapacity. Note that long-term team performance above the marginal process capability (P_m) may actually result in a lower requisite process demand (P_r) than previously maintained as long-term negative effects of work domain demands above its capability (e.g. team member burnout, increasing equipment wear and tear, employee attrition and replacement with newer and less skilled people, team conflict, suppliers providing low-quality parts to meet process demands) deteriorate sociotechnical system interactions and subsequently shrinking the team process capability (Fig. 4).

Note that requisite process demand (P_r) is below the marginal process capability; the points along the diagonal line between requisite process capability (P_r) and marginal process capability (P_m) represents the adaptation region where the team works harder to meet work domain demands by operating outside its normal homeostatic (harmonic) capability. Long term team performance with work domain demand between P_r and P_m can harm team capability over time but with consequences that are typically less severe and potentially temporary in nature if the factors leading to

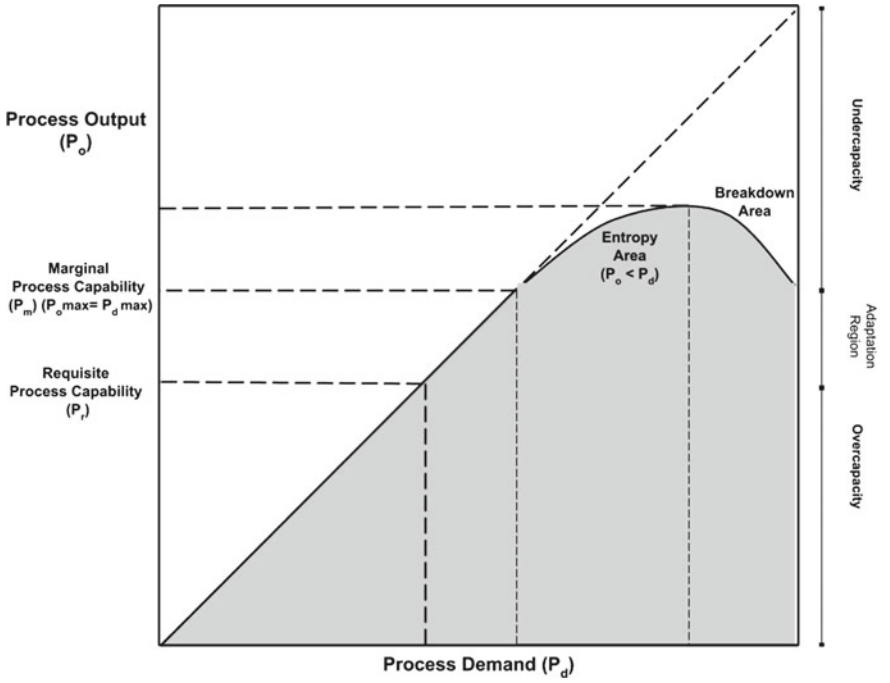

Fig. 4 The team process capability model

the increased demand are addressed in a timely manner (e.g. the team steps up to address a short-term spike in demand that returns to normal levels soon afterwards).

The curved line above the *marginal process capability (P_m)* represents the point in which *process output (P_o)* is no longer is capable of matching its output to a corresponding *process demand* (P_d)($P_d > P_o$). Teams performing in this region (called the *entropy area)* begin to suffer a form of *entropy* where additional efforts by the team to address the additional demand results in *diminishing returns* as the team expends more and more resources and energy for less results. The performance of teams within the *entropy area* may begin to suffer from long-term effects as the sociotechnical system begins to break down resulting in decreased future process output (P_o) over time. An increase in *process demand (P_d)* may result in a complete breakdown of the sociotechnical system under extreme circumstances resulting in a dramatic decrease in team performance. This sudden and dramatic change in performance (denoted on the process capability model as the *breakdown area*) results in a team breakdown which can create catastrophic effects which the team may not be able to recover from (e.g. team members quit, equipment irreparably breaks down, customers begin to leave). It is important to note that a team's shift into the *breakdown area* can also be caused by an expansion of the work domain with no corresponding increase in process capability in addition to a shift in *process output (P_o)* (Fig. 5).

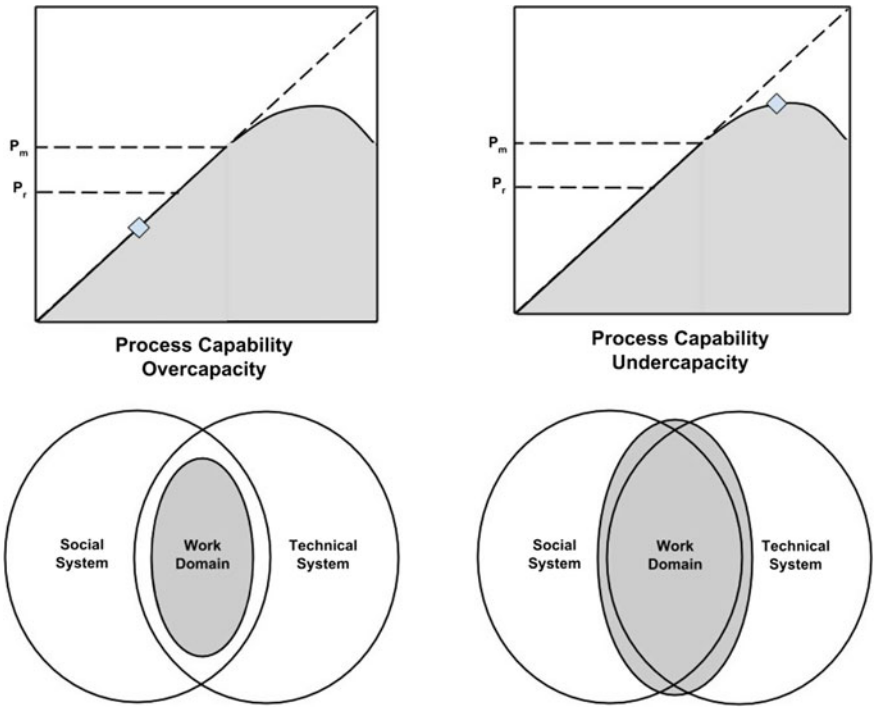

Fig. 5 Process capability illustrated on the sociotechnical and process capability models

5 Team Process Capacity Areas

Process capacity can be defined within three general areas of this curve. The overcapacity area is the points on the diagonal line where process demand falls below the requisite process capability and identifies when team process capability is higher than current demand. A general observation of the overcapacity area can suggest that the team has higher costs than needed to address work domain demands upon the environment. Note, however, that either (1) the section of the environment representative of the work domain increases and decreases due to such factors as changing demand for the work domain over time, (2) the social system interactions can increase and decrease over time as team transactive relationships (defined as relationships in which the team optimizes team member roles based on expertise or knowledge advantage) evolve over time or team member relationships evolve (either positively or negatively)., and (3) technical system elements break down or become obsolete (e.g. equipment breaks down due to wear and tear, processes and procedures become obsolete).

The undercapacity area is the opposite of the overcapacity area; the location on the diagonal line in which process demand exceeds the marginal process capability. Any points located on the undercapacity area results in a situation where environmental

demands on the work domain exceeds the capability of the team to satisfy these environmental demands. An important factor to remember within the context of the undercapacity area is the region between the marginal process capability and the requisite process capability where the team is still capable of maintaining process output sufficient to meet work domain demands through working harder and not through a sustainable level of performance.

An interesting aspect of the process capability spectrum is the adaptation area. The adaptation area is the set of points between the marginal process capability and requisite process capability where the team has exceeded its harmonic limit (defined as the homeostatic balance between the sociotechnical system and the work domain demands). Teams whose performance lies within this region will work harder in an attempt to meet the work domain demands. As stated earlier, prolonged performance in this region can ultimately lower the requisite process capability and subsequently shift the adaptation area downward (this downward shift occurs due to both a reduction in the harmonic balance between the sociotechnical system and the work domain demand and a long-term breakdown of the sociotechnical system. This region also represents the area along the process capability line that defines a social system's process resilience, defined as the capability to react to systemic disruptions and adjust its performance to changing conditions to restore operations to a normal or improved operating state [4]. The size of the adaptation region represents the amount of variation as represented by the process demand that the social system can absorb while also maintaining its current state. Process resilience can occur within this region with the adaptation of current processes through a continual learning process found in higher levels of team and organizational competence [3].

6 Conclusion

The team process capability model is an effective means to illustrate important interactions related to team performance. The model also illustrates the complex relationship between the sociotechnical elements and the environment as represented by the work domain (representative of the environment) and the process capability area (representative of the effectiveness of the sociotechnical system design). Future evolutions of the model can incorporate such factors as organizational resilience (through the expansion of the adaptation region) and dynamic capability. Individuals interested in competency and capability modeling can also use the model to illustrate team or organizational performance related to existing capability and competency metrics [3]. Metrics designed from prior context-specific research such as competency models can be readily applied to the model to improve understanding of existing process capability and their relationship to dynamic capability and resilience to better understand existing capabilities to absorb variation stemming from environmental uncertainty [4].

This model has several benefits to digital innovations. The developers of digital innovations can use this model in conjunction with cognitive work analysis tools to

aid in integrating the innovations into existing technical systems. Existing technical systems can be examined using the model to highlight potential opportunities for future digital innovations or ways to make existing ones more effective within a sociotechnical context. Specific interactions such as technical system feedback effects caused by the introduction of digital innovations can also be shown using the model to aid decision-makers in identifying potential weaknesses within an existing structure [3].

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Reverse Logistics Costs: Case Study in a Packaging Industry

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Abstract With the issue of sustainability on the rise, companies are beginning to take measures to mitigate the environmental impacts generated by the production process. In addition, legislation is becoming more severe on environmental issues, and this factor involves the correct disposal of waste produced by companies. Thus, the reverse flow of the products for their recycling becomes more and more important every day. From the knowledge of the costs involved in this reverse flow, the company can better understand this process and implement improvements in order to reduce waste. The objective of this work is to map the reverse logistics of an industrial packaging company in northern Santa Catarina, Brazil. The data were obtained by means of a case study. From the RL mapping it was possible to raise the costs involved in this practice and distribute them to the logistics activities involved. After analyzing these costs, it was verified that the reverse logistics can generate positive revenue for the company, besides generating environmental and social gains.

Keywords Reverse logistics · Costs · Recycling

1 Introduction

Among the challenges of contemporary companies is the need to remain competitive in the market. In this sense, logistics presents itself as an important tool Another concern of the companies is the search for solutions for excess waste generated along the production chain, and one of the ways to achieve this goal is through Reverse Logistics (RL). Moreover, legislation is increasingly severe regarding the

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correct disposal of waste, which makes it necessary for companies to rethink their responsibilities over their products after their use [8].

Thus, RL can be divided into two general areas: product and packaging. The product may be associated with reverse flow due to remanufacturing, renewal or returns; The packaging returns to be reused or recycled, usually due to regulatory issues, which restrict its disposal [23]. For Pokharel and Mutha [16], RL includes dismantling, remanufacturing, recycling, supply chain planning, inventory coordination and control. Today, RL's main objectives are: waste management, recovery of materials through recycling and reuse of products.

With regard to costs in general, the monitoring is done from traditional costing systems, which are organized in a functional way, Logistics, on the other hand, has a procedural approach, since it involves resources from several departments, which requires other techniques to calculate their costs [20]. Thus, in order to calculate RL costs, the costs of all activities involving Logistics, namely transport, storage, inventory, information and administration, must be calculated. However, few authors have investigated costs in RL, a topic that is not the main focus of researches.

Ramos et al. [17] sought to support tactical decisions and operational planning of RL systems. Considering the economic, environmental and social aspects, the authors approach the economic aspects through the collection of variable costs. Teunter et al. [26] created a specific model for RL with installation costs, delivery and elimination deadlines. The authors state that possible cost reductions have increased attention to implementation, as well as legislative and environmental issues. Kannan [10] proposes a model to evaluate and select the best RL service provider by outsourcers, the authors argue that the focus is on the flow of materials from the customer to the supplier (or alternative arrangement) in order to maximize the value of the item returned or minimize the total cost.

Recognized that there is little research that addresses the costs of RL, this article aims to map RL costs in an industrial packaging company operating in northern Santa Catarina, Brazil. The article was organized as follows. Section 2 presents the literature review. Section 3 presents the methodological procedures. In Sect. 4 is the case study and in Sect. 5 the conclusion.

2 Literature Review

2.1 Reverse Logistics (RL)

With regard to Logistics, one of the relevant points is the distribution channels, which take the products to the consumers, being of great economic importance. These channels can be direct (from the company to the consumers) or reverse, which go the other way, bringing after-sales or post-consumer products back into the production cycle so that they can be reused with the aim of closing the cycle [13]. Over the

years, environmental impacts and waste generated throughout the production chain began to be questioned.

For Silva et al. [25], companies have become increasingly proactive with a focus on improving their corporate image through changes involving environmental and social aspects. In this sense, the concern of companies with the return of waste made the after-sales and post-consumer goods become an integral part of the production process.

Ravi and Shankar [18] argue that managers must demonstrate RL's commitment to other organizational goals by integrating all members of the chain. According to the same authors, continuous support for RL should be provided in the strategic plans and action plans for implementation success.

However, RL can be a cost-generating process due to the lack of reverse planning, since it is a more complex process and involves other factors for implementation [1]. However, with proper planning, it can be a profitable and environmentally beneficial practice.

As in most cases RL is an area that does not involve profits, only costs, many companies stop practicing it [8]. However, according to Daga [7], p. 3, "an efficient RL system can turn a highly costly and complex return process into a competitive advantage." Many companies claim that RL is the last frontier in cost reduction.

According to Barker and Zabinsky [4], there are three reasons for companies to invest in RL. The first is compliance with legislation, present in several countries, regarding the remanufacturing, reuse and recycling of materials. The second is the existence, in many cases, of significant economic value in post-consumer products. The third motivation is in the image of the company, as consumers look for companies that adopt a "green" solution for their waste.

2.2 Costs in Reverse Logistics

According to Min et al. [14], the increasing concern with the costs of product returns and the reduction of profit margins made RL a competitive differential, since the company can save a substantial amount of transport, inventory and storage resources associated with returns of products.

For the calculation of RL costs it is necessary to calculate the costs of each logistic activity separately.

Transport Costs. The calculation of transport costs varies according to the own or outsourced fleet. When the fleet is outsourced it is enough to analyze the amount paid per month for the carrier. But when transportation is proper it is necessary to determine the costs of this activity, which can be divided into fixed and variable [20].

Inventory Costs. Inventories are linked to fixed capital. For Rodriguez et al. [20], inventory costs involve: acquisition cost, maintenance cost, cost of inventory in transit and cost-of-stock.

The cost of acquisition includes the price or cost of manufacturing the product [2]. The cost of inventory maintenance is related to risk, losses, insurance and damages resulting from the maintenance and custody of inventories [20]. The cost of inventory in transit involves the losses that may occur during the transit of the product and the immobilized capital during the course [20]. The cost of missing inventory refers to lost sales and late orders [2].

Costs with Storage, Handling of Materials and Packaging. Rodriguez et al. [20] lists the following costs involved in the warehouse:

- Cost of capital related to the construction, purchase or rental of the warehouse;
- Maintenance, water, electricity, taxes and insurance;
- Material handling and storage equipment: rent or maintenance, depreciation and capital cost of equipment;
- Labor and charges;
- Information and communication technology: rent or maintenance, depreciation and cost of capital of the technologies.

3 Methodological Procedures

The first step was to establish a theoretical basis with material that approached the concepts necessary to subsidize the research. To do so, searches were made with keywords divided into two axes:

Axis 1: "reverse logistic" OR "reverse logistics".

Axis 2: "cost" OR "costs" OR "charge" OR "expenses" OR "expense" OR "expenditure" OR "spend" OR "outlay" OR "disbursing" OR "disburse" OR "outgo".

The keywords were searched in the following databases: Scopus, Science Citation Index Expanded (Web of Science), OneFile (GALE) and ProQuest. The search was limited to scientific and review articles published since 2005. A total of 1396 articles were found.

Firstly, repeated articles were excluded and the selection process was started. The first selection was made from the reading of the titles of the articles. The second selection occurred from the reading of the abstracts, selecting only those that fit the theme of the research. The third selection occurred from the full text of the articles.

Most of the articles found did not align with the research topic, as they did not address the costs of RL as a whole. Some articles only verified transport costs, others did not address the issue of costs, only describe the RL and report cases of its application. Amid the reading of the articles were found authors who stood out from their statements on the subject. Thus, from the theoretical reference of these works, other publications pertinent to the subject were found and used in the construction of the theoretical reference of this research.

In the second step, a single longitudinal case study was carried out, which allows for a more in-depth collection of data. The practical application of this study occurred in an industrial packaging industry operating in Brazil. The data collection took place

through a visit to the company and an interview with the manager. The data of this interview allowed the elaboration of the company's RL mapping and the analysis of the costs involved in this practice.

4 Case Study

The case study seeks to analyze the costs involved in the RL system of a polymer manufacturing industry. For reasons of confidentiality the name of the company chosen for the case study is not disclosed.

The company under study occupies a prominent position as producer of packaging for industrial products. Its headquarters is in the state of Santa Catarina and has several units in Brazil. It has been in the market for several decades and in 2007 started its operations in RL and recycling. With the emergence of the National Solid Waste Policy (NSWP), the company realized the need to give a correct destination for the waste generated and, after some studies, created a Recycling Center (RC).

The RC is responsible for the recycling of the post-consumer product. After recycling, about 20% of the material returns to the company premises to be reprocessed and re-inserted into the production chain as raw material (RM). The remaining 80% is sold to other processing industries that also use it as an RM. RL's expansion is part of the company's sustainable growth strategy. In 2014 the recycling program was expanded to all units. There was also an increase in the disclosure of the same with the creation of an online portal that indicates the points of collection of the material. In that same year there was a 7% increase in the number of partners involved in the collection of products, which corresponds to a total of 710 agents.

4.1 RL Mapping

Each unit of the company has a RC. The reverse flow covers a radius of 200 km of each unit. This range may be larger depending on its viability. The company has partnerships with 3 types of scrap suppliers for recycling, according to Table 1.

Not always the participation of the 3 suppliers in all the recycling units occurs, some can only receive materials from 1 or 2 types of suppliers in a given month.

From these suppliers the waste is sent to the RC. Transportation takes place in 4 different ways, as shown in Table 2.

Upon arriving at the RC the waste is unloaded in an area designated to the stock of raw material. This area does not have any type of inventory control. From this stock the material passes through the production line where it is recycled and, in the end, is packed and stored.

After the production and sale of industrial packaging, the product reaches the final customer and is consumed. After being consumed, the material returns to the cycle

through one of the 3 types of waste suppliers, closing the RL cycle. Figure 1 shows this cycle.

Like the NSWP, the closed cycle of RL requires shared waste management, both by the company and by consumers, by separating and recycling their waste, and by waste managers, by sending them to recycling.

4.2 Distribution of Costs by Activities

The company does not have detailed cost control of the RL, only the costs with transportation and acquisition of materials are treated with accuracy. The rest of the costs were measured by the researchers. Table 3 presents the data for the month of September 2016 for 6 recycling units. The availability of data is insufficient for the use of Total Living Cost due to the lack of information regarding the costs of manufacturing the product and the direct logistics.

Unit E does not receive scrap from cooperatives or from waste managers, it receives only from companies with direct generation. Unit F does not receive material from cooperatives. The other units receive scrap from the 3 types of suppliers.

Table 1 Scrap suppliers

Types of scrap suppliers	Performed activities
Recycling cooperatives	They receive waste, usually from waste managers, where they are recycled or sold
Waste management	Companies that collect waste from cities and send it to landfills, recycling centers or cooperatives, dumps, among others. One of the means for the disposal of waste is the company being studied
Direct generation companies	Companies that have high production of waste and, to meet the NSWP, send the waste to the RC in order to have a correct destination through recycling

Table 2 Types of transport

Transport	How it is performed
Own vehicles	They use the same distribution channel from the company's direct logistics to the reverse flow
Reverse Freight	Freelance truckers who look for the company to make a reverse freight. Charge about 40% of the normal freight amount
Supplier vehicles	When the supplier is responsible for transportation
Outsourced	Carriers contracted to transport the scrap when the supplier has a full load and none of the other transportation options is available

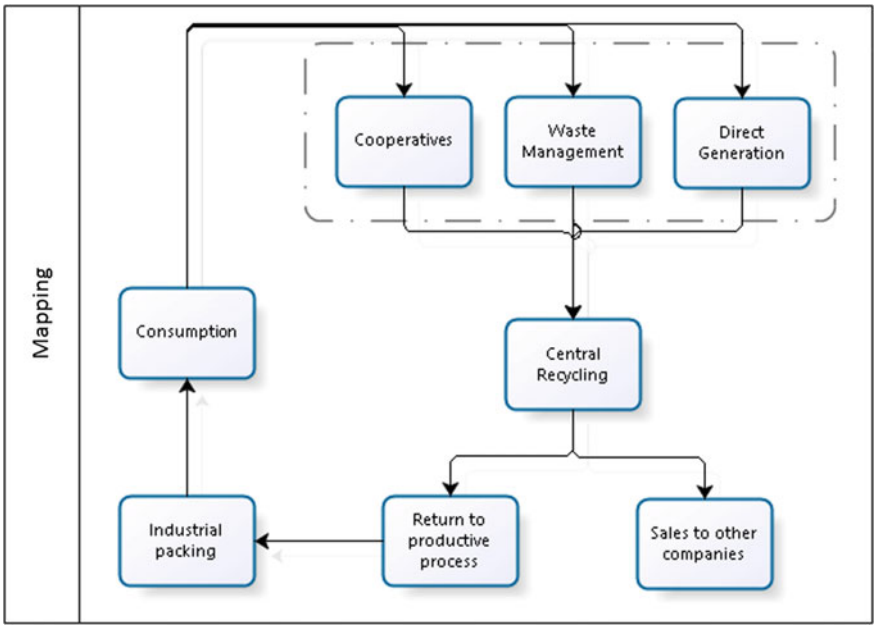

Fig. 1 RL process flow chart

Table 3 Financial control September—2016

Uni.	Cooperatives (kg)	Managers (kg)	Direct managers (kg)	Total (kg)	Freight	Waste	Revenues
A	6759	1655	40654	49068	R$ 11,590.00	R$ 23,828.48	R$ 372,159.06
B	3185	6020	6970	16175	R$ 5,539.90	R$ 5,843.20	–
C	11665	6577	28763	47005	R$ 14,800.00	R$ 26,062.00	R$ 209,263.98
D	2579	600	17451	20630	R$ 550.00	R$ 3,934.90	–
E	–	–	10186	10186	R$ 8,000.00	R$ 907.00	–
F	–	570	3150	3720	R$ 95.52	R$ 2,265.00	–
Total	24188	15422	107174	146784	R$ 40,575.42	R$ 62,840.58	R$ 581,423.04

Table 4 Cost of transport and acquisition

Uni	Total (kg)	Transport				Acquisition		
		Total cost freight	N° freight	Average cost per freight	Average cost per kilo	Total cost of scrap	Average cost per kilo	Average cost
A	49068	R$ 11,590.00	82	R$ 141.72	R$ 0.24	R$ 23,828.48	R$ 0.49	R$ 0.72
B	16175	R$ 5,539.90	27	R$ 205.50	R$ 0.34	R$ 5,843.20	R$ 0.36	R$ 0.70
C	47005	R$ 14,800.00	78	R$ 188.92	R$ 0.31	R$ 26,062.00	R$ 0.55	R$ 0.87
D	20630	R$ 550.00	34	R$ 16.00	R$ 0.03	R$ 3,934.90	R$ 0.19	R$ 0.22
E	10186	R$ 8,000.00	17	R$ 471.24	R$ 0.79	R$ 907.00	R$ 0.09	R$ 0.87
F	3720	R$ 95.52	6	R$ 15.41	R$ 0.03	R$ 2,265.00	R$ 0.61	R$ 0.63
Total	146784	R$ 40,575.42	245	R$ 173.13	R$ 0.29	R$ 62,840.58	R$ 0.38	R$ 0.67

Cost of Transport and Acquisition. The transportation costs depend on the way this transportation was done: through the company's own vehicles or outsourced. Either way, freights are always made with closed cargo of 600 kg.

Adding the total scrap and dividing this value by 600 kg results in the number of freights made in that month. It is possible to estimate the average value per freight and the transportation cost for each kilo of scrap transported from the total freight cost made available. These values were calculated for the 6 RCs. The cost of purchasing the kilogram of scrap is the result of the division of the total value of scrap by the total amount of kilograms acquired. Table 4 shows the average value spent on acquisition and transportation for each unit.

Unit E has the lowest cost of acquisition, R$ 0.09 per kilo. This is because their suppliers are companies that generate waste and sell them to the unit at a lower price as a way to meet NSWP. Despite this, the transportation cost is the highest, raising the average cost. Units D and F have the lowest cost of transportation, which helps drive D to obtain the lowest average cost.

The variation in cost of acquisition, which is from R$ 0.09 to R$ 0.61, occurs due to the three types of suppliers, where each one, in each city, practices a different price. For transportation, the variation is between R$ 0.03 and R$ 0.78. This oscillation occurs due to the form of transport practiced and the distance between RC and its suppliers.

Cost of Inventory. From this average cost, it is possible to calculate the cost of the inventory, which takes into account the cost of transportation because, while it is transported, the material is immobilized, and legally it is considered as a stock.

Table 5 Inventory cost

Unit	Total (kg)	Average cost	i_{am}	Inventory cost
A	49068	R$ 0.72	0.0080	R$ 282.43
B	16175	R$ 0.70	0.0080	R$ 90.77
C	47005	R$ 0.87	0.0080	R$ 325.84
D	20630	R$ 0.22	0.0080	R$ 35.76
E	10186	R$ 0.87	0.0080	R$ 71.03
F	3720	R$ 0.63	0.0080	R$ 18.82
Total	146784	R$ 0.67	0.0080	R$ 784.47

The stock levels per unit are variable, since they are related to the consumption of industrial packaging and the post-consumer collection rate of this material. Currently, the sector is undergoing a retraction, which reduces the consumption of packaging and, consequently, recycling. Thus, the average stock will be considered as the total inventory generated in the month of September.

The rate of immobilization of material practiced by the company is 10% per year. As the cost will be calculated per month, it is necessary to convert this rate to a monthly amount. This transformation is made from Eq. 1, proposed by Casarotto Filho and Kopittke [6].

$$i_{am} = -1 + (1 + i_{aa})^{1/12} \tag{1}$$

where:

i_{am} capital immobilization rate per month
i_{aa} capital immobilization rate per year

$$i_{am} = -1 + (1 + 0.1)^{1/12} = 0.8\%$$

$$i_{am} = 0.8\%$$

Thus, the inventory cost for each CR was calculated from Eq. 1 and can be observed in Table 5.

Recycling Center A. RC A is the recycling unit of the company's headquarters in Santa Catarina. It was the first RC to be created in 2007 and is more organized and developed compared to the others. This RC has 21 employees, 3 in the administrative sector and 18 in the area of recycling and material handling. In September 2016, RC A reached a turnover of R$ 372,159.06.

The costs for transportation, scrap purchasing and inventory have already been calculated previously, remaining the calculation of storage, material handling and packaging.

Table 6 Storage cost

Storage	
Salaries and administrative costs	R$ 10,752.00
Warehouse process	R$ 32,256.00
Maintenance	
Energy	R$ 20,000.00
Water	R$ 200.00
Taxes	R$ 1,666.67
Cost of capital	R$ 1,251.84
Total	R$ 66,126.50

Costs for storage, handling and packaging. The company has its own shed destined only to RL processes. In this place the process of recycling and storage of the materials takes place, besides an administrative sector. The cost of capital referring to the construction can be estimated by means of the depreciation. Real estate is depreciated, usually in 25 years, this results in a rate of 4% per year. From Eq. 1, the monthly depreciation rate is 0.33%. This rate must be applied on the value of the property, which in the case has a constructed area of approximately 2,250 m^2, the value per square meter of a masonry shed, determined by the local city hall in the neighborhood where the company is located is R$ 169,95. Thus, it is estimated that the property has the value of R$ 382,387.50, applied to the rate, the monthly depreciation is R$ 1,251.84.

The company has an average annual cost of R$ 20,000.00 with taxes. Dividing this amount by 12 months results in an average monthly cost of R$ 1,666.67. Table 6 below sets out the storage costs.

The company does not have handling, packaging or information technology equipment involved in RL processes.

4.3 Costs Analysis

After defining the costs of each logistic activity, an analysis of them can be done. The costs of RC A are summarized in Table 7, which also shows the percentage of participation in the costs of each activity. It should be noted that storage costs have the greatest contribution. This is due to the inclusion in this activity of all the costs of recycling the material and all the people involved in this process.

From these costs it is possible to analyze the impact of logistic costs on the turnover of RC A. Simply divide the costs by the revenues of the unit in that month, which was R$ 372,159.06. The logistic costs consume 20.96% of the billing, that is, each real invoiced R$ 0.21 is spent on logistics. This revenue comes from the sale of the recycled material to other polymer processing companies.

The amount spent on inventory is small and represents less than 1 cent each real invoiced. Transportation and warehousing costs are significant, totaling R$ 0.03 and R$ 0.18, respectively.

The values indicated in Table 8 show the size of logistics in the company's competitiveness. From this table it is possible to know which activity deserves greater attention in the search for the reduction of costs and increase of the profits.

Since RC A is composed only of RL processes, all unit costs are logistical costs and were calculated. Thus, the gross profit for the month of September 2016 can be obtained for RC A by reducing the logistics costs and the costs of acquiring the scrap of the billing. Gross profit can be seen in Table 9.

Thus, the company under study shows that it is possible to obtain positive results when implementing RL.

4.4 Discussion

Although the company obtains positive revenue from the RL processes, some points can be improved and contribute to a better result. One of the points would be to improve inventory control. Although the impact of inventory costs is not significant, an improvement in the receipt and organization of the materials could reduce labor costs and time in stock. By reducing labor costs, consequently reduces storage costs, which is the activity with the greatest weight in logistics costs.

According to Min et al. [14], with the implementation of RL the company can save a significant amount of transport, inventory and storage costs associated with the return of products. The company has its own shed destined only to RL, which facilitates the recycling and storage processes of the materials.

Table 7 Logistic costs

Logistic costs		
Activities	Cost	%
Transport	R$ 11,590.00	14.9
Stock	R$ 282.43	0.4
Storage	R$ 66,126.50	84.8
Total	R$ 77,998.94	100.0

Table 8 Logistic costs by real invoiced

Logistic costs/invoiced	
Activities	Value (cent per real invoiced)
Transport	R$ 0.031
Stock	R$ 0.001
Storage	R$ 0.178
Total	R$ 20.96

Table 9 Net and gross profit—center A

Recycling center A	
Invoiced	R$ 372,159.06
Costs	R$ 77,998.94
Acquisition cost	R$ 23,828.48
Net and gross profit	R$ 270,331.64

According to Ko and Evans [11], RL implementation requires a specialized infrastructure that requires special information systems for tracking, capture of equipment for return processing, and standardized specialized manufacturing processes throughout the chain (EVOS 2007). With the increasing cost of returning products and declining profit margins, the optimal handling of product returns can be a competitive differential [15], a fact that can be observed in the results obtained by the company object of this study.

According to Daher et al. [8], the inclusion of an RL system requires the total life cycle costing approach, since the return of the products to the companies until the end of their useful life, for any reason, is the responsibility of the same. In order to adopt RL it is necessary to extend the life cycle of the materials and efficiently plan the return of the products to the logistics cycle [9]. However, the availability of data is insufficient for the use of Total Cost Analysis due to the lack of information regarding the costs of manufacturing the product and direct logistics.

In general, in terms of cost reduction, initiatives related to RL practices have brought significant returns to the company. Thus, it is proven that it is possible to reduce costs and obtain positive results when implementing RL. Ravi and Shankar [18] argue that continued support for RL should be provided in strategic plans and action plans for implementation success.

5 Conclusions

In order to meet the objective of this research, the logistic activities involved in the process were mapped. The mapping contributed to raise the costs of each activity focused on RL. Based on some data provided by the company, it was possible to calculate the costs of each activity, besides showing the amount spent by the company with the RL for each real invoiced. This survey revealed which activity has the greatest contribution to reverse flow costs.

It can be concluded from the results presented that RL practices can contribute to lower company costs and generate positive revenue, as well as environmental and social gains.

Knowledge of the RL process through the mapping and costs involved in each activity can help the company to improve some specific practices. Although the RL of

the company is organized and achieving a positive result, the search for improvements in a process must be continuous.

Among the limitations encountered during the research is that few companies have an RL system implemented and controlled. Those who implemented RL have some fear of making their financial data available. Thus, the main limitation was to obtain all the necessary data for the research.

As a suggestion for future work, a comparative analysis of the costs of direct logistics with RL can be carried out, raising the data of the entire logistics chain of the company. Another suggestion is the creation of a model for calculating RL costs, which serves as a basis for companies that do not have the reverse flow implanted yet, or, if they already have it, so that they can improve it. It is also interesting to create a RL mapping in Brazil, showing how this system is used in the country and the greatest difficulties in its implementation.

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Comparative Cost Evaluation of Material Removal Process and Additive Manufacturing in Aerospace Industry

F. Facchini, A. De Chirico and G. Mummolo

Abstract In last years, the market penetration of the Additive Manufacturing (AM) processes in aerospace industry is continuously growing, if on one hand the advantages of AM process are indisputable under technological perspective, on the other hand the costs due to AM process are quite variable and, in many cases, identifying a preliminary cost estimation is very difficult. Indeed, engineering and manufacturing costs are strongly dependent by complexity and by specificity of the part to be manufactured. The purpose of this paper consists in developing a cost model based on a computational algorithm that allows to quickly asses the overall cost due to design and production of part by means of one of the most recently AM technology (Wire+Arc AM). Consistently, the model is adopted for evaluate and compare the process costs due to production of a batch of aerospace parts, adopting both Wire+Arc AM (WAAM) and traditional machining technologies. The results of the experimental study conducted, show that the most cost-effective technology, between WAAM and traditional machining, is strongly depending on batch size to be manufactured.

Keywords Parametric cost model · Product development process · Target costing

1 Introduction

Additive manufacturing (AM) is a layer-by-layer process technology that allows the production of three-dimensional solid objects. There is a growing interest, both scientific and industrial, for production systems under economic and environmental perspective [1]. The American Society for Testing and Materials (ASTM) defines AM as a collection of technologies able to join materials, layer upon layer, in order to make objects from 3D model data. The AM technology process is exactly the opposite of traditional machining process (collectively known as Material Removal

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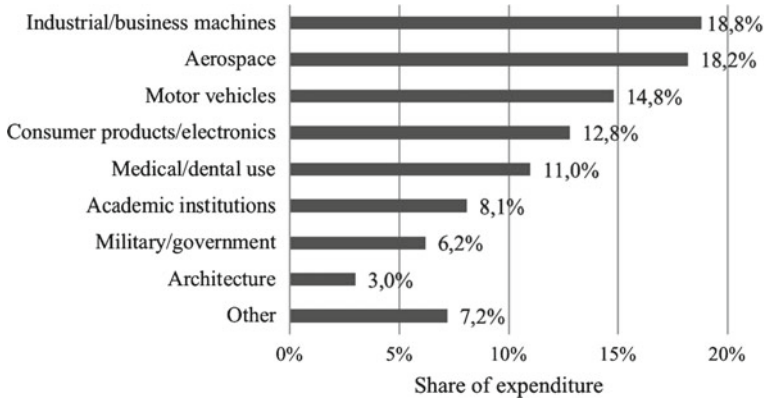

Fig. 1 AM system—global use by industry sector 2016 (www.statista.com)

Process), in which the controlled material removal allows to obtain the desired shape of the final solid object, starting from a piece of raw material.

The market penetration of AM technology in different industrial area depends on different factors, generally the adoption of AM is strictly required for the production of customized parts characterized by complex shapes, light-weight, and structures with a graded density. According the Manufacturing Readiness Level (MRL), that evaluates the maturity level of a given technology under a manufacturing perspective, the full rate production of parts by means of AM technology is achieved in dental, tooling and aerospace industries. Nowadays, the aerospace represents the sector where the worldwide use of AM systems is accounted for 18.2% of global system use (Fig. 1).

Worldwide markets are poised to achieve continuing growth adopting the AM in aerospace sector, the strategy is very clear: reduce the cost of manufacturing and increase the efficiency in process. According to [2] in only seven years (from 2017 to 2024) the expecting investments in global market for aerospace will grow up from $2.2 billion in 2017 to $20.9 billion by 2024. A detailed analysis of the current manufacturing cost and evaluation of expected improvements reveals a cost reduction potential of about 60% in the next 5 years and another 30% within the next 10 years, these reductions will significantly boost the market for metal AM. Consistently the subtractive manufacturing processes will be replaced with AM processes and in this perspective, flexible manufacturing and low product cost represent the key benefits of a successful technology.

Even if each aspect is crucial for the new disruptive technology, the impact due to costs is one of the most important aspect that a decision maker evaluates before to identify the best manufacturing strategy. Therefore, the development of a specific cost model, focused on aspects like time and energy consumption, activities cost, production scheduling and many other aspects, allows to evaluate the impact of the single factors involved in AM processes.

Currently there is an increasing request of support decision tools able to identify the suitable strategy allowing to minimize the external costs [3] under economic and environmental perspective [4]. Many papers are published about the cost evaluation in AM process. The first AM cost model is based on a 'part-oriented' approach, this means that the cost estimation is related to the number of the layers manufactured. In this case, the cost equation is divided into three stages related to different layers manufactured: prebuild preparation, build, and post processing stages. The model is adopted for evaluating the cost of Fused deposition modeling (FDM) and Stereolithography (SLA) processes. Although, the approach is actually too general, can be easily incorporated for all technology based on 'layer-by-layer' approach without the need to change the methodology [5]. In 2003 a cost analysis, in terms of the unit cost for part that include machine, labour and material costs is performed, in order to compare the traditional manufacturing technology (injection modeling) with layer manufacturing processes (SLA, FDM and Laser Sintering(LS)). The authors found that the costs are strictly related to kind of geometries to be manufactured. In particular, they show that for the production of 'small parts-size' the layer manufacturing methods are more economical than traditional approaches, in case of maximum production batch-size around to 6000–12000 units (the range depends on technology adopted: SLA, FDM or LS), over this batch-size, the traditional approach is cheaper. The 'threshold batch-size' changes for the production of 'medium parts-size', indeed in these cases the economic convenience of the layer manufacturing methods is ensured for the maximum production batch-size around to (independently by layer manufactured process adopted) [6]. Limits of the work mainly concern the absence of economy of scale (the curve of production costs should have a deflection) and the authors didn't consider the power consumption, this and other aspects are improved in [7]. Ruffo et al. present a cost model formulated in order to attribute the full cost (including costs of plant, administration, and overheads) to the layer manufacturing process. The approach adopted placed the model between the parametric approach (cost expresses as an analytical function that identify the 'cost-estimation relationships') and the engineering approach (overall cost is given by the sum of elementary components used in each step of the production process). The new cost model was used to calculate the production cost of the same parts already used in the previous study by Hopkinson and Dickens and the comparison evidenced an underestimation of the costs (around 20%) in old model, due to a significant increase of the indirect costs (neglected in the old model) and to light reduction of material costs (overestimated in old model) [7]. Despite a more accurate costing analysis is conducted by Baumers et al. according to a new approach that consider costs due to build-time, energy consumption, production, and economies of scale [8], the results are very similar to the cost model already introduced by Ruffo et al. Therefore, the evaluations of previous model are considered still valid. In 2015, the Cranfield University presents a report about cost comparison between AM and traditional machining from solid. On the basis of the cost evaluation, which includes costs (direct and indirect), performance of the machines, and size of the parts to be manufactured, the authors claims that cost of AM technology are lower, from 7 to 69%, than to traditional machining [9]. Recently, Fera et al. have analyzed the AM technologies under an operations

management perspective. In this study, parameters like Overall Equipment Effectiveness, production mix, completion time, etc., are taken into account. According to this approach, four performance indexes of the process are identified and a Mixed Production Cost Allocation Model for AM (MiProCAMAM) is developed, in order to evaluate the costs for each phase of the process (e.g. setup, building, removal, etc.) [10]. It is very interesting to note that in most models considered for the evaluation of costs related to AM process, the Non-Recurring Engineering (NRE) costs are neglected or are not sufficiently detailed. The NRE costs refer to the one-time cost to research, design, develop and test due to production of new parts. In case of batch-size with a limited number of units (very frequently for the production of parts through AM technologies), the NRE value provides an important information for identifying the most cost-effective manufacturing strategy.

The aim of this study is to develop a cost model in order to evaluate the overall cost (manufacturing and NRE costs) of AM for innovative technology as Wire+Arc AM (WAAM). Consistently, the model is adopted for evaluating and comparing the process costs, adopting AM and traditional machining technologies, for the production of a batch of parts in aerospace industry.

The rest of the paper is structured as follows: a brief survey on the AM technologies most commercially available is presented in Sect. 2, in Sect. 3 the model developed is introduced, results obtained in case of a full-scale comparison between AM and machining technologies are in Sect. 4; finally, conclusions of this work are shown in Sect. 5.

2 Additive Manufacturing Process in Aerospace Industry

The ASTM, established in 2013 a standard for AM technologies in order to group current AM process methodologies together. The result is a group of 7 different processes which comprehend all different variants of the technologies known nowadays. The standard definitions for each technology according to ASTM are:

1. Direct energy deposition: process in which focused thermal energy is used to fuse materials by melting as they are being deposited;
2. Powder Bed Fusion: process in which thermal energy selectively fuses regions of a powder bed;
3. Binder jetting: process in which a liquid bonding agent is selectively deposited to join powder materials;
4. Material extrusion: process in which material is selectively dispensed through a nozzle or orifice;
5. Material jetting: process in which droplets of build material are selectively deposited;
6. Sheet lamination: process in which sheets of material are bonded to form an object;

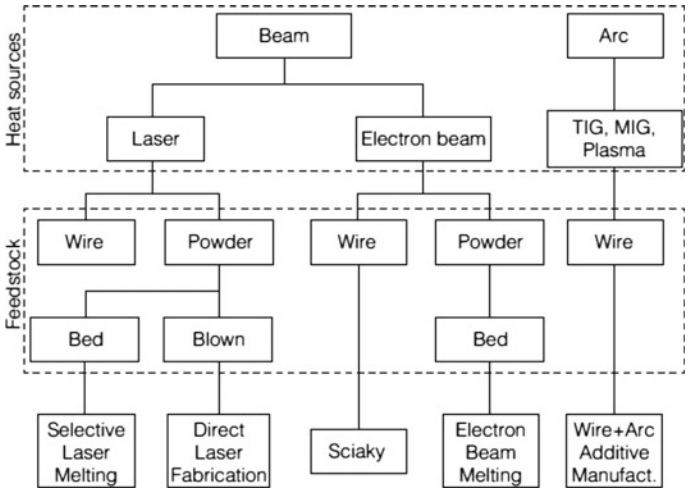

Fig. 2 Classification of current main AM processes

7. Vat photopolymer: process in which liquid photopolymer in a vat is selectively cured by light-activated polymerization.

Cranfield University classified AM processes according to power source and feedstock type (Fig. 2) and outlined several possible configurations [9].

The technology considered in this paper is Wire+Arc Additive Manufacturing (WAAM) that uses an electric arc as heat source and wire as feedstock, reputed the most mature AM technology and the most convenient due to the lower cost of the wire and the utilization of standard, off the shelf welding equipment [11]. In most cases the parts manufactured by WAAM are characterized by a near-net shape, therefore further tasks of finishing, through CNC machining, can be required. If on one hand, this approach requires the adoption of different tasks through two technologies, on the other hand the adoption of the CNC machine ensures a quality of finished surface comparable to the parts manufactured by traditional machining. Further strong points of the WAAM technology are related to the flexibility in terms of feasible geometries. Consistently, is possible to reduce the number of sub-components that make up the final part, improving at same time the reliability and the light-weight of the manufactured part. The high cost of the material generally adopted, the low volume required, the reduction of the overall lead time (due to In-process quality control) and the possibility of producing small batch in remote locations are very important aspects in aerospace industry. Therefore, nowadays the aerospace industry represents, more than others, the industrial sector in which the AM technologies, if supported by a cost-effective strategy, can be a viable alternative to the traditional machining.

3 Cost Evaluation Model

The model developed is based on computational algorithm that allows to evaluate the overall cost due to the manufacturing of a generic part through the adoption of WAAM process. For this scope the input parameters required are:

1. Time for generating the near net shape WAAM digital preform (tp_1, tp_2), starting by CAD project and checking the feasibility of part to be manufactured under geometrical (tp_3) and technological perspective (tp_4) (e.g. presence of undercuts, material temperature distortion, etc.) [h];
2. Time for producing the slices CAD (tp_5), generating the toolpath (tp_6), evaluating the material thermal variation (tp_7), and simulating the AM process (commonly known as dry run—tp_9) [h];
3. Time for programming the CNC machine for finishing the parts manufactured from near-net shape to net-shape (tp_8) [h];
4. Time for identifying wire material and diameter (tm_1), as well as shielding gas (tm_2) to be adopted in manufacturing process [h];
5. Install wire (tm_3) and connect up the shielding gas (tm_4) [h];
6. Time for substrate preparation (tm_5, tm_6, tm_7, tm_8) (e.g. cutting, drilling, clamping, etc.) [h];
7. Time for the identification, installation, and calibration of electrode, nozzle, sensor, as well as roller (ts_1, ts_2, ts_3, ts_4, ts_5, ts_6, ts_7) [h];
8. Time required for filling the chamber with shielding gas (ts_8), if considered necessary in process [h];
9. Hourly staff cost for engineering activities (C_R and C_T) [€/h];
10. Volume of final part (V_f) and substrate (V_s) to be processed [m^3];
11. Cost of wire (c_w) and forged material (c_{mt}) to be adopted for AM process [€/kg];
12. Density of wire and forged material (ρ) to be adopted for AM process [kg/m^3];
13. Buy-to-Fly ratio (BTF) [kg/kg],
14. Deposition (DR) and material removal rate (MRR) [kg/h];
15. Hourly running cost of WAAM (HR_{AM}) and CNC (HR_{CNC}) under the assumptions considered in Sect. 3.1 [€/h];
16. Batch size of parts to be manufactured (N) [units].

The output of the model is the overall cost per part manufactured [€/units].

3.1 Assumption

The assumptions listed below, are considered in the model for WAAM costs evaluation:

1. The activities included in NRE costs can be grouped into three main phases: programming, material preparation and setup, each of them requires the activities shown in Table 1;

Table 1 Skill required for each NRE activities

Programming	SR	Material preparation	SR	Setup	SR
Import CAD file (tp_1)	R	Choose wire (tm_1)	R	Choose Φ nozzle (ts_1)	R
Generate WAAM (tp_2)	R	Choose gas (tm_2)	R	Install sensors (ts_2)	R
Geom. evaluation (tp_3)	R	Install wire (tm_3)	T	Calibrate service (ts_3)	R
Study distortion (tp_4)	R	Connect up gas (tm_4)	T	Install electrode (ts_4)	T
Slice CAD file (tp_5)	R	Cut substrate (tm_5)	T	Install nozzle (ts_5)	T
Generate toolpath (tp_6)	R	Drill substrate (tm_6)	T	Choose roller (ts_6)	T
Thermal analysis (tp_7)	R	Prep. substrate (tm_7)	T	Set the roller (ts_7)	T
Program CNC (tp_8)	R	Clamp substrate (tm_8)	T	Fill chamber with gas (ts_8)	T
Dry run (tp_9)	R				

Legend Skill Required (SR), Researcher (R), Technician (T)

2. The manufacturing costs include the activities of deposition by WAAM and finishing by CNC machine, this activity is necessary for substrate removal and obtaining the net-shape part;
3. Costs due to activities as: tooling and set-up, non-destructive testing, on-line monitoring, and post-processing are not included in cost model evaluation;
4. Most activities included in NRE costs evaluation are considered labour-intensive activities, therefore the model neglects the equipment cost (e.g. investment, maintenance, etc.), the facilities cost, as well as the energy consumption;
5. Hourly running cost of WAAM and CNC for manufacturing activities includes:
   - fixed costs are evaluated considering the equipment (hardware and software) depreciation period assuming a given available capacity per year (comprehensive of utilization rate);
   - variable costs are evaluated considering the hourly staff cost, the energy consumption, the shielding gas, as well as the welding consumables;
6. There is a correspondence one-to-one between activities and the available human resources, therefore each worker cannot carry out, at the same time, more activities;
7. The staff skills include two different categories: Technician (T) and Researcher (R), therefore the assignment of the different tasks depends by the skill of the worker (Table 1).

3.2 Theoretical Model

The model is based on the equations introduced in this section, the overall cost per each part manufactured (C_{pp}) depends on cost of WAAM manufacturing process (C_{AM}) and cost estimate of the NRE activities (C'_{NRE} and C''_{NRE}), increased by a percentage factor (CX) due to time loss for process inefficiency. CX is greater than 1 (Eq. 1), generally is included in the range of 1.05– 1.2

$$C_{pp} = N^{-1}(C_{AM} + CX \cdot \left(C'_{NRE} + C''_{NRE}\right)) \tag{1}$$

C'_{NRE} and C''_{NRE} include the NRE activities conducted, respectively, by researcher and technician. Therefore, two different hourly labour costs (C_R for researcher and C_T for technician) are considered (Eqs. 2 and 3):

$$C'_{NRE} = C_R(\sum_{i=1}^{9}\sum_{j=1}^{2}\sum_{k=1}^{3} tp_i + tm_j + ts_k + ztp_9 + (\alpha - 1)\sum_{i=1}^{7} tp_i) \tag{2}$$

$$C''_{NRE} = C_T \cdot \sum_{j=3}^{8}\sum_{k=4}^{8}(tm_j + ts_k) \tag{3}$$

The Boolean variable (z) is introduced in order to evaluate the time required for a dry-run cycle, in case of dry run is performed $z = 1$, otherwise the z-value will be zero.

In most cases, more dry run cycles are required, therefore α parameter identifies the amount of cycles performed ($\alpha \in N; \alpha \geq 1$).

The estimate cost due to WAAM manufacturing process (Eq. 4) depends on substrate material cost (C_{SB}) and costs due to deposition (C_D), as well as machining (C_M) activities [9].

$$C_{AM} = C_{SB} + C_D + C_M \tag{4}$$

$$C_{SB} = V_s \rho c_{mt} \tag{5}$$

$$C_D = \rho\left(V_f BTF - V_s\right)\left(c_W + L_S HR_{AM} DR^{-1}\right) \tag{6}$$

$$C_M = \rho V_f (BTF - 1) L'_s HR_{CNC} MRR^{-1} \tag{7}$$

The substrate cost (Eq. 5) is related to material cost (C_M) and to weight of the substrate, C_D (Eq. 6) includes the final volume of the part manufactured, the cost of wire per kg (c_w), the hourly quantity of deposited material (DR) and the hourly running cost of WAAM machine (HR_{AM}). A percentage factor due to time loss for deposition activities (L_S), generally included in the range of 1.1–1.2, is considered. As far as concern BTF parameter, usually is assumed a value of 1.2 that corresponds

to 20% of surplus material. C_M (Eq. 7) evaluates the machining cost due to finishing operation performed by CNC machine, depends on cost due to surplus material removal evaluated on the basis of volume of material to be removed, time loss for activities of material subtraction (L_S), hourly cost of CNC (HR_{CNC}), as well as hourly quantity of removed material (MRR).

3.3 Computational Algorithm

A VBA routine is programmed in order to implement the evaluation cost model, the user queries the routine by a command-line tool that allows to introduce the input-data needed for the cost estimation (see Sect. 3). The "if-then" statement ensures the times quantification required by one or more dry run cycle (Fig. 3).

The results (C_{pp}) are provided for a given value of N or for different N-values, in last case a curve on scatter chart is returned by routine. The incidence of the NRE costs on the C_{pp} is provided by means of a pie chart generated for a given N.

4 Numerical Simulation of the Model

The model is adopted in order to estimate the overall cost per unit (with different batch size) due to manufacturing of an aerospace structural part in titanium in Ti–6Al–4 V (see Fig. 4) through the AM technology. The part size, according to x, y and z directions, are respectively about of 20 × 30 × 5 [cm], for an overall weight of 15 kg per unit.

The input parameters, listed in Table 2, that include working times (detected in field), process parameters, and characteristic of the part to be manufactured are considered for estimating the NRE and the manufacturing costs of WAAM process. According to the cost model proposed, assuming only one dry-run repetition and given N = 1, the evaluation cost of WAAM process amounts to: C_{pp} = 11 k€ in which the amount of NRE costs (C'_{NRE} and C''_{NRE}) is equal to 6,9 k€ and C_{AM} = 4.1 k€.

The cost evaluation of the traditional machining is estimated adapting the simplified cost model, recently introduced by Priarone et al. [12]. According to the theoretical formulation (Eq. 8), the overall cost of traditional machining (C_{ppM}) depends on cost (C_{wp}) and mass of raw material (m_{wp}), specific cost per kg (S_{CM}) of removed material (m_c) as well as engineering costs (C_{NREM}) i.e. import CAD file, CAM programming, machine setup, part fixturing, etc.

$$C_{ppM} = ((m_{wp} \cdot C_{wp} + m_c \cdot S_{CM}) + C_{NREM})N^{-1} \tag{8}$$

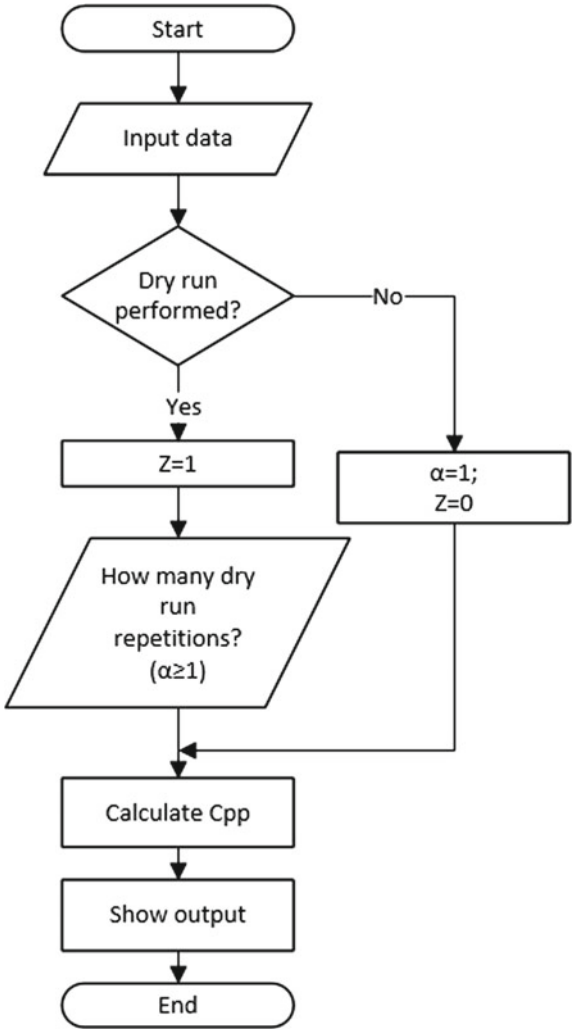

Fig. 3 Flow chart of VBA routine for cost model implementation

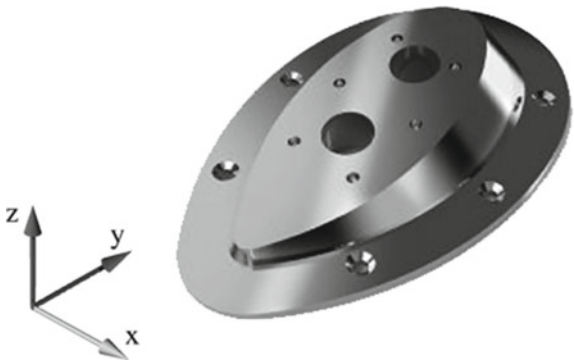

Fig. 4 Aerospace structural part, manufactured for the numerical simulation

Table 2 Input parameters of cost model for AM process

Input parameters									
tp_1	4 h	tm_1	0.1 h	ts_1	1 h	V_f	0.003 m^3	c_W	147 €/kg
tp_2	4 h	tm_2	0.1 h	ts_2	8 h	V_s	0.007 m^3	c_{mt}	68 €/kg
tp_3	3 h	tm_3	0.25 h	ts_3	8 h	ρ	4430 kg/m^3	HR_{CNC}	70 €/h
tp_4	0 h	tm_4	0.2 h	ts_4	0.1 h	BTF	1.2	HR_{AM}	91 €/h
tp_5	2 h	tm_5	1 h	ts_5	0.1 h	DR	3.5 kg/h	z	1
tp_7	4 h	tm_7	8 h	ts_7	8 h	MRR	8.0 kg/h	α	1
tp_8	4 h	tm_8	3 h	ts_8	2 h	$L_s = L'_s$	1.1	HR_{CNC}	68 €/h
tp_9	4 h	C_R	80 €/h	C_T	60 €/h	CX	1.15	N	1 unit

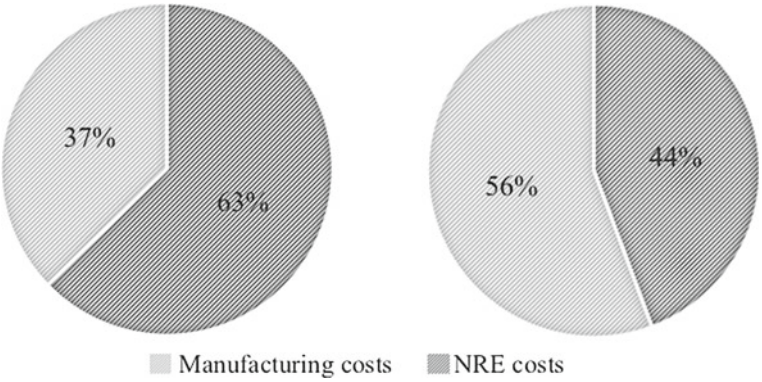

Fig. 5 Percentage of manufacturing and NRE costs for the production of one-part through. WAAM (**a**) and traditional (**b**) process

In case of traditional machining the estimated overall manufacturing cost, for the production of one part, amount respectively to $C_{ppM} = 9.7$ k€ that includes an amount of engineering cost equal to $C_{NREM} = 4.2$ k€.

Therefore, according to the cost models adopted, traditional machining is the most cost-effective technology process. Indeed, the overall cost per part, adopting the material removal process, are lower of about 12% than WAAM process. As far as concern the percentage of NRE cost and of manufacturing cost on overall cost, is very interesting to note that in case of WAAM process the share of NRE is higher than manufacturing cost. The opposite is observed for the traditional machining in which the NRE cost is lower than manufacturing cost (Fig. 5).

Increasing the batch size of the manufactured parts, is possible to observe that Cpp decreases (NRE cost is spread-out on more parts). Consistently is possible to note that the overall cost per part is heavily dependent by lot size, therefore most cost-effective technology changes by varying N.

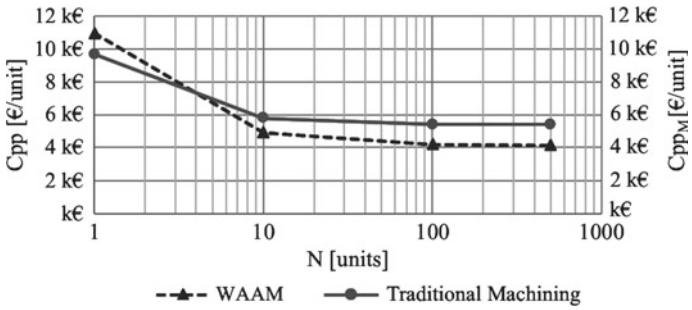

Fig. 6 C_{pp} ranging in batch size from 1 to 10^3 parts manufactured in case of WAAM and traditional machining

In this case, the traditional technology is the most cost-effective process for manufacturing of batch size from 1 to 3 parts. For higher batch size, WAAM is the most convenient process (Fig. 6).

5 Conclusion

Although the AM technologies currently are not widespread for large-scale production, the comparison showed that there are layer-by-layer processes, able to ensure, for some industrial sectors, competitive performance under economic perspective. This result is further underpinned by cost items analyzed, that, considering the weight of NRE activities on overall cost, provides an exhaustive evaluation for different batch size to be manufactured.

Furthermore, the advantages provided by model can be summarized as follows:

- Evaluation, through an easy-to-use interface, of NRE and manufacturing cost due to WAAM process;
- Identification of most cost-effective process technology to be adopted, on the basis of characteristic of part to be manufactured, resources available, as well as of batch size to be manufactured;
- Evaluation of the single cost items due to NRE and manufacturing activities, in order to identify, and optimize, the most labor-/capital-intensive activities.

Consistently with the target cost introduced, is possible to adopt the same approach for evaluate NRE and manufacturing costs referring to other AM technologies (described in Sect. 2), in order to develop a tool able to identify the most cost-effective AM technology case by case basis.

A full cost assessment can be developed by integrating to the query input parameters, a database that provides the statistical times estimated for each single activity.

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Modelling the Need for New Blood Donors Following a Change in Deferral Period

John T. Blake

Abstract Blood donation is considered a safe procedure. Injuries are not common during blood donation and are most frequently fainting or minor bruising. Blood donation does, however, lower iron stores. Recently, Canadian Blood Services announced plans to increase the deferral period for females from 56 to 84 days between consecutive donations to avoid the risk of anemia. The change will reduce the number of collections that can be obtained from women. Lost donations have both a permanent component in terms of fewer donations, as well as a transient effect, due to the timing of the last donation by female donors prior to the implementation of the deferral change. In this paper, we present a forecasting model and optimization routine to identify donor requirements following the change in deferral durations. Model results suggest that the deferral change should be phased-in as female donors book new appointments. Phasing in the policy change reduces the need for newly recruited donors by 5–10%. Nevertheless, a substantial recruiting effort will be required for the first five weeks following the deferral change. Results also show that 32,000 to 35,000 additional donations will be required to during that period. These results were subsequently adopted by CBS, as donation targets following the change in deferral policy and the figure of 35,000 additional donations has been widely quoted in the press.

Keywords Blood collections · Donor recruiting · Linear programming

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1 Background

1.1 Donor Deferral Intervals at Canadian Blood Services

Canadian Blood Services (CBS) is the not-for-profit agency responsible for the collection, production, and distribution of blood and blood products in all parts of Canada, outside of the Province of Quebec. CBS serves 27.3 million people and provides 820,000 units of red blood cells annually to hospitals. Units are collected from 430,000 individuals, who make on average, 2.0 donations per year.

Blood donation is considered to be a safe procedure. Injuries are not common during blood donation and are most frequently syncopal episodes or minor haematomas [1]. Blood donation does, however, lower iron stores, which places individuals at risk of anemia. Until recently in Canada, all donors had a deferral period between consecutive donations of 56 days to limit this risk. However, evidence emerged that females with a history of frequent blood donation are at higher risk of developing anemia [2]. In response, Canadian Blood Services announced plans to increase the deferral period for females to a minimum of 84 days between consecutive donations, starting in October 2016.

Changes in deferral policy were expected to reduce the number of donations made by females, since women would have fewer opportunities to donate each year. See Table 1. Extending the deferral period for female donors to a minimum of 84 days infers that female donors can donate a maximum of 4 times per year at permanent clinics. Furthermore, since mobile clinics visit most communities at intervals approximately equal to 56 days, females may only be eligible to attend every second mobile event in their local area, implying an effective deferral period of 112 days or 3 donations per annum. It is a simple matter to calculate that the change in maximum donation frequency would decrease donations from females at mobile clinics by 13,600, and by 7,100 at permanent clinics for a reduction of 20,700 units in total each year.

In addition to the steady state drop in donations from females, a transient loss in collections was anticipated, since many female donors had inter-donation intervals of less than 84 days in the period prior to the change in deferral interval. 2016 data indicated that 66,000 female donors, combining for a total of 122,000 units, visited a clinic within 84 days of their previous donation. Estimates suggested a collection shortfall of at least 5,400 units per week for the first five weeks following the change in deferral interval and before all female donors would be eligible to donate again. However, the exact shortfall in donations was expected to depend on the profile of donations made in the months leading up to the deferral change and the organization's ability to retain existing donors or attract new donors.

Attracting individuals to become new donors is not straightforward. The rationale for why individuals donate is not well understood, but it is known that less than 4% of eligible adults in Canada are blood donors. Thus, recruiting a bolus of donors to bridge the transient decrease in female donations was not considered an ideal manner of dealing with the decrease in collections. Accordingly, we were asked to develop a

Table 1 Distribution of donations by sex and donor frequency

Sex	Freq	Donors			Units		
		Mobile clinics	Permanent clinics	All clinics	Mobile clinics	Permanent clinics	All clinics
f	1	55,919	51,570	107,489	55,919	51,570	107,489
f	2	23,401	22,688	46,089	46,802	45,376	92,178
f	3	11,924	11,762	23,686	35,772	35,286	71,058
f	4	5,962	6,196	12,158	23,848	24,784	48,632
f	5	2,563	3,327	5,890	12,815	16,635	29,450
f	6	781	1,573	2,354	4,686	9,438	14,124
f	7	39	211	250	273	1,477	1,750
m	1	44,261	45,447	89,708	44,261	45,447	89,708
m	2	20,300	21,863	42,163	40,600	43,726	84,326
m	3	12,927	14,284	27,211	38,781	42,852	81,633
m	4	8,962	10,176	19,138	35,848	40,704	76,552
m	5	6,098	7,804	13,902	30,490	39,020	69,510
m	6	2,711	6,222	8,933	16,266	37,332	53,598
m	7	147	1,069	1,216	1,029	7,483	8,512
m	8		1	1	–	8	8
f		100,589	97,327	197,916	180,115	184,566	364,681
m		95,406	106,866	202,272	207,275	256,572	463,847
Total		195,995	204,193	400,188	387,390	441,138	828,528

mathematical model to inform recruiting targets for the period following the change to the donor deferral interval.

1.2 Problem Statement

The change in donor deferral policy will reduce the number of collections that can be obtained from females. Lost donations have both a permanent component, due to the decreased frequency with which women can donate blood, as well as a transient component due to the timing of the last donation by female donors prior to the implementation of the change. In this paper, we present a methodology for identifying donor requirements to fill demand for blood, immediately following a change in deferral durations.

2 Literature

Even though blood is a universal medical product and similar systems exist for collecting blood throughout the world, the literature on donor clinic operations is surprisingly sparse [3]. While the blood supply chain management (BSCM) literature is extensive, much of it focuses on inventory management [4], and little has been written specifically on clinic operations. Osorio, Brailsford, and Smith, in a recent review, divide the clinic management literature into broad topic areas, but note deficiencies in coverage, including consideration of the periodicity of donations [5].

Within the donor clinic literature, the allocation of staff and methods of scheduling donors to make best use of available resources is common consideration. For example, Pratt and Grindon [6] use a simulation model to study a variety of donor scheduling strategies; they suggest sequencing male and female donors differently, to take advantage of differences in processing times. Brennan et al. [7] employ a simulation model to evaluate a series of alternative clinic designs. Blake et al. [8] use a similar technique to determine donor metrics in a planning system that evaluates the impact of staffing levels and break schedules on peak donor wait times. Later Blake and Shimla [3] combine a queuing model for estimating resource capacities with a simulation model to evaluate policies for a series of blood donor clinics in Canada. Alfonso et al. [9] evaluate a range of donor templates, under the assumptions of cancellations and no-shows, using a simulation model. Quite recently, van Brummelen produced a set of models to optimize jointly donor schedules, staffing, and resource requirements, using a discrete time Markov model [10].

Less well developed in the literature are models dealing with donor policies. However, Lowalekar and Ravichandran [11] use a simulation model to prove that unrestricted collections policies (i.e. without specific upper bounds on units to be obtained) is neither cost effective, nor operationally beneficial. Working on the interface between tactical and operational planning, Alfonso et al. [12] use mixed integer programming to determine the routing for mobile collection clinics and suggest daily collection goals and staffing requirements to achieve those goals. Custer et al. [13] provide a statistical analysis of completed donations relative to donor arrivals, providing information on which donors are most likely to be deferred from donation, why they are deferred, and the average length of their deferral. Perhaps most applicable to this study is a work by Madden et al. that uses a simulated cohort study to evaluate the use of different collection methods in an environment of increased deferrals due to travel restrictions [14]; they conclude that implementing "double-red cell" apheresis collections can ameliorate a decrease in eligible donors, though at a marked increase in cost. The Madden et al model, while stratifying by donor age and sex, is unable to accommodate the interaction between donor demographics and the method of collection. For instance, their model does not include the impact of more restrictive hematocrit requirements for apheresis red cell donations on female deferral rates.

We conclude, therefore, that the literature on blood donor clinics is incomplete. While there is an existing literature, most modelling efforts have focused on steady state analysis to optimize inventory policies or to maximize resource utilization, subject to constraints on donor wait time. There are fewer studies focusing on donor scheduling and none, that we are aware of, that evaluate the transient effects of changes to donor policies on recruiting requirements.

3 Methodology

To determine the impact of the change in the deferral period for donations, a linear programing model was created that identifies the number and type of appointments required immediately following the policy implementation. Donors are categorized by sex (m/f), clinic type (Mobile/Permanent), and preferred frequency of donation (1 $\rightarrow$ 8 times per year or 52 $\rightarrow$ 8 weeks between donations). The model estimates the number of donors who will return within their preferred interval ("scheduled"), the number of existing donors who are registered, but have not booked an appointment within their preferred donation interval and who must be induced to return ("extras"), and the number of donors who must be newly recruited ("new") to reach a donation target.

3.1 Data

Data was obtained for all collections made at a CBS facility between 01 Sep 15 and 31 Aug 16. Data included basic demographic data (sex, age, and donor status) for all donors, as well as a list of units collected (date, location, type), and a list of appointments, for each donor, scheduled between 03 Sep 16 and 31 Mar 17.

3.2 Method

The solution includes four elements:

a. a summary of past donation behavior for the period between weeks −61 through −9 weeks (i.e. prior to the scheduled policy change);
b. a summary of the number of donors who are known to have booked appointments but who have not yet attended those appointments up to the +29th week in the planning horizon;
c. a projection of donors from week −8 through the week 0 of the planning horizon;

d. a linear programming model that determines both the number of registered, but unscheduled donors, who should be induced to return to donate, and the number of new donors required to make up any shortfall in donation.

The donation record provides the history of donor attendance for active and recently lapsed donors in the CBS donor database. The information can be summarized by week, sex of the donor, clinic type, and donor's preferred donation frequency (called donor class). Data was obtained for the 52 weeks preceding the analysis, or −61 through −9 weeks of the planning horizon.

Also available at the time of the analysis was a list of the known appointments for all donors through the end of the fiscal year (week +29 from the planned change date). Through an anonymized key, future appointments could be linked to previous donation records. Thus, the number of known appointments was available for up to +38 weeks from the time of analysis. In addition, the number of donors who were registered, but who had not booked within their regular return interval, could be determined. Assuming a fraction of donors who have not booked as of the date of analysis (i.e. 9 weeks before the policy change), would book, a forecast of the expected number of appointment slots to be filled could be obtained. Thus, the expected number of scheduled donations in weeks −8 through −1 of the implementation horizon is determined by:

Subscripts

g sex (m/f)
c clinic (M/P)
k donor class (1, …, 7) with an inter-donation interval of z_{gck} weeks.
t time period in the planning horizon

Variables

q_{gckt} the number of donors of sex g, clinic c, class k who have booked an appointment in period t, where $t = -z_{gck}, \ldots, -1$

u_{gckt} the number of donors of sex g, clinic c, class k, without an appointment, but who last donated in period t, where $t = -z_{gck}-9, \ldots, -1$

p^{A}_{gck} the proportion of currently unscheduled donors of sex g, clinic c, class k who are expected to book an appointment prior to week 0.

y^{S}_{gckt} the estimated number of scheduled donors of sex g, clinic c, class k, in period t, where $t = -8, \ldots -1$. y^{S}_{gckt} is thus:

$$y^{S}_{gckt} = q_{gckt} + p^{A}_{gck} * u_{gck(-z_{gck}+t)} \; for \; t = -8, \ldots, -1 \tag{1}$$

Equation 1—Estimating the number of scheduled appointments prior to week 0.

For example, consider week −8 on the planning horizon. At the time of analysis, there were 843 scheduled appointments for female donors attending a permanent clinic with a preferred frequency of 1 donation per year, or a return period (z_{gck}) of 52 weeks. 5 donors, who had last donated in week −60, had not yet booked an appointment. Historically, 50% of all un-booked regular donors return, so it is

assumed that $\lfloor 2.5 \rfloor = 2$ additional donors would be scheduled in week -8 of the planning horizon. Thus, the expected number of scheduled appointments in week -8 for female attendees of permanent clinics would total 845. Similar calculations can be made for all other classes of donors and a forecast of the filled appointment slots can be generated up to the time of the policy change at week 0.

The final component of the solution method is a linear programming model that determines the number of unscheduled donors (extras) who must be called in and the number of new donors required to achieve a target collection. Donors are assumed to either be (a) in-schedule; or (b) out-of-schedule. In-schedule donors have a donation (planned or actual) within z_{gck} weeks of the change over date (t_0); out-of-schedule donors do not have a scheduled donation within z_{gck} weeks of t_0. Donors who are out-of-schedule are candidates to become "extra" donors; out-of-schedule donors who are induced to return to schedule are assumed to continue to repeat donations at the same frequency as in-schedule donors.

Male donors are assumed to be unaffected by the change in deferral policy, but female donors are assumed to have an 84-day (12 weeks) deferral if they donate at a permanent clinic. Female donors who donate at a mobile clinic, while technically deferred for 12 weeks, are assumed to have an effective deferral period of 16 weeks, since many female donors cannot attend two back-to-back mobile clinics at a given locale.

New donors, when selected by the optimization phase of the model, are assumed to enter donor class 1 and thus to make only 1 donation during the planning horizon. Donor attrition is not included in the forecast and donor class changes are not considered by the model.

The optimization component of the solution conjointly determines the minimum number of new and returning "extra" donors needed to achieve a target collection volume.

Model Variables

y^S_{gckt} the number of scheduled donors of sex g, clinic c, class k, in period t
Y^S_t the total number of scheduled donors in period t
y^A_{gckt} the number of extra donors of sex g, clinic c, class k, in period t
r^A_{Max} the maximum fraction of extra donors that can be recruited
Y^A_t the number of extra donors required in period t
C_t the target collections in period t
w^N the penalty (cost) to recruit a new donor
w^A the penalty (cost) to induce an unscheduled donor to make an extra donation
w^O the penalty (cost) for over collecting.

Decision Variables

x^N_{gckt} the number of new donors of sex g, clinic c, class k, in period t
X^N_t the total number of new donors needed in period t
d^+_t the number of donors over target in period t
d^-_t the number of donors under target in period t

r^{A}_{gck} the fraction of the maximum number of extra donors of sex g, clinic c, and class k to be recruited.

Minimize:

$$\sum_t w^N x_t^N + w^A Y_t^A + w^O d_t^+ \tag{M0}$$

Subject to:

$$Y_t^S = \sum_g \sum_c \sum_k y^S_{gck(-z_{gck}+t)} \quad t = 0, 1, \ldots \tag{M1}$$

$$Y_t^A = \sum_g \sum_c \sum_k r^A_{gckt} * y^A_{gck(-z_{gck}+t)} \quad t = 0, 1, \ldots \tag{M2}$$

$$X_t^N = \sum_g \sum_c \sum_k x^N_{gckt} \quad t = 0,\ 1, \ldots \tag{M3}$$

$$Y_t^S + Y_t^A + X_t^N + d_t^- - d_t^+ = C_t \quad t = 0, 1, \ldots \tag{M4}$$

$$r^E_{gck} \leq r^E_{Max} \quad \forall g, c, k \tag{M5}$$

Bounds

$$0 \leq r^E_{gck} \leq 1 \tag{M6}$$

$$X^N_t, d^-_t, d^+_t \geq 0 \tag{M7}$$

The linear programming model minimizes the weighted cost of selecting either extra or new donors, while ensuring that over collections do not occur (M0).

Equation M1 counts the number of scheduled donors per week in the decision horizon. Scheduled donors are summed over sex, clinic, and frequency type. For model purposes, it is assumed that $y^S_{gckt} = y^S_{gck(-z_{gck+t})}$ or that the number of donors to schedule an appointment in period t is equal to the number of donors who scheduled an appointment z_{gck-t} periods ago. For example, at t = 0, the number of female donors attending a permanent clinic having a donation frequency of 1 year, or 52 weeks between donations, is assumed to be equal to $y^S_{fP1(-52+0)}$, the number of scheduled donors in week −52. Of course, z_p changes for some classes of donors following the implementation of the extended deferral period for females. See Table 2.

Similarly, Eq. M2 counts the number of regular donors without appointments who should be invited to return within their regular donation period. As was the case for scheduled appointments, the number of extra donors available to be recruited is assumed to be equal to the number of unscheduled donors in period $-z_{gck}$ + t. For instance, in planning week 10, the number of unscheduled male donors attending a mobile clinic and having a preferred donation frequency of 26 weeks (y^A_{mP10}) is assumed to be equal to the number of unscheduled male donors in week −16 (y^A_{mP-16}).

Table 2 Change to deferral periods following policy change

Donation frequency per year	Clinic type	Time between donations (old in weeks)	Time between donations (new in weeks)
1	Mobile	52	52
2	Mobile	26	26
3	Mobile	18	28
4	Mobile	13	16
5	Mobile	11	16
6	Mobile	9	16
7	Mobile	8	16
1	Permanent	52	52
2	Permanent	26	26
3	Permanent	18	28
4	Permanent	13	13
5	Permanent	11	12
6	Permanent	9	12
7	Permanent	8	12

Constraint M3 counts the number of new donors who must be recruited in each period. This value is summed over sex, clinic type, and donor class.

Constraint M4 sets elastic targets for donations over the planning horizon. The number of scheduled donors (Y_t^S) plus the number of extra donors (Y_t^A) plus any newly recruited donors (X_t^N) should equal the desired collection target. Any shortfall (d_t^-) or surplus (d_t^+) is assigned to variables and d_t^+ is minimized in the objective function.

4 Experiments and Results

The linear programming model was run under an assumed set of weights indicating the relative cost of recruiting new donors vis-à-vis inducing unscheduled donors to return and the cost of modest overcollection: $w^N = 10$, $w^A = 1$, and $w^O = 0.1$. Two sets of scenarios were run. In the first set of scenarios, called immediate change, it was assumed that the extended deferral period for females would be applied to any appointment occurring after the date of policy change. In the second set of scenarios, called phased-in change, the extended deferral period was applied only to appointments booked after week 0. Both sets of scenarios were run with bounds on the maximum fraction of unscheduled donors who could be induced to return set at 0.25, 0.50, 0.75, and 1.0. The results appear in Tables 3 and 4.

Table 3 Model results for the immediate change scenarios. Bounds represent the assumed recruiting limit on unscheduled donors, New represents newly recruited donors. Req'd indicates the number of additional required donors. Results are presented for the first five weeks of the change and for a 52-week period

	1st five weeks					Annualized				
Bounds	Sched	Extra	New	Req'd	Total	Sched	Extra	New	Req'd	Total
0.25	60008	3704	33789	37493	97501	564000	44000	237000	281000	845000
0.50	63303	7408	26789	34197	97500	607000	88000	150000	238000	845000
0.75	66599	11112	19790	30902	97501	651000	131000	68000	199000	850000
1.00	68894	14816	14160	28976	97870	694000	175000	22000	197000	891000

Table 4 Model results for the phased-in change scenarios

	1st five weeks					Annualized				
Bounds	Sched	Extra	New	Req'd	Total	Sched	Extra	New	Req'd	Total
0.25	61909	3704	31888	35592	97501	572000	44000	229000	273000	845000
0.50	65204	7408	24888	32296	97500	616000	88000	141000	229000	845000
0.75	68500	11112	18062	29174	97674	659000	131000	60000	191000	850000
1.00	71795	14816	12741	27557	99352	703000	175000	19000	194000	897000

As may be observed from the results, phasing-in the deferral period for female donors reduces the requirements for extra donors by 5% in the first five weeks of the policy implementation across all scenarios, with between 5 and 10% fewer new donors required, depending on the assumptions regarding the maximum fraction of unscheduled donors who will return. Extending model results out to +52 weeks from the implementation date, a phased-in policy change results in a reduction of between 2 and 4% for extra donors needed, with a decrease of between 4 and 14% for new donors with a phased-in policy change. Thus, given the obvious operational benefits, a phased-in policy change is clearly advantageous.

As expected, the model results for the phased-in policy in Table 4 show that a substantial effort must be expended to recruit new donors in Week 0 through Week 4 of the planning horizon and at intervals throughout the year. See Fig. 1 for an example plot in which the maximum fraction of unscheduled donors who will return is assumed to be 0.5. This pattern is common to all runs within the phased-in model change, but the number of new donors decreases as more unscheduled donors are induced to return. However, diminishing returns applies and the largest decrease in new donor requirements was observed when the bound on the maximum fraction of unscheduled donors is increased from 0.25 to 0.5, or roughly equal to the historical return rate for CBS donors. Assuming similar operational performance after the deferral policy change, it was estimated that 32,296 additional donors needed to be recruited in the first five weeks of the planning horizon, with the ratio of new to extra donors being 1:8 in Week 0 but falling to 1:1 by Week 5.

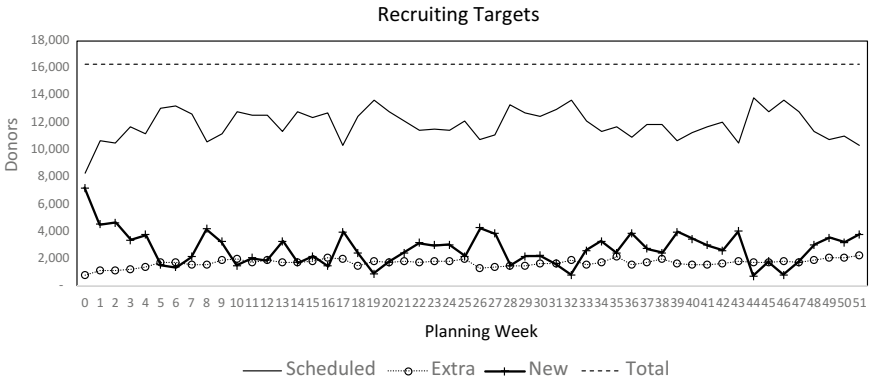

Fig. 1 Plot of recruiting targets for scheduled, new, and extra donors following a change in deferral duration for females. The data in the graph assumes a phased-in strategy and that 50% of unscheduled donors can be induced to donate

5 Remarks and Conclusions

In this paper, we have presented a model to guide donor recruitment strategies for Canadian Blood Services, following a change in the inter-donation deferral period for females. Once low ferritin levels became a concern, CBS moved quickly to maintain donor health and safety. Thus, the time available to complete the analysis of additional donor requirements was very tight; in total, a little over six weeks was available to generate recommendations. While we would not claim that the model represents donor behavior with perfect fidelity, the tool created for this project provided a testbed to trial different ideas and scenarios quickly and efficiently within the available timeframe. A substantial number of scenarios was built and tested using the tool.

Law [15] suggests a hierarchy of model veracity that extends from verified to validated to credible, with credibility for decision makers being the pinnacle of proof of a model's form and function. In this case, our model results were clearly accepted by the organization and adopted as targets for recruiting in advance of the deferral change. We note, in particular, the broad dissemination our recommendation of 32,000 to 35,000 additional donations received inside the organization and in the popular press [16].

Collecting blood from volunteer donors is an important task with uncertain parameters. While donor motivation is not completely understood, it has been established that donor safety and ease of donation increases the likelihood that individuals will remain as donors [17]. As part of its digital transformation in donor relations, Canadian Blood Services has invested in state-of-the art systems for interacting with donors and potential donors electronically, including functions for booking appointments, completing health assessment questionnaires, and managing clinic flows. These systems are central for managing collections [18]. The digital platform col-

lects the data that allows CBS to characterize its donor base, to model the impact of changes in the clinical environment, and to develop strategies to respond to regulatory changes. The digital donor platform, furthermore, enabled the two-way communications with the donor base and simplifies efforts needed to make individuals aware of changes in their established donation patterns [19].

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The Future Risk of Internet Companies: Is There a Medium-Term Convergence?

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Abstract After the fact of the Internet Bubble, the technology companies, especially the Internet companies, were characterized as a sector of greater risk when compared to the other consolidated sectors. Thus, the present study aims to analyze whether the market risk of companies in the internet sector is still higher than companies in consolidated sectors. For this comparison, the Value-at-Risk (VaR) risk management method was used, which summarizes, in a single number, the worst expected return within certain confidence intervals and time. This methodology was applied to two groups: internet companies, traded in NADASQ, and companies in consolidated sectors, such as consumer goods, manufacturing, financial services, among others, traded on the NYSE. Samples are divided between 2000–2007 and 2008–2014 periods to compare behavior over time. The final result suggests that Internet companies still had a higher market risk than firms in consolidated sectors, but this risk decreased substantially between the periods studied.

Keywords Internet companies · Value-at-risk · Risk management

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1 Introduction

The investment decision process involves several variables, including risk perception. This factor has a high subjective component, driven by psychological factors that differ from person to person, which interferes with the individual's choices throughout life [1].

This parameter, brought to the investment area, makes the perception of risk even more relevant for investors, since several investment decisions are made based on non-technical knowledge [2]. In the stock market, this pattern is even more visible, mainly because of the ease of access to this type of investment and the high volume of information currently available.

Managers' concern with the notion of risk (whether in corporate finance, financial markets, product quality, environment) has increased in terms of assessment, characterization, and management [3]. In addition, risk issues are intrinsically dynamic, changing profile over time and across geographic and cultural space [4].

In this context, delimiting Internet companies as companies whose majority of their revenues comes from the Internet, it is hypothesized that dot-com companies present greater risks when compared to companies from more traditional sectors of the economy.

Thus, this paper tends to answer the question: Do companies in the Internet sector present a market risk superior to companies in other sectors?

Therefore, the objective of the research problem is to analyze the relationship between the market risk of Internet companies and other sectors of the economy, through the Value-at-Risk (VaR) risk management technique. In this way, it will be analyzed whether there is a process of convergence between the market risks in the internet sector in relation to the other sectors occurring in the last years, and if the average VaR of the shares of companies in the internet sector equals the average VaR of companies from other sectors of the economy.

The present work is organized in four sections besides this introduction. The second section presents a literature review on Risk Management in companies. In the third section is the research method and in the fourth section the results and discussions. Finally, the main considerations are found in the fifth section of this paper.

2 Literature Review

In this topic a review of the literature on Risk Management in companies is carried out in order to explore applications of this approach. In the process of searching and analyzing the articles, the Scopus portal was used.

The authors Klepác and Hampel focused on the application of volatility models when estimating the portfolio of equity at risk based on data from companies traded on the stock exchange in Prague from January 2010 and April 2014. The results

indicate an overestimation of the level of risk for almost all approaches to the model. The Kupiec and Christoff models are the most effective in the VaR forecast. This model is the only case too, in which the violations model are distributed over time independently [5].

Bianconi and Yoshino [6] analyzed a sample of 64 non-renewable energy industry oil and gas companies from 24 countries using daily observations on the return on stock from July 15, 2003 to August 14, 2012. It was found that the size and leverage are important to explain the returns of energy companies. The exchange rate effect explains the fact that many companies in the industry receive the revenues denominated in national currency while the costs are in their foreign currency [6].

Bianconi and Yoshino [7] analyzed a sample of non-renewable energy industry oil and gas companies from emerging countries composed of: Brazil; Russia; India; China; and, South Africa (2003–2012). The conditional dynamic correlations between returns and the market premium under the exposure that some companies show arise as clear hedges against significant negative market risk [7].

The authors Jing and Wu based on the current comprehensive valuation system both domestically and abroad, this work established a valuation system whose VaR has market capacity and 12 financial indices to evaluate the comprehensive performance of Chinese real estate companies. First, Eviews 6.0 is used to calculate the risk sample size of 50 companies. Then SPSS is used to perform the factor analysis and five factors that are extracted among 14 indexes [8].

The study of Hsu and Li used complete valuation methods to calculate Value at Risk (VaR) as the measurement of market risk for economic capital. According to the New Capital Accord, the risk of the Internal Model market should be adjusted, and the Bank for International Settlement suggests the use of the backtest to select the best method to estimate full VaR assessment adjusted. Overall, there was weak evidence that the performance of FHC increases over time [9].

2.1 Value-at-Risk (VaR)

The risk characterization is present in managerial decision making, in peculiar and uncertain scenarios and is based on the principle of loss aversion from the decision made. This concept suggests that the experience or heuristic adopted is a preponderant risk factor in decision making [10].

Specifically in financial management, [11] essentially, risk is a possibility of financial loss, but the assets considered more risky will be the ones that will bring the greatest chances of financial loss. In this sense, it is the variability of returns associated with an investment. VaR is a measure capable of summarizing in a single number the total exposure to an institution's market risk. Thus, according to Jorion's definition (2007, p. 18), "the VaR summarizes the largest (or worst) loss expected within a given period of time and confidence interval" [12].

2.2 *Goodness-of-Fit Tests Based on the FDE (Empirical Density Function)*

The Goodness-of-fit tests are statistical tools to test whether two samples belong to the same population or if the probability distribution of a series belong to a theoretical probability distribution. This feature provides useful applications for risk management, given the importance of knowing the correct probability distribution. The Empirical Density Function (EDF) is a statistical medium that measures the difference (vertical distance) between two functions of cumulative probability density (fdpc), Fn(x) and F(x). In this case, Fn(x) and F(x) can be two empirical or empirical and one theoretical fdpc, thus being able to measure the adhesion of an empirical data with a particular theoretical distribution [13].

3 Methodology

The project in question aims to measure the relations of variables in order to understand a phenomenon through a statistical model. Therefore, this work can be characterized as a quantitative experimental research of a descriptive character [14]. The research method is centered in the study of the Parametric VaR of extreme values based on tests of adherence of the studied variables (historical series of returns of the assets) and later verification of the hypothesis of convergence between the same, in order to reach the declared objective, this is, whether or not internet companies have a risk value comparable to companies in consolidated sectors.

3.1 *Variable Designs*

The variables were composed of publicly traded companies traded in the United States stock market, as they have a more developed economy in terms of Internet companies, which gives greater strength and volume of data available for study. The data analyzed refer to the daily closing price, collected through the database available on the Yahoo Finance website. The samples were divided into two groups: internet companies and companies from consolidated sectors. Both samples from each group were composed of 9 different shares of companies traded between January 2000 and December 2014, that is, 168 months.

Internet companies have been classified as those that rely on the internet to do most of their business. These shares are part of the NASDAQ Internet Index (QNET), an index made up of companies that have the Internet as the primary means of business. These companies are: Amazon, Citrix, eBay, Internap Corporation, j2 Global, LivePerson, Priceline, VeriSign and Yahoo. Note that some well-known Internet companies, such as Google or Facebook, are not on the list because their Initial Pub-

lic Offerings (IPO) date back to 2000. Even companies in the technology sector, but involving the Internet, such as Microsoft, Apple, or Intel, were not considered. The reason for this is because its core businesses do not relate to the internet, but with operating system in the case of Microsoft; or hardware such as Apple, Intel and others. Another important point is that some of these companies are popularized before the internet is widely recognized, which reaffirms the position of being companies that do not have the Internet as the core of their business.

Companies in consolidated sectors can be understood as those related to manufacturing, energy, consumer goods, financial services and other traditional areas of the economy. All these shares are traded on the New York Stock Exchange (NYSE), with IPO before 2000. These companies are: Caterpillar, Chevron, Exxon Mobil, Ford Motors, JP Morgan, McDonalds, Procter & Gamble, Volkswagen and Wal-Mart.

3.2 Application of VaR

After the data collection, the difference between the closing of one day (rt) and the previous closure (rt − 1) for the data set was calculated. For this calculation, since some distributions do not accept negative values, we used the exponential return Rt of Eq. (1):

$$Rt(x) = (\ln rt / \ln rt - 1) = \ln rt - \ln rt - 1 \tag{1}$$

Parametric VaR was selected among other methods because of its reliability and simplicity due to the normal distribution that can be attributed by choosing samples with a vector of 3773 variables, which is considerable to attribute such reliability to the normal distribution. In order to calculate the VaR, the EasyFit® software was used to analyze the samples and obtain the mean Parametric VaR, based on the adhesion test, calculated year by year, as presented in Eq. (2):

$$\text{VaR (average)} = \text{W}_0 \, \alpha \, \sigma \, \sqrt{\Delta \text{r}} \tag{2}$$

The confidence level chosen to calculate the VaR was 95%, since it is a level that gives sufficient efficiency, accordVaR (average) = W_0 α σ $\sqrt{\Delta \text{r}}$ ing to the literature. Therefore, the 10% of the worst returns of the empirical distribution of each sample group were chosen to obtain a sample value consistent with the adhesion tests. Thus, VaR was obtained for the best probability distribution classified by EasyFit® software for both the Kolmogorov-Smirnov (KS) and Anderson-Darling (AS) tests.

3.3 Method of Analysis

The distributions obtained in VaR were validated within a confidence interval, known as backtesting, through the Kupiec test. Also, a comparison was made between the two sectors to understand if there is a process of convergence between the periods studied, performed by the Man-Whitney U test. The provenance of both tests done are reported below.

Precision Test (Backtesting)
In order to know which distribution presents the most accurate estimation of VaR, the Kupiec test was used for this process. This test, better known in the financial market as backtesting, analyzes a certain confidence interval with the historical data group to know how accurate the method would have predicted actual results. The Kupiec test is efficient in this step because it creates a confidence interval for the number of violations of the calculated VaR based on the probability of the Bernoulli distribution given by (3):9l

$$2\ln(\mathrm{L}) - 2\ln(\mathrm{L}_0) \sim X^2_{(1)} \tag{3}$$

The probability ratio (L) allows to calculate the limit of the range, which the null hypothesis that the VaR actually reaches 95% of the cases is accepted, which can be represented by (4):

$$L = -2\ln(1-\mathrm{p})^{T-N}\mathrm{p}^{N} + 2\ln[(1-\mathrm{N/T})^{T-N}(\mathrm{N/T})^{N}] \tag{4}$$

For example, taking a sample with 1000 days, with 23 days exceeding the VaR limit, having $\mathrm{p} = 2.3\%$, if $\mathrm{p}_0 = 2\%$, it is necessary to test if the sample value is compatible with the hypothesis null that the value is 2%. Thus, we use the probability rate where L_0 is the probability that in 1000 cases, the event (with probability p_0) occurs 23 times, and the complementary event (with probability $1 - \mathrm{p}_0$) occurs 977 times, while L is the probability that in 1000 cases, the event (with probability $\mathrm{p}_0 = \mathrm{N/T}$) 23 times against 977 times the complement event (probability $1 - \mathrm{P}$). If the statistics $2\ln(\mathrm{L}) - 2\ln(\mathrm{L}_0)$ is less than the chi-square tabulation with a degree of freedom, then H_0 is not rejected.

In order to carry out such a verification, a program has been developed, using Matlab® software, which establishes the confidence interval, that is, it finds the number "n" where $2\ln(\mathrm{L}) - 2\ln(\mathrm{L}_0)$ is nearest the tabulated value of chi-square with a degree of freedom, rounding the result to an integer.

Convergence Analysis
The Mann-Whitney U test, an ideal non-parametric test to compare two independent populations, was calculated using Eq. (5) to compare the convergence between internet and consolidated company groups within a same period also performed using Matlab® software:

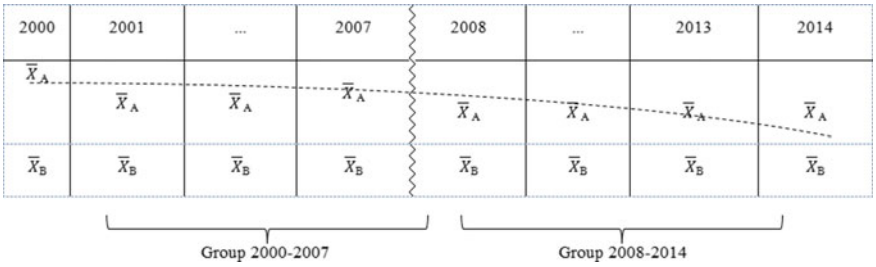

Fig. 1 Convergence analysis of VaR year by year. *Source* Prepared by the authors (2017)

$$U = N1.N2 + (N1.(N1 + 1))/2 - W1 \quad (5)$$

Consider N1 = number of cases in group 1; N2 = number of cases in group 2; W1 = sum of the stations.

Therefore, it is possible to verify if the difference of the means of the two sample groups between 2000–2007 and 2008–2014 is statistically significant and if there is a convergence process between them. Besides to compare the behavior with respect to time. Figure 1 illustrates the proposed analysis where –XA is the average value of the VaR of internet companies and –XB is the average value of the VaR of the companies of consolidated sectors. In this case visually exemplified, it shows that there is a process of convergence between the two groups, that is, companies in the Internet sector have reduced market risk when compared to companies in consolidated sectors.

This analysis has four possible paths, explained in the sequence:

path 1: there is a statistically significant difference between the mean values of the samples in the 2000–2007 group, but this difference ceases to exist in the 2008–2014 group, which means that there is a convergence between the samples, that is, the Internet companies are reducing risk compared to companies in consolidated industries;
path 2: there is no statistically significant difference between the mean values of the samples in the 2000-2007 group, but there is a significant difference in the 2008-2014 group, which indicates a process of divergence, that is, the companies of the internet had a lower risk in the past and are increasing the risk as of 2008;
path 3: there is no statistically significant difference between the mean values of the samples in the 2000–2007 group and this difference is also not found in the 2008–2014 group, which indicates that there is no convergence between the samples, Internet companies present higher risk when compared to companies in consolidated sectors;
path 4: there is a statistically significant difference between the mean values between the samples in the 2000–2007 group and this difference still exists in the 2008–2014 group, which means that there is no convergence between the samples, that is, the Internet companies continue to present a greater risk when compared to companies

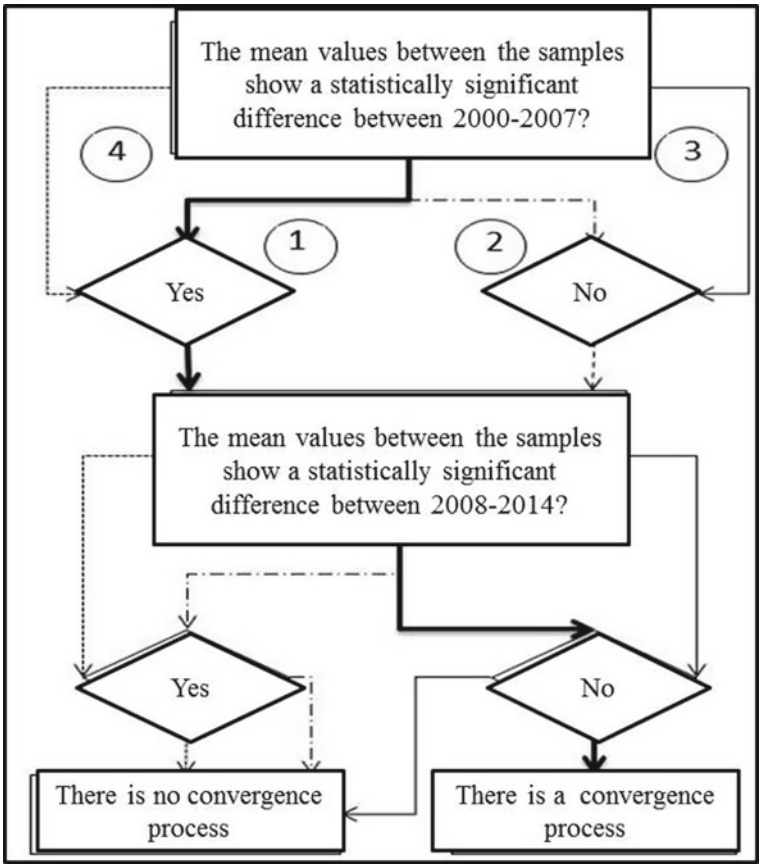

Fig. 2 Possible paths of analysis. *Source* Prepared by the authors (2017)

in consolidated sectors. A schematic of the possible paths considered can be visually analyzed in Fig. 2.

4 Results and Discussions

The results were separated into three topics to facilitate understanding of the data. The first topic comprises only the value of the VaR found for the companies studied according to their types of distributions, in addition to revealing the average VaR by sector. The second topic is the validation of the VaR (backtesting) found together with the analysis of the convergence of results (Man-Whitney U test). Finally, the third topic shows the result with the inclusion of new internet companies more recognized in the Internet companies group to validate the result.

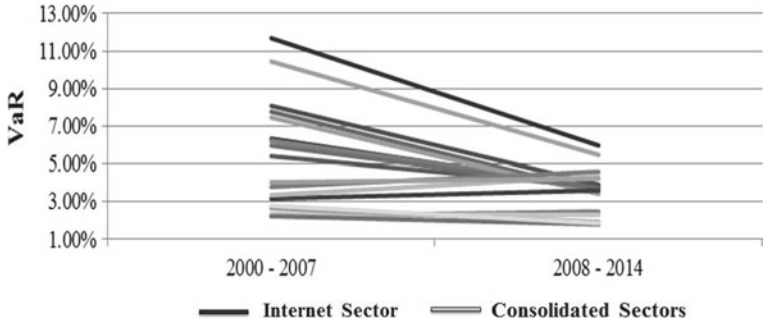

Fig. 3 Variation of the VaR of companies of the sector of the Internet versus consolidated sectors. *Source* Prepared by the authors (2017)

4.1 Value of VaR for Each Distribution

More succinctly, it is possible to analyze the VaR values separated only by the group in the internet sector and consolidated sector, as seen in Table 1.

According to the result, it is possible to state that internet companies have considerably reduced their market risk over time. This claim is demonstrated by the reduction of the average VaR by −46.2% of Internet companies between 2000–2007 and 2008–2014, from −7.70% to −4.14%, respectively. Meanwhile, the average VaR among companies in consolidated sectors increased +1.4% in the same period, going from −2.96 to −3.00%. This panorama is more easily perceived when shown in a visual form, presented in Fig. 3. For the compilation of such a graph, the distribution average between the VaR values of the KS and AD distribution was made for each company. As the purpose is to show the disparity between the companies of the Internet sector versus the consolidated sector, there is no denomination of each company in the graph, but rather the variation of the group in general.

Table 1 Mean VaR values by sector. *Source* Prepared by the authors (2018)

Period	KS (%)	AD (%)	Average (%)
Internet sector			
2000–2007	−7.45	−7.96	−7.70
2008–2014	−4.04	−4.23	−4.14
Consolidated sector			
2000–2007	−2.95	−2.97	−2.96
2008–2014	−2.92	−3.08	−3.00

4.2 Precision and Convergence Test

To verify which distribution presents the most accurate VaR estimate, the Kupiec test was used. Only the value for the Volkswagen VaR for the AD distribution in the 2008–2014 period was not within the confidence interval. All other VaRs were within the confidence interval for each period.

4.3 Revalidation of Results

In order to confirm this result, other large internet companies were included, but with IPO after the year 2000, in order to know if the result obtained is also valid when one inserts Internet companies more recognized in the market, that is, with lower perception of risk. The added actions and their respective IPOs are Google (2004), Netflix (2004), Salesforce (2002). The latter is the largest publicly traded cloud company, less well-known in Brazil, but rather solid in the US. Thus the division of the period was kept the same, counting from the date of the IPO until 2007 and without modifications in the other group, from 2008 to 2014.

This new result reinforces the result obtained previously. In other words, this new test reaffirms that the actions of internet companies presents a higher market risk than companies in consolidated sectors.

5 Conclusions

From the obtained results, it is possible to affirm that the companies of the sector of internet present a market risk superior to the other sectors, which responds the problem of research. The alleged conclusion is supported by two factors: (a) there is no convergence process between the market risks in the internet sector in relation to the most consolidated sectors within the analyzed period; (b) The average VaR of the shares of companies in the internet sector is higher than the average VaR of the companies in consolidated sectors.

In order to cancel this assertion, the same results were obtained even after being recalculated with the inclusion of companies that made the IPO after the internet bubble and that are recognized in the market worldwide. However, it is worth mentioning that the average VaR of internet companies decreased 46.4% between 2000–2007 and 2008–2014, from -7.70% to -4.14%, respectively. Meanwhile, the average VaR among companies in consolidated sectors showed a slight increase of 1.4% in the same period, going from -2.96 to -3.00%. Also, in the period 2000–2007, the average VaR of internet companies was 4.40% points higher than that of companies in consolidated sectors, but for the period 2008–2014, this difference is only 1.14, which shows the trend of risk equalization.

The results achieved, however, need to be considered within their limitations, since there were very few Internet companies with IPO before 2000 and that they remained in the stock exchange with public capital until the end of 2014, which considerably reduces the size of the sample. However, the validity of the study is maintained because of the Mann-Whitney U test, which gives a comparison of small group samples.

In terms of risk management, this study showed that VaR with 95% confidence can be a suitable measure for investment security, being neither conservative nor aggressive, since the backtesting was within the limits of 43 among 44 distributions studied. VaR has proved to be an intuitive and easy-to-understand measure because it clearly summarizes the level of risk of an action.

It is also important to mention that every period of IPO presents a greater risk to companies of any sector, having a higher volatility in the first years due to several factors, such as speculation. Therefore, one way to mitigate this event would be to do an analysis with internet companies only after the first 2 years after the IPO. For greater equality of comparison between sectors, it would also be advisable to analyze these actions of internet companies along with other companies from consolidated sectors that made the IPO in similar periods. In this way, it is possible to equate the risk characteristic of the IPO for any type of company, regardless of the sector in which it is inserted. Another suggestion for future work is to include other types of risk, such as the liquidity and operational risks of the objects studied, to obtain a more complete understanding of the interdependencies of the companies' market risk.

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The Impact of ERP Systems on the Organizational Maturity of Brazilian Construction Companies

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Abstract Construction companies have been searching for alternatives to increase their profits margins, based on reducing costs, raising productivity, technological solutions and management of production. The sector finds in the Enterprise Resource Planning (ERP) system the possibility of controlling and managing the execution of the works on any work step. The ERP, through comercial software packages for the construction industry, operate in an integrated network. The tool has been used by companies in the construction industry to make production and management more efficient. The ERP system has been used by companies in the construction industry to make production and management more efficient. However, implanting this system provokes a great organizational change, which justifies why some companies achieve good results while others do not. The objective of this article is to identify which variables regarding implantation, management and performance of the ERP system interfere in the organizational maturity of a construction company. It has been proven that construction companies with ERP system have more developed aspects of organization and similar management processes. These construction companies distinguish themselves for their bigger integration between processes and departments; a better information flow; and a higher formalization of activities, projects, processes, company positions and functions.

Keywords ERP system · Organizational maturity · Management processes · Organizational characteristics · Construction industry · Information technology (IT)

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1 Introduction

The construction industry is built up by numerous organizations, ranging from suppliers of materials, projects, manpower and proper engineering companies. The process of transformation in the construction industry takes into account the final product, the property, usually unique and with a long cycle of existence and inconsistency of resource use [1].

Despite the socioeconomical importance of the sector for the Brazilian economy, its form of management is one of the less developed, traditional and conservative of the Brazilian industry [2, 3].

The managers of Brazilian construction companies focus mostly on technical specification and the structural and architectural design of the project [2].

In this way, fundamental aspects of production such as technology, qualification, productivity, specification and training were neglected, which resulted in noncompliance with deadlines, improvisation, rework, losses, wastage, low productivity and quality [3].

On the other hand, Brazilian construction companies have been searching for alternatives to increase their profits, based on reducing costs, raising productivity, technological solutions and management of production to raise the degree of industrialization of the productive process [4].

The insertion of new concepts, especially in strategy and systemic view, make companies implement information technology (IT) that allows a integrated and productive workplace. IT can help the construction industry sector follow new paths, but its use is still very late compared to other industrial sectors [1].

Construction companies are searching for integrated management systems, known as Enterprise Resource Planning (ERP), as a tool to make production and management more efficient. This can be seen because of the significant number of builders that created or implemented integrated management softwares [5]. However, while some companies achieved good results and improvements, others failed on the implementation of the ERP and did not obtain the desired results.

Many are the reasons for the lack of success. One of the most relevant factors is that the implementation of the system provokes a huge organizational change [6] that in face of the unpredictability of human reactions, prevent the desired results from being obtained [7].

The development of processes and organization systems contributes for a higher probability of success because of its repetitive nature. This is called maturity; however repetitive systems and processes cannot guarantee success, but increase the probability of success [8].

The maturity of the organization impacts the success in implanting the ERP system and the identification of negative aspects that must be neutralized [9]. Implementing an integrated system is strategic and provokes impacts on organization management, business processes and organizational architecture [10].

The objective of this study is to identify which variables regarding the processes of implementation, management and performance of the ERP system interfere in

the variables regarding the organizational maturity of companies in the construction industry.

2 ERP System in the Construction Industry

The ERP systems were created to meet new business needs and the necessity for a rapid development of integrated systems. Any sector of business activities can use ERP, including the construction sector.

Some of the advantages of implementing an ERP system are the integration of internal processes, trust in information, collection of management data that assist decision-making and the unification of different industrial plants [11].

The ERP system promotes the integration of several sectors of the organization (including all the construction sites) and speeds up the execution of activities and the optimization and automation of business processes [12]. This lowers the amount of mistakes and redoing of tasks, consequently allowing the company to profit with lower costs and a bigger productivity. The obtained information is clearer, safer and instantaneous, causing a better control of the whole business. By providing the construction company control over the execution of tasks on any stage, the ERP system shows a significant improvement in the efficiency of the organization [12].

When companies in the sector choose the ERP system they hope to achieve benefits such as: a technological update, more possibilities to control processes, lower costs in computing, return on the investment, integration of the information system and access to quality data in real time for decision-making [13].

There are numerous studies that analyze technological innovations, IT and integrated management systems in the construction sector. Most researchers highlight that the ERP system has high potential for use in the construction industry and can contribute with gains in productivity [13, 14]. Research, however, demonstrates that construction companies of several countries suffer similar challenges when it comes to implementing this system. Small and medium-sized enterprises for example, besides not finding specific software for their demands in the market, have problems with the high costs and investment of time and resources in the system [14].

The success of implementing the ERP system depends on the commitment of the system collaborators, the need to make the IT compatible with the business strategies of the company, the IT strategy, the organizational maturity, the method of implementation, remapping of the information flows and the support towards the planning and implementation [5, 12, 13].

3 ERP and Maturity

The implementation of the ERP system by itself, does not integrate a company. As observed by many of the mentioned authors, the ERP systems require big investments in technology and functional changes in the operation of the organizations. The authors claim that the organizations need to implement organizational changes, so information can flow easily throughout the whole organization. The adoption of the ERP system's technology provokes changes that range from work processes and the conduction of training programs to the users until actions that balance the organizational forces, fine-tuned to the behavior of each individual [6].

To achieve change, a company needs first to neutralize some factors. The literature [15] points out ten critical success factors in the implementation of an ERP, in order of importance: (1) support from senior management; (2) education and training; (3) efficient management of the project; (4) reengineering of the business processes; (5) management of the changes; (6) business plan (clear goals, focus and range); (7) project team; (8) external professional experience (consultants); (9) efficient communication; (10) precise data.

The success of ERP requires that its deployment process is aligned with organizational maturity [13]. Some authors [16] go further, considering that the implementation of an IT tool depends on the organizational maturity that supports it.

Organizational maturity is related to experience gained over time [17]. Maturity is the extent in which the process is explicitly defined, managed, measured and controlled [18]. The degree of maturity is important since mature organizations tend to present more structural balance, and consequently a higher performance [19].

For the scholars that dedicate themselves to defining organizational mapping patterns, the organizations can be described according to their passage through a series of stages or cycles in life. This series starts at birth, continues with a sequence of transitions and culminates with maturity, later on being revitalized or dying out [20, 21]. Harmon [18] interprets the degree of maturity as an evolutionary stage with defined goals of progression that provide support for improvements to be employed at the next stage, conducting the growth of capacity in the organizational process.

Some organizations during long periods, do not progress in the usual cycle of life, but follow a more complex path that depends only and exclusively of each organization [17]. Phelps, Adams, and Bessant [21] show that for the organization to continue growing it should overcome successfully the challenges presented by the turning points. The authors developed six turning points: management of personnel, strategic guidance, formalization of systems, entry to a new market, improvements in finance and operations, and the consideration of organizational knowledge as a requirement to help navigate through these turning points.

Navigating through the turning points, the company must have the capacity to identify, acquire and apply new knowledge. These are basic requisites to tackle the crises and the challenges produced at the turning points with success in a competitive world [21]. The capacity to assimilate and absorb knowledge assist companies in the development of better practices for their processes [22].

4 Methodology

To concretize the goal of this work, a descriptive research was performed, with a quantitative approach in 106 constructors. The defined target population were civil construction companies installed in Brazil with or without the ERP system implanted. Half of the sample (53) has the system implanted, while the other half does not.

Due to the difficulty to identify Brazilian companies with or without the ERP system (collection of the sample), a non-probabilistic sampling was chosen for convenience, selecting accessible members from the population (companies that answered the solicitation of the study).

This way, the sample of selected companies in this research cannot be considered as representative for the whole population, causing extrapolations and generalizations to not be possible.

In this study data collection was applied through a questionnaire, subdivided in four parts: (1) profile of the organization and interviewee (8 open-ended questions and 8 closed-ended multiple choice questions); (2) organizational characteristics associated with maturity (31 closed-ended multiple choice questions); (3) processes effectiveness level (44 closed-ended multiple choice questions); and (4) basic characteristics, level and ERP system management (9 open questions and 43 closed-ended multiple choice questions).

Part "b" of the questionnaire was based on the attributes of the growth phase identified by Levie and Lichtenstein [23] and on the inflexion points proposed by Phelps et al. [21]. The 31 questions represent independent metric variables referent to organizational characteristics.

Part "c" in turn, was defined based on the PCF model (Process Classification Framework), a taxonomy of business processes idealized by the American organization APQC (American Productivity and Quality Center).

Part "d" corresponds to the questions regarding the ERP system and was developed based on the literature review. For a better identification of the ERP system, the questionnaire was split into two parts. The first identified the basic characteristics of the ERP systems in the organizations contemplated in the research (acquisition year, current modules, investments and others). The second was subdivided in four parts: management level, implantation process, ERP system performance and results obtained after the ERP system implantation.

To measure the quantitative variables, verify the intensity level of processes and the degree of agreement in relation to the responses marked by the respondents, two scales were used, both with 7 answer categories: (1) at the part of implantation process and performance of the ERP system in the questionnaire: semantic differential; (2) at the part of management and results obtained after the ERP system implantation in the questionnaire: increasing intensity.

The correspondent values to the processes were spread over as follows: (1) inexistent; (2) minimally developed (or being implanted); (3) undeveloped (or partially used); (4) developed (implanted and operating); (5) well developed (implanted and

Table 1 Sample profile

Organization profile	
Foundation year	The companies have in average 25 years of foundation
Location	The researched companies are located on the 5 regions of Brazil, distributed between 10 States and 23 cities, Curitiba corresponding to 64% of the sample and the State of Parana with 77% of participations in the research
Constitution type	81% Limited (Ltd.), 12% SA, 4% State, 2% Mixed capital
Management type	The companies report that the management type utilized is 33% of family nature and 42% professional
Number of employees	23% up to 19 employees, 31% from 20 to 99 employees, 16% from 100 to 499 employees and 22% more than 499
Operating sector	The main operating sector of the civil construction area of the respondents is civil construction (79%)
Respondent profile	
Time in the company	Most part of the respondents work in the organization for 1 year (42%), which the average operating time is 4 years
Occupied position	Most part of the positions is Engineering and Development (22%), Direction (20%), Trainee (17%), Management (15%) and Coordinator (7%).
ERP system characteristics	
Year of acquisition	Average of 5 years of ERP system. However, 32% of the researched companies acquired the system to less than one year
Modules acquired	At the researched organizations, the main modules acquired were: 15% supplies, 15% financial, 14% engineering, 12% management. 10% tax accounting and 9% commercial

fully operating); (6) very developed (fully operating and stabilized); (7) highly developed (fully utilized with constant improvements).

Descriptive and inferential statistics were applied in this research. The descriptive analysis used in this study allowed a global understanding of the contemplated companies. The analysis was applied based on answers obtained in the questions regarding the profile of the company and respondent, characteristics of the organization, degree of effectiveness of the processes, characteristics of the ERP system and management and results of the ERP system. Table 1 presents the main elements that characterize the sample.

Collected data was processed by multivariate statistics. The applied technique was the discriminant analysis and Pearson correlation. The utilized tool for data analysis was the Statistical Package for the Social Sciences (SPSS).

The discriminant analysis, which is indicated to point variables that differentiate two or more subgroups of a sample, had the objective of identifying the variables associated to the characteristics and maturity of organizational processes that distinguish the researched organizations with or without the ERP implanted.

In this research, it was identified as a dependent variable to have or not an ERP system implanted and as independent variables the organizational characteristics and effectiveness level of the processes. The effectiveness level of the processes was used to measure maturity.

To verify the distinction between organizations with or without ERP, two approaches were performed in the grouping of data from the sample. In the first approach the sample was divided in two categories: companies with ERP and without ERP. In the second, the sample was subdivided in three categories: with ERP acquired over a year, ERP acquired in less than one year and without ERP. The justification for this procedure is the fact that 32% of the researched companies with ERP acquired the system in less than one year, in other words, the companies of this group still are adapting to the ERP system.

The results for the organizational categories were more expressive with the utilization of three categories of dependent variables. In the case of evaluation of the maturity level of the processes, the contrary was observed, presenting few differentiations. Thus, to identify the distinguishable variables only two dependent variables were used: with ERP and without ERP.

Then, the analysis of the Pearson correlation took into account factors associated with implementation, management and performance of the ERP systems. The following correlations were taken into account regarding the questions answered at part "d" of the questionnaire:

- Management level versus implantation process;
- Management level versus performance;
- Management level versus results after implantation;
- Implantation process versus performance;
- Implantation process versus results after implantation;
- Results obtained after the implantation versus performance level;
- Management level and implantation process versus performance and results after implantation.

To interpret the results of the Pearson correlation coefficient (r) a variation from −1 to 1 was used. The positive or negative direction of the relation between the variables was obtained by the signal that suggests the strength of the relation between them. A perfect correlation (−1 or 1) identifies that the score of a variable can be determined exactly by knowing the score of the other. A correlation of zero value indicates that there is not a linear relation between the variables [24].

The correlation coefficient measures the degree of linear relation between two variables with quantitative indexes and the strength of this association, classified according to the intensity of the correlation (Table 2).

The final considerations of this article result from the consensus of the results obtained in the discriminant analysis supported by theoretical references and in the Pearson correlation and descriptive analysis.

Table 2 Correlation coefficient [24]

Practical rules about the correlation coefficient value	
Coefficient variation	Association strength
±0.91 – ±1.00	Very strong
±0.71 – ±0.90	High
±0.41 – ±0.70	Moderated
±0.21 – ±0.40 ±0.01 – ±0.20	Small, but defined Light, almost imperceptible

5 Results and Discussion

The goal of this research is to identify which variables associated to the implantation process, management and performance of the ERP system interfere in the variable associated with the organizational maturity in companies of civil construction. To correspond to the objective of this study, the data obtained by quantitative research was submitted to discriminant analysis, Pearson correlation and lastly, descriptive analysis.

5.1 Discriminant Analysis

The intention of discriminant analysis is to identify how the implantation of the ERP system impacts in the organization and the management processes of civil construction companies. The impact was measured based on variables associated to organizational maturity (organizational characteristics and effectiveness levels of processes) that distinguish between researched organizations with or without ERP implanted.

The research started with the equality test of the group averages, using two categories of dependent variables: with or without ERP. Soon after, the equality test was re-done with three categories of dependent variables: with ERP acquired over a year, ERP acquired in less than one year and without ERP. It was assumed that the organizations that acquired the ERP system in less than one year were still implanting the process, suggesting small differentiation (regardless of having or not ERP implanted). The results for the organizational characteristics were more expressive with the utilization of three categories of dependent variables. In the case of evaluation of the maturity level of processes, in the contrary, a small differentiation was observed. Thus, to identify the discriminant variables, only two dependent variables were used (with or without ERP).

The discriminant analysis intended to identify which organizational maturity variables distinguish the organizations with the ERP system implanted from the ones that do not have the integrated system.

5.2 Pearson Correlation

The Pearson Correlation intended to identify the association strength of the correlations between implantation, management and performance that influence the satisfactory results of the ERP system.

At the analysis of the correlations it is verified that the better the performance of the ERP system, the better the results for the organizations, and that the implantation process impacts directly in the obtained results. With a more moderated correlation, the management level interferes in the performance and also impacts the results obtained by the ERP.

5.3 Discriminant Analysis, Pearson Correlation and Descriptive Analysis

The results obtained by the distinguishable analysis and the Pearson correlation are described in Table 3, where the factors with more relevant associations were correlated with organizational maturity variables that differ a company with or without ERP. This way it is possible to observe how the implantation reflects on the organizations.

To identify how organizational variables are impacted by the ERP system, the descriptive analysis was used. The behavior of the discriminant variables between the companies with or without ERP is described in Table 3.

Table 3 shows the compiled results of the Pearson correlation, discriminant analysis and descriptive analysis.

In short, it appears that the implementation of the integrated management system in construction companies impacts the organizational maturity variables in the following areas: strategic vision, customer relations, human resource management, IT management and financial management. Organizations with the ERP system have a higher growth rate, recognition and a bigger amount of customers, more dynamic performance in the market and increased focus on differentiating their businesses and services from the competition.

It was found that organizations with an integrated management system differ because they have a higher level of training of managerial staff, lower levels of hierarchy, greater knowledge of techniques and management models and a clear and effective policy of human resource management. Companies with ERP also set themselves out by having a greater integration between processes and departments; a better flow of information; greater formalization of activities, processes, roles, functions and formal planning processes, execution and control of activities and projects.

It is important to stress that in this research, the most important distinguishable feature of construction companies with ERP refers to IT management. These com-

Table 3 Relation between Pearson, discriminant and descriptive

Pearson correlations results	Discriminant analyses results	Descriptive analyses results
More relevant association	Discriminant variables	Descriptive analysis evaluation
Support in decision-making processes Participation of governing team	Growth rate of the company in the last 3 years	Highest growth rate
	Market that the company operates	Companies more dynamic performance in the market
	Explicit concern to differentiate your enterprises and services regarding the competitors	Greater focus on differentiate themselves from their competitors
	Importance of the "brand" to consumers	Greater recognition of brand
	Current number of clients	Increased number of customers
	Hierarchy level inside the company	Lower hierarchical levels
Technical-financial capacity Training programs	Evaluation of skills needed by employees to perform their activities	Further evaluation of employee skills
	Level of knowledge about techniques and methods utilized by managers to perform their tasks	Higher level of knowledge about techniques and management models
	Clear and effective policy of human resources management of the company	Greater implementation of clear and effective policy of human resource management
	Management team trained and aligned with company's goals	Companies with ERP more trained management team and aligned with business objectives
Mapping of routines and indicators	Formalization level of positions and functions	Higher level of formalization of positions and functions
	Formalization level of activities and processes	Greater formalization of activities and processes
	Level of control exercised over activities and employees	Lower level of control over the activities and employees
	Formal process of planning, execution and control of project activities	Greater formalization of project activities

(continued)

Table 3 (continued)

Pearson correlations results	Discriminant analyses results	Descriptive analyses results
More relevant association	Discriminant variables	Descriptive analysis evaluation
Departmental synergy Satisfaction regarding the system Engagement with the system's goals and continuous improvement Profile of the implantation's responsible Access and protection of information Users' needs Evaluation and improvement of ERP	Level of integration between processes	Higher level of process integration
	In simultaneous constructions, the chronogram is performed together, considering human resources, machines and equipments	Companies with ERP perform a chronogram of simultaneous constructions together, with an organized process intended to be more developed
	Processing payroll computerized, with time and taxes control	Greater computerization of payroll processing
	Access to company's information by UT system, distinguishing hierarchically the users	Greater access to information by an IT system
	Continuous update, bringing the best solutions available in IT to the business	Greater continuity update bringing to the business the best solutions available in IT

panies organize better access to information, seeking to remain updated by bringing to the business the best solutions available in IT.

6 Conclusions

More than ten years ago began the first deployments of ERP systems in Brazil and the issue is still very important in business and academia. This is justified because of several cases of failure on implementing the system. Many studies have identified in this sense that the implementation process and the level of organizational maturity are critical factors for the success of the ERP system.

This study demonstrates that the implementation of the system of integrated management impacts differently the characteristics of organizations and management processes of the surveyed construction companies. It became evident that companies with ERP have more developed organizational characteristics, and similar levels of management processes of companies without the implanted system.

It is important to highlight that the implementation of the ERP system affects more the organizational features than the processes. In other words, the effect of

implementation impacts more rapidly the organizational characteristics than the processes.

It should be noted that for the integrated management systems to promote more significant results in construction companies, the implementation of specific software for the industry is important. However, even if specific software was used, the results were poor. This fact can be justified on basis of the year in which the system is acquired, since 32% of respondents purchased the system in less than a year. The results of the system reaffirm the statement of Chung et al. [5] that it takes 1–3 years for the ERP project to achieve actual transformation.

To obtain good results with the ERP is necessary to adopt the following practices: (a) the person responsible for the implementation must have credibility with the employees; (b) synergy among the implementation team; (c) a qualified system manager to motivate the users; (d) map the processes and routines; (e) adopt an integrated organizational management; (f) support, participation, leadership, control and monitoring by the governing body; (g) monitor the system through performance indicators.

Finally, it can be indicated that the implementation of the ERP system promoted in the surveyed companies: integration of processes, gains on operational flow, reducing after-sales and reworks. The benefits obtained with the integrated management system tend to increase due to the better performance of the ERP and amount of time using the system.

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Choosing the Most Effective Networking Strategy and Practice for Open Innovation

Gizem Ferliler, Burcu Felekoglu and A. Serdar Tasan

Abstract In today's world, innovation is a very important force to enable companies to survive. It is no longer enough for companies to develop products or services using only their internal resources. For this reason, companies are receiving support from external sources in order to save time and cost while continuing innovation activities. This approach is an open innovation approach that includes customers, suppliers, consumers and other firms. In recent years it has been observed that companies that adopt open innovation are ahead of the competition. Choosing effective strategies and practices when networking with external partners plays an important role for success. In this study, 20 large companies interested in open innovation in America were selected and criteria they consider when creating their open innovation networks and strategies and practices they use were investigated. After reviewing the literature on open innovation, eight criteria and fifteen strategies and practices have been identified that are effective in creating networks of companies. TOPSIS method was used as a multi criteria decision-making methods to determine the most effective strategies and practices. While the importance level of the criteria was determined, the opinions of the employees of the companies within the scope of the research were taken. Based on the results, the most effective strategies and practices when creating a network, were discussed and future work directions were highlighted.

Keywords Open innovation · Network · TOPSIS

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1 Introduction

The increasing interest in technological and scientific work today is seen as a distinctive force in the competitive environment among companies. In this environment, companies are in a race to be able to continue their existence and be innovative. This means that innovation activities are not an option for companies, they are a necessity. For this reason, creating innovation by using internal resources of companies makes it difficult to compete, no matter how strong the resources are. Considering that resources are limited, companies turning to external sources for creating innovation and share resources, it has been a step that has added value [1].

The open innovation model created by Henry Chesbrough is seen as a pioneering approach in the innovation of companies [1]. According to Chesbrough and Chowther, increasing uncertainty and variability in the market together with the need for information makes businesses inadequate in-house R&D activities, pushing enterprises to go beyond their internal efforts for innovation [2]. This has led to the creation of the concept of open innovation by going beyond internally stemmed innovation.

The open innovation model has seen as a new focal point for companies and has spread to the world. Companies have expanded their networks and used the sources of network partners, thus improving their operations and increasing their productivity [1]. From this point of view, open innovation can be considered as a leading factor in networking. Companies linked to each other as networks are on the path of creating common value.

The remainder of this study consists of four parts. In the first part, information on open innovation networks is given, the criteria considered in network formation in the literature and networking strategies and practices are explained. In the second part, criteria are weighted, the methodology of TOPSIS method is explained and the strategies and practices were ranked using this method. In the last section, the findings are interpreted and the paper is concluded.

2 Networking in Open Innovation

It is described by Chesbrough and Chowter that networks are an important tool in open innovation approach [2]. Firms use external resources during the open innovation application phase to create a network and thus provide information flow [3]. The path to success in open innovation is to gain the ability to put together internal and external resources effectively and efficiently [4]. Given that an open innovation is based on a deep partnership [5], companies that come together for a common value need to understand inter organizational coordination so that they can adapt to an open innovation approach.

Companies are demanding more networks in order to increase the number and diversity of resources in order to do innovative activities in the field of technology. These networks are an ecosystem that encompasses all the networks, partnerships

and association relationships that a company has established nationally and internationally. In addition, strategic partnerships, projects, joint ventures and partnerships with other organizations are within this ecosystem [6]. In a constantly changing and evolving technological environment, companies have developed networks for sustainable innovation. Thus, the networking initiative was of international significance [7, 8]. These networks, seen as an innovative step, have helped companies gain access to information and technology resources by building good relationships with other companies. At the same time, networks established by creating a common strategy, taking a common risk, and sharing similar goals can also make companies profitable in the economic sense. The new innovation networks established continue to struggle with new competition methods rather than traditional competition, which is seen in similar locations and which are close competitors [6].

In this study, the criteria considered in network formation and the strategies and practices used in networking for open innovation are described in the literature and in the review of open innovation strategies and practices of the 20 most innovative companies in America, which are known to use open innovation approach. The names and sectors of the companies are listed in Table 1.

2.1 Criteria

As a result of the literature survey and examining the open innovation practices of the 20 most innovative companies, eight criteria that are considered to be effective in network formation have been determined.

Well-known Company. When partnership relationships and networks of the most innovative companies are examined, it has been observed that when networking, companies have given priority to companies that are particularly well known and recognized all over the world.

Reliable Company. Worldwide research shows that the profitability ratios of companies that have a strong culture of trust are quite high [10]. For example, companies such as Uber have succeeded because they can provide the environment of trust to their customers besides being technological [11].

Geographical Location. Although the geographic location in the technology age has gradually lost its importance, proximity is still valuable. Companies pay particular attention to being close to their suppliers [12].

Technological Capabilities. Every company wants to establish close ties with companies which have high technological capability [13]. Canon is one of the leading companies in the world with high technology and engineering capabilities. The areas where Canon is competent are optical and design, such as copiers, desktop laser printers and cameras [14].

R&D Activities. Many successful collaborations are based on joint R&D work. In addition, firms' capabilities are combined to provide more qualified R&D works [15].

Table 1 The most innovative companies [9]

	Company	Industry
1	Amazon.com	Retailing
2	Alphabet	Software and services
3	Intel	Technology
4	Microsoft	Software and services
5	Merck & Co.	Healthcare
6	IBM	Technology
7	Apple	Technology
8	Tesla Motors	Automotive
9	Johnson & Johnson	Pharmaceuticals, biotechnology
10	General Motors Company	Industrials
11	Pfizer	Pharmaceuticals, biotechnology
12	Procter & Gamble	Household products
13	Ford Motor Company	Automotive
14	Oracle	Software and services
15	Cisco Systems	Technology
16	Facebook	Software and services
17	AmerisourceBergen	Pharmaceuticals, biotechnology
18	PepsiCo	Food, beverages and tobacco
19	Walmart	General merchandisers
20	Coca-Cola	Food, beverages and tobacco

Capable of Taking Risk. Together with the investments made by the companies, the risks they are getting are increasing. In order to be able to follow and adapt to changing competition conditions and technologies, businesses are in constant change to renew and receive new risks [16].

Expert Human Resource. This is the criteria valid for building a strong human resource network. Because human resources can be considered as a unique resource for companies [13].

Social Skills. The network is a social competence, so the people and companies that are good at social well-being are a step ahead in creating a network [13].

2.2 Strategies and Practices

Based on the sources in the literature and searching the most innovative companies, the following strategies and practices are identified to be used by companies in networking.

Good Communication. The communication strategy is developed to help communicate effectively and achieve the goals of the organization.

Market Research. Market research is an important practice for companies to examine their environments. What products and services do customers need? Which are the most effective firms to meet these needs? They provide answers to such questions. Thus, it directs the business network [17].

Information Sharing. Company-to-company information sharing contributes positively to company performance. Companies can develop their own common knowledge by structuring and reshaping the environments, working rules and options among firms [18].

Technology Sharing. Technological capabilities were mentioned as an important criterion for networking [19]. In this sense, companies tend to cooperate on technological possibilities [20].

Conferences, Seminars and Fairs. Companies participate or host many national and international congresses or fairs. This environment, which brings together many companies, is a very effective field for networking [21]. According to a study, 85% of the companies' success is due to the networking performance of the teams in the stand, exploring the invaluable importance of fair networking approach [22].

Webinar Application. Webinar is a method that enables audio and video training, meetings and presentations on the Internet. It is an environmentally friendly network tool that saves money. Instead of traditional face-to-face meetings, events or trainings, companies can save time using Webinar.

University Cooperation. Recently, some universities have turned into technology centers. Stanford University in the USA, Harvard, MIT, and Cambridge, Leuven and Munich University in Europe were the best examples of such universities [23]. University-Industry cooperation is a way for companies to reach scientific and technological research findings and jointly transform the findings into a marketable product or service, a new or improved production or distribution method, or a new social service methodology. In fact, the existence of many other elements of the national innovation system, such as techno parks or techno cities, has created the optimal environment for this cooperation to be established.

Research and Development (R&D) Programs. Involving in research and development programs is another networking practice. One example is Roche, a world leader in biotechnology products, which accounts for 40% of drug sales, working on drugs for unresolved health problems in seven research and development centers in various countries. Roche provides unlimited opportunities for new discoveries

within the Genentech, Chugai and many other partnerships around the world, it aims to strengthen and maintain its leadership in the field of special treatment for individuals.

Organizations. Companies participate or host many formal or informal organizations. These organizations enable meeting many companies, is a very effective strategy for networking [24, 25].

Consultancy services. Companies can benefit from consulting firms in finding solutions to their problems [26]. A strategy of using consultancy services can provide more easy and quick access to external sources and expert knowledge.

Benchmarking. Benchmarking is a tool that allows companies to compare themselves with other companies. By using benchmarking, companies get an idea about each other and consider the possibilities of cooperation.

Stakeholders. On the basis of open innovation, stakeholders are the most effective external sources. Incorporating stakeholders into the network is also a strategy.

Partnership Strategies. Sharing is an irrefutable fact of business. With the right networking, companies can lead to long-term business partnerships. This also provides companies saving time, resources and so on. It is a networking strategy with potential benefits [27].

Forecasting. The ability to make predictions about future work is important for a company. Most companies would prefer to cooperate with companies that have the right forecasting strategy and thus reduced risk in their business.

Joint ventures. In this strategy, two or more companies merge to form another company that is legally independent of them. Thus, on the one hand firms become the partners of the newly established company while maintaining their assets [28].

The decision-making criteria of forming a network, effective strategies and practices of networking and their relationship to one another are shown in Fig. 1.

3 Methodology

In the context of the research, the literature has been examined and eight criteria have been determined that are effective in creating networks by considering the applications of the 20 most innovative companies. In order to determine the weights of the criteria, the most innovative 20 companies were contacted via social media. In the form submitted, respondents were asked to score between one and eight for the perceived effectiveness level of the eight criteria in forming network (the most effective criterion would get eight points, the least effective criterion would get one point).

Four respondents from four companies out of 20 provided feedback. Based on the scores of these four respondents, the weights of the criteria are calculated and

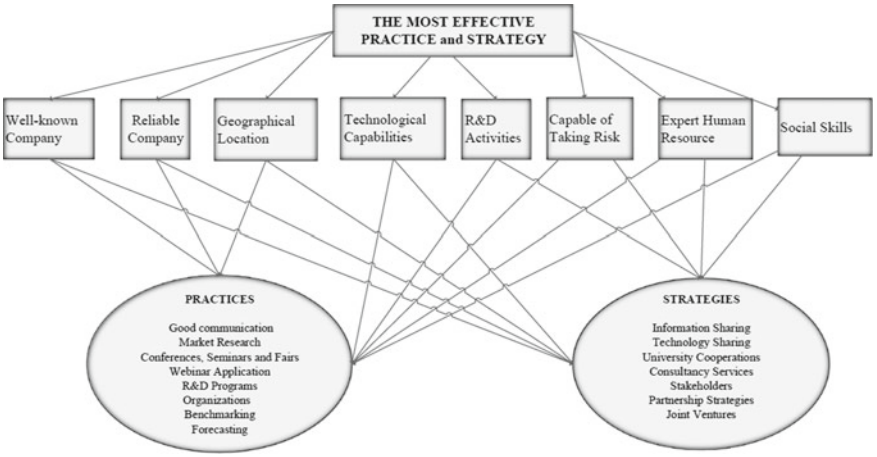

Fig. 1 The most effective practices and strategies

Table 2 Weights of criteria

Name	Normalized
1. Well-known company	0.152777778
2. Reliable company	0.131944444
3. Geographical location	0.111111111
4. Technological capabilities	0.208333333
5. R&D activities	0.118055556
6. Capable of taking risk	0.076388889
7. Expert human resource	0.118055556
8. Social skills	0.083333333

normalized. After this step, the TOPSIS method was used to determine the most effective strategy and practice. TOPSIS method has been developed by Hwang and Yoon as a multi criteria decision making technique [29]. Hwang and Yoon constructed the TOPSIS method according to the positive-ideal solution shortest distance and negative-ideal solution longest distance idea of the solution alternative [30, 31].

3.1 Determination of the Weights of Criteria

The weights of the criteria are based on the scores of the relevant practitioners. Score values are normalized. As a result, "Technological Capabilities" emerged as the most important criterion as seen in Table 2.

Table 3 The Decision Matrix

		Well-known company	Reliable company	Geographical location	Technological capabilities	R&D activities	Capable of taking risk	Expert human resource	Social skills
Practices	Good communication	2.25	1.25	1.5	3.75	1	1.25	2	4.75
	Market research	3.75	2.5	2	1.75	1.5	1.75	2.75	1.5
	Conferences. seminars and fairs	5	1.5	2.25	3.25	2	1.25	4	3
	Webinar application	2.25	1	3.25	2.25	3.25	1	2.25	2
	R&D programs	4.5	4.75	3	1.75	4.5	2.25	3	3.25
	Organizations	5	3	4	2.75	2.25	1.75	1.75	2.75
	Benchmarking	2.75	1.25	3.5	3.25	3.75	3.25	2.75	2.5
	Forecasting	2.5	1.5	1.75	4.25	4.5	2.75	3	2.25
Strategies	Information sharing	3.5	4.5	1.5	4	2.25	1.5	1.75	1.5
	Technology sharing	4.25	3.25	2.75	4.75	2.75	1.75	1.25	2.25
	University cooperation	4.75	4.25	2.5	4.5	4.25	2.25	3.25	4.25
	Consultancy services	3.5	2.25	2.25	4	2.5	2	3.5	1
	Stakeholders	3.5	2.75	1.5	1.5	2.75	2.5	2.5	3.5
	Partnership strategies	4	3.5	2.25	3.5	4	3.5	2.25	4.25
	Joint ventures	3.75	4.25	1.75	2	2.25	3	1.5	3.25

Table 4 Normalization

		Well-known company	Reliable company	Geographical location	Technological capabilities	R&d activities	Capable of taking risk	Expert human resource	Social skills
Practices	Good communication	0.0688	0.0382	0.0459	0.1147	0.0306	0.0382	0.0612	0.1453
	Market research	0.1147	0.0765	0.0612	0.0535	0.0459	0.0535	0.0841	0.0459
	Conferences. seminars and fairs	0.1530	0..0459	0.0688	0.0994	0.0612	0.0382	0.1224	0.0918
	Webinar application	0.0688	0.0306	0.0994	0.0688	0.0994	0.0306	0.0688	0.0612
	R&D programs	0.1377	0.1453	0.0918	0.0535	0.1377	0.0688	0.0918	0.0994
	Organizations	0.1530	0.0918	0.1224	0.0841	0.0688	0.0535	0.0535	0.0841
	Benchmarking	0.0841	0.0382	0.1071	0.0994	0.1147	0.0994	0.0841	0.0765
	Forecasting	0.0765	0,0459	0.0535	0,1300	0.1377	0,0841	0.0918	0,0688
Strategies	Information sharing	0.1071	0.1377	0.0459	0.1224	0.0688	0.0459	0.0535	0.0459
	Technology sharing	0.1300	0.0994	0.0841	0.1453	0.0841	0.0535	0.0382	0.0688
	University cooperation	0.1453	0.1300	0.0765	0.1377	0.1300	0.0688	0.0994	0.1300
	Consultancy services	0.1071	0.0688	0.0688	0.1224	0.0765	0.0612	0.1071	0.0306
	Stakeholders	0.1071	0.0841	0.0459	0.0459	0.0841	0.0765	0.0765	0.1071
	Partnership strategies	0.1224	0.1071	0.0688	0.1071	0.1224	0.1071	0.0688	0.1300
	Joint ventures	0.1147	0.1300	0.0535	0.0612	0.0688	0.0918	0.0459	0.0994

Table 5 Ranking of strategies and practices

		S+	S−	C_i	Rank
Practices	Good communication	0.0268	0.0175	0.3950	12
	Market research	0.0274	0.0113	0.2926	15
	Conferences. Seminars and Fairs	0.0207	0.0209	0.5030	9
	Webinar application	0.0283	0.0120	0.2980	14
	R&D programs	0.0205	0.0247	0.5468	4
	Organizations	0.0197	0.0203	0.5080	8
	Benchmarking	0.0216	0.0186	0.4635	10
	Forecasting	0.0208	0.0232	0.5273	6
Strategies	Information sharing	0.0192	0.0227	0.5418	5
	Technology sharing	0.0162	0.0259	0.6149	3
	University cooperation	0.0072	0.0309	0.8102	1
	Consultancy services	0.0192	0.0205	0.5166	7
	Stakeholders	0.0265	0.0140	0.3467	13
	Partnership strategies	0.0138	0.0239	0.6336	2
	Joint ventures	0.0238	0.0176	0.4242	11

3.2 Ranking of Strategies and Practices

By using the selection criteria weights obtained above, eight practices and seven strategies were ranked by TOPSIS method and the best ones were determined. At this part, the four respondents gave scores from one to five points to the practices and strategies for the specified criteria. By using these scores and the criteria weights, the practices and strategies were listed. Using the responses from the practitioners, the decision matrix in Table 3 was obtained. In the next step, the values were normalized as shown in Table 4. Weighted normalized decision matrix was created. Positive and negative ideal solutions were obtained. Distinction measures and ideal solution proximity vales were calculated. Practices and strategies were ranked according to proximity values.

4 Findings and Discussion

The findings obtained from the multi criteria decision analysis will be explained and interpreted in this section. Results of the TOPSIS are shown in Table 5. Strategies and practices are ordered according to their ideal solution relative affinity ($*C_i$) values. The larger $*C_i$ values are important [31].

Strategies and practices are grouped, ranked among themselves, and shown in Figs. 2 and 3.

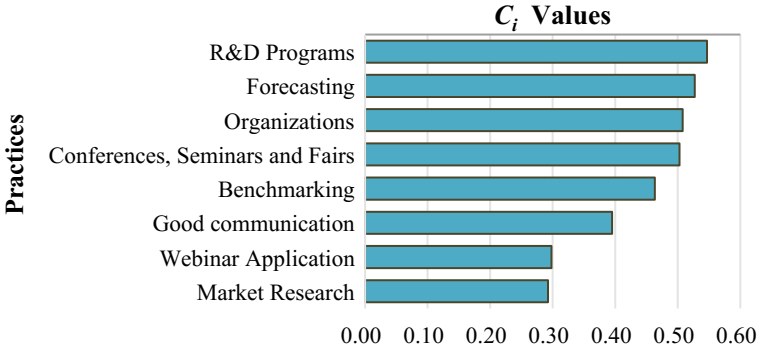

Fig. 2 Results of practices

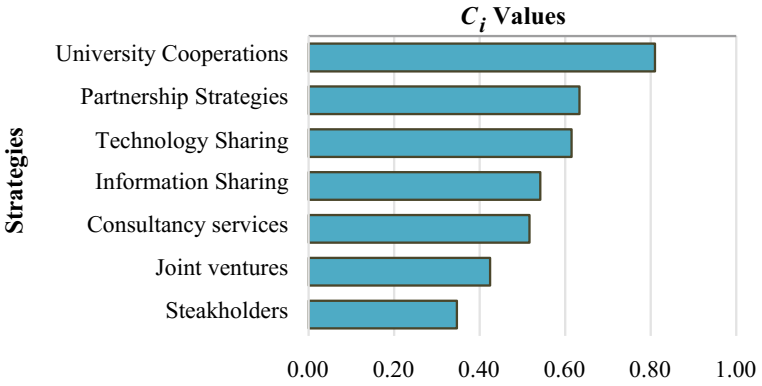

Fig. 3 Results of strategies

The results show that the most effective practice of companies when establishing an open innovation network is perceived to be involving in R&D Programs where collaborative R&D activity occurs. This practice is followed by forecasting as involving companies that have the right forecasting strategy and thus reduced risk in their business is considered to be important in networking. Other practices having high rank are organizations and conference, seminars and fairs. Attending or hosting formal and informal organizations for networking and participating conferences, seminars and fairs to find a competitive space, to compare participants and products, and to obtain both time-saving and financial benefits are considered to be important in open innovation networking.

The most effective strategy in networking is found to be university cooperations. In the literature review, it has been seen that companies work jointly with universities in innovative projects, for example Merck & Co. partners with Harvard University to develop treatments for cancer. The results reveal that companies see universities as an important network player in terms of research and development studies [32].

The second strategy is partnership strategy. Google's partnership with Cisco to help customers in Google Cloud and provide solutions is an example. Other strategy considered to be important in networking in open innovation is technology sharing as it enables companies to save time and money when enlarging their technological capabilities as well as share risk when investigating technological possibilities.

5 Conclusion

In this study, the most effective strategies and practices for companies' open innovation networking were evaluated. First, the information in the literature and the applications of the most innovative companies were examined and the most popular criteria and alternative strategies and practices used were identified and criteria weights were determined together with practitioners from the four of the 20 companies in the study. Establishment of cooperation with universities has been determined as the most effective network strategy and R&D programmes has been determined as the most effective networking practice.

We focus on the 20 innovative companies, but four companies contributed to research question. This aspect can be improved with other companies' opinions. On the other hand, different strategies and practices can be considered in future researches.

In the study, TOPSIS method, which is based on the closest distance from the ideal solution, was used together with many criteria which are frequently used in literature and can be easily understood by decision makers. The criteria used may vary from company to company. Each company can implement this integrated method by setting appropriate criteria according to the methods they apply to network formation.

Other multi-criteria decision methods can be used in choosing the most effective strategy/practice and the results obtained may be compared. Because of the ambiguities in the decision-making process, the fuzzy theory can also be included in the decision-making process in the future studies.

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Forecasting the Innovation Potential Under Uncertainty

Ozmehmet Tasan Seren and Felekoglu Burcu

Abstract The nations are looking for ways to increase the capacity and potential of innovation at national and international level. In order for the nations to use the competitive advantages resulting from innovation practices, a country should predict its innovation potential and hence prepare its strategic plans accordingly. The traditional forecasting methods are usually insufficient where sudden and unexpected changes happen nationwide and/or worldwide and limited information is available. The aim of this study is to provide a forecasting approach to predict the future innovation potential. To forecast the innovation potential, the percentage of enterprises with innovative activities is used as the main indicator. In the case of predicting the Turkey's innovation potential, there exist a few bi-yearly historical data where traditional forecasting methods are insufficient. Therefore, grey forecasting approach that can handle uncertain environments is used in this study. The results indicate that the grey forecasting approach achieved satisfactory results while constructing the grey model with a small sample. In the innovation potential of Turkey, the predicted percentage for organization and/or marketing innovator is found to be highest with 60% where the actual is approximately 51%, and the predicted percentage of enterprises with abandoned/suspended innovation is found to be lowest with 6.5% where the actual is 8%. These predictions of innovation potential can be used to evaluate the effects of national and international policies within the country. Moreover, according to these predictions, the national policies should be improved to enhance the country's competitive advantage in terms of innovativeness.

Keywords Innovation · Forecasting · Grey forecasting

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1 Introduction

The organizations should be more innovative in order to survive in today's competitive global arena. However, survival is not usually enough, they also need to grow in order to meet the demand, compete with the competitors and eventually lead the market according to their strategies [1]. In the last century, the interest in innovation has been gaining momentum at national and international level. The nations are looking for ways to increase the capacity and potential of innovation at national and international level [2, 3].

In order to establish the concept of innovation and rise its' understanding, Turkish government has been organizing "Turkey Innovation and Entrepreneurship Week" since 2012. The percentage of R&D expenditures in Gross Domestic Product (GDP) was stable around 0.8% until 2013, but since then it maintained its upward trend. Figure 1 illustrates the rise in percentage of R&D expenditures in GDP [4]. In comparison to previous year, the percentage of R&D expenditures in GDP increased by 6.8% in 2016 and the total R&D expenditures in 2016 indicate 19.5% rise.

Similar to the rise in R&D expenditures, the percentage of innovative enterprises has been maintaining its upward trend in Turkey. Table 1 illustrates the rise in percentage of innovative enterprises [5]. During the period 2006–2008, there has been a sharp decrease due to the world economic crisis. In 2010–2012 we also see a slight decrease. During the period 2014–2016, the percentage of innovative enterprises in Turkey was 61.5%; i.e. 64.5% for manufacturing sector, 57.7% for service sector. In contrast, the percentage of non-innovative enterprises in Turkey was 38.5%, where 82.2% of these enterprises reported that they had no compelling reason to innovate, 17.8% of them considered innovation, but it was found that barriers to innovation was too large.

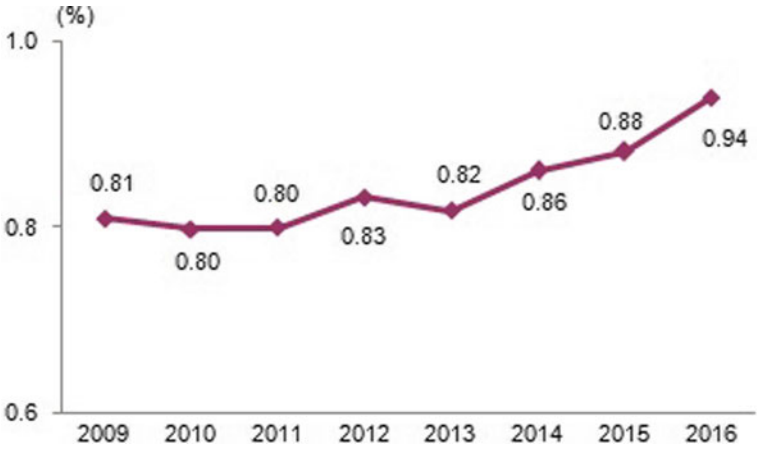

Fig. 1 The percentage of expenditure on R&D in GDP between 2009 and 2016 in Turkey [4]

Table 1 The percentage of innovative enterprises between 2004 and 2016 in Turkey [5]

	Percentage (%)					
	2004–2006	2006–2008	2008–2010	2010–2012	2012–2014	2014–2016
Innovative enterprises	58.2	37.1	51.4	48.5	51.3	61.5

Innovation provides a competitive advantage to a country in a global area. In order for the nations to use the potential competitive advantages resulting from innovation practices, a country should predict the national innovation potential and hence prepare its strategic plans accordingly. This forecasting is difficult in such an uncertain environment. The traditional forecasting methods usually are enough where sudden and unexpected changes happen at the national and international level. There are some forecasting methods that can handle uncertainty but require high volume data for prediction. However, in the case of predicting the Turkey's innovation potential, there exist a few bi-yearly historical data where these forecasting methods are insufficient. Therefore, in this study, grey forecasting approach based on grey system theory was used, where the forecasting approach can handle uncertain environments with the usage of a few or limited information [6].

This paper focuses on predicting the innovation potential of a country in an uncertain environment where there exist a few data, by using grey forecasting approach. The remainder of this paper is organized as follows. Section 2 gives brief information about innovation and the types of innovation activities. In Sect. 3, forecasting under uncertainty is explained together with the grey forecasting approach. Section 4 includes the application of the grey forecasting approach for the prediction of innovation potential of Turkey. Finally, concluding remarks are given in Sect. 5.

2 Innovation

In today's global dynamic environment, almost all nations and organizations face the vital need for innovation in order to succeed and compete. According to the Oslo Manual [7, p. 46],

> An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations.

Today, most of the developed and developing countries are using an innovation survey to measure innovation at national level. The countries are usually using the data from these surveys in order to calculate the percentage of enterprises with innovative activities as one of the main indicators of innovation [8, 9]. In this context, further investigation on innovation is usually done on the types of innovation activities, namely product, process, organizational and marketing innovation. Products that have new or significantly improved technical characteristics, components and

materials in terms of function and/or their intended use are considered as product innovation. Process innovation refers to new or significantly improved ways of production or delivery with the aim of increased quality, reduced waste, decreased cost, etc. New methods used in business practices, external relations and workplace organization initiated by management as a strategic decision are considered organizational innovation. New approaches used in product pricing, promotion, positioning in the market, packaging are considered as market innovation.

3 Forecasting Under Uncertainty

Predicting the future has always been the desire of the mankind. The process of predicting the future is called as forecasting, which is usually based on historical data or speculations. Methods used for forecasting is categorized according to the data characteristics; qualitative and quantitative forecasting methods. Qualitative forecasting is used when there is little or no reliable data and when the forecasting environment is vague, where prediction is usually based on experiences and judgments collected using scientifically conducted surveys to intuitive hunches. Quantitative forecasting is used when there is available numerical data, i.e. time-series, cross-sectional, or mixed data, where prediction is usually based on causal models and time series methods.

Since every business attempt is based on forecasting, the selection of an appropriate and accurate forecasting method has become a very important problem. Hence, every business aims to use forecasting methods which are easy to use and low-cost, while predicting the future with high accuracy. Unfortunately, the traditional quantitative forecasting methods often require large sample sizes and/or assumptions about normality that are usually hard to satisfy in practice. To overcome these limitations, forecasting methods such as grey forecasting approach have been introduced to handle uncertain forecasting environment, where the conventional quantitative forecasting methods are inadequate. In this paper, we will be using grey forecasting method for the analysis.

3.1 Grey Forecasting

Grey systems theory was originally developed by Deng in [6]. It aims to provide theory together with techniques for analyzing latent and complex systems in an uncertain environment. The concept of grey systems theory lies between the identifications of black and white systems, where the knowledge of a system lies in two opposing corners; i.e. unknown for black and known for white. The black and white systems are usually insufficient in modeling of real world systems where the knowledge is inadequate. The vague area between two opposing corners of a system is called grey

Table 2 Comparison of black, grey, and white systems [10, p. 5]

	In black systems	In grey systems	In white systems
Knowledge	Unknown	Not adequate	Known
View	Dark	Grey	Bright
Process	New	Transition	Old
Property	Very complex	Complex	Organized
Method	Negative	Erratic	Positive
Attitude	Leniency	Tolerances	Strict
Solution	No solution	More solution	One solution

system. Table 2 compares black, grey and white systems in terms of knowledge, view, process, property, method, attitude and solution.

Instead of classical mathematics, grey systems theory applies grey mathematics which is based on grey relations, and grey numbers. In this study, grey forecasting approach is applied as forecasting method based on grey system theory. Grey forecasting is a forecasting method that is used in an uncertain situation where the basic stochastic and blurred forecasting methods are inadequate to solve a problem with few data. The minimum sample sizes needed for some of the best known conventional forecasting methods are as follows; i.e. methods using time-series data, 5–10 for basic exponential smoothing method, 10–20 for regression analysis, 50 for Box-Jenkins methodology, methods using cross-sectional data require even more than these, where grey forecasting approach works effectively even with four sample. It can be clearly stated that among the other forecasting methods grey forecasting requires the least data with the basic requirements of mathematics. This makes grey forecasting an ideal method for using in real-world applications, where the enterprises often deals with little data while forecasting for uncertain future. In contrast, most of the quantitative and qualitative conventional forecasting methods require more data for prediction.

After the grey system theory had developed, grey forecasting approach became popular with its advantages such as needing less information, consideration of uncertain environment. In 2008, Wang and Hsu developed a forecasting method by combining genetic algorithms and grey forecasting [11]. They tried to predict output and trends of high technology industry in Taiwan, where it is only possible to collect a few observations since this industry is rapidly changing in terms of technology and requirements. Same year, Tsaur proposed a new hybrid fuzzy-grey regression model for solving problems with vague and fuzzy-input values and applied the model to predict the LCD TV demand [12]. In 2010, Kayacan, Ulutaş, and Kaynak used grey forecasting approach to predict US dollar/euro parity and analyzed the prediction performance of different grey models [13]. In 2012, Jing and Zhi-Hong focused on grey relational analysis and multiple linear regressions in their study [14]. They

applied these models on water supply industry in China and pipeline leakage problem, which includes hard and less accurate data collection. In 2013, Benitez, Paredes, Lodewijks, and Nabais tried to forecast growth of the passenger demand in the airline industry [15]. In 2014, Chen proposed a grey forecasting approach with fuzzy logic relationship through artificial neural network to predict the change in Taiwan Stock Exchange [16].

4 Forecasting the Innovation Potential of Turkey

4.1 Innovation Potential of Turkey

The data regarding the innovation potential of Turkey was taken from Turkish Statistical Institute (TurkStat), which aims to compile data and information, and also create, publish and provide statistics in several areas to be used as a reliable guide for all levels of society in decision making processes. Since 1995, TurkStat has been gathering the innovation statistics from enterprises [17]. Innovation statistics are collected for two year periods using the Community Innovation Survey (CIS) by a Web based questionnaire. CIS was created based on Oslo Manual [7] in order to obtain information on innovative activities of enterprises based in Turkey. Between 1995 and 2004, innovation statistics only focused on innovative enterprises by economic activity and size. Starting from 2004, the statistics also includes information about the innovative enterprises by the types of innovation activities with NACE economic activity codes. The next innovation enterprise data will be collected in 2018 and the results will be published in December 2019. From the innovation statistics, the first five bi-annual statistics are used for forecasting procedures. The last bi-annual data is used for comparison purposes.

In this study, we will be focusing on the enterprises with innovative activities. Table 3 shows the innovative enterprise statistics used in this study. The analysis will be performed according to their types of innovation activities. The types of the enterprises with technological innovation activities considered in this study include product and/or process innovator, product innovator, process innovator, enterprises with abandoned innovation activities, enterprises with ongoing innovation activities, organization and/or marketing innovator, organization innovator, and marketing innovator.

4.2 Grey Forecasting Approach

In this study, the accumulated generating operation (AGO) is used in data regeneration and first-order one-variable Grey Model, i.e. GM(1,1) is used in grey model

Table 3 Statistics regarding to innovative enterprises and types of innovation activities between 2004 and 2016 in Turkey [17]

		Percentage (%)					
		2004–2006	2006–2008	2008–2010	2010–2012	2012–2014	2014–2016
According to types of innovation activities	Product and/or process innovative enterprises	29.9	27.4	33.2	26.9	38.0	47.3
	Product innovative enterprises	22.0	21.7	24.4	17.7	22.7	31.8
	Process innovative enterprises	22.6	19.9	27.4	20.4	26.8	34.0
	Enterprises with abandoned/suspended innovation activities	5.4	4.9	5.0	3.7	5.5	8.1
	Enterprises with on-going innovation activities	17.5	12.6	14.6	14.2	20.4	24.2
	Organization and/or marketing innovator	50.8	22.7	42.5	43.7	41.0	50.8
	Organization innovator	43.2	12.7	24.7	31.7	28.5	34.0
	Marketing innovator	29.4	16.6	35.5	34.7	33.6	42.0

identification. The basic grey prediction model GM(1,1) is widely preferred due to its computational advantages [18].

The overall procedure for the grey forecasting approach is outlined as follows:

procedure: Grey forecasting approach
input: historical non-negative data sequence $X^{(0)}$={ $x^{(0)}(1), x^{(0)}(2), x^{(0)}(3),\ldots x^{(0)}(n)$}, AGO data generation model, grey model GM(1, 1)
output: the predictions

begin
//step 1: Apply the ACO to form the new data sequence, $X^{(1)}$={ $x^{(1)}(1), x^{(1)}(2), x^{(1)}(3),\ldots x^{(1)}(n)$}
$k \leftarrow 1$;
if $k<=n$ then
$x^{(1)}(k)= \sum_{i=1}^{k} x^{(0)}(i)$;
$k \leftarrow k+1$;
else step 2;
//step 2: Calculate background value of ACO, $Z^{(1)}$={ $z^{(1)}(2), z^{(1)}(3), z^{(1)}(4),\ldots z^{(1)}(n)$}
$k \leftarrow 2$;
if $k<=n$ then
$z^{(1)}(k)=0.5[x^{(1)}(k) + x^{(1)}(k-1)]$;
$k \leftarrow k+1$;
else step 3;
//step 3: Use the ordinary least square method by solving $\frac{dx^{(1)}}{dt} + a.x^{(1)} = b$ to calculate the pending coefficient vector of first order differential grey equation $x^{(0)}(k) + a.z^{(1)}(k) = b$
$C= \sum_{k=2}^{n} x^{(0)}(k)$;
$D= \sum_{k=2}^{n} z^{(1)}(k)$;
$E= \sum_{k=2}^{n} [z^{(1)}(k).x^{(0)}(k)]$;
$F= \sum_{k=2}^{n} [z^{(1)}(k)]^2$;
$\hat{a} = \frac{D.C-(n-1).E}{(n-1).F-D^2}$
$\hat{b} = \frac{F.C-D.E}{(n-1).F.D^2}$
//step 4: Calculate the estimation values, $\hat{X}^{(0)}$
$x^{(0)}(1)=x^{(1)}(1)$
$k \leftarrow 1$;
if $k<=n$ then
$\hat{x}^{(0)}(k+1) = \left(1-e^{\hat{a}}\right)\left[x^{(0)}(1) - \frac{\hat{b}}{\hat{a}}\right].e^{-\hat{a}.k}$;
$k \leftarrow k+1$;
else step 5;
//step 5: Calculate the mean absolute percentage error (MAPE)
$MAPE = \sum_{k=1}^{n} \frac{\left|x^{(0)}(k) - \hat{x}^{(0)}(k)\right| / \left|x^{(0)}(k)\right|}{n}.100$
output the predictions $\hat{X}^{(0)}$={ $\hat{x}^{(0)}(1), \hat{x}^{(0)}(2), \hat{x}^{(0)}(3),\ldots \hat{x}^{(0)}(n)$}, MAPE
end

4.3 Results and Discussions

The grey forecasting approach is applied to predict the percentage of innovative enterprises in Turkey according to the type of the activities. For each innovation activity type, the results of the grey forecasting methodology are summarized in Table 4. In this table, the third column indicates the predicted percentage of innovative enterprises and the fourth column indicates the mean absolute percentage error as the forecasting accuracy measure by using the grey forecasting approach. The fifth column shows the actual values which were not used during the implementation of grey forecasting approach.

Table 4 Grey forecasting results and the actual values of percentage of innovative enterprises according to the type of activities for 2014–2016

		Forecast		Actual percentage for 2014–2016
		Percentage for 2014–2016	MAPE (%)	
According to types of innovation activities	Product and/or process innovative enterprises	45.42	2.6086	47.3
	Product innovative enterprises	27.81	1.8551	31.8
	Process innovative enterprises	33.02	3.2982	34.0
	Enterprises with aban-doned/suspended innovation activities	6.51	0.5375	8.1
	Enterprises with on-going innovation activities	25.43	0.8090	24.2
	Organization and/or marketing innovator	60.09	10.919	50.8
	Organization innovator	47.54	10.744	34.0
	Marketing innovator	49.23	9.3145	42.0

The results indicate that MAPE values are relatively low for the percentage predictions of each innovation activity type. In terms of comparison between the predictions and the actual values, the grey forecasting approach has found higher percentage values for enterprises with on-going innovation activities, organization and/or marketing innovator, organization innovator and marketing innovator, and lower values for product and/or process innovative enterprises, product innovative enterprises, process innovative enterprises, and enterprises with abandoned/suspended innovation activities. In this context, it can be clearly seen that the predicted percentage of organization and/or marketing innovator is found to be highest percentage with 60% where the actual percentage is 51% whereas the predicted percentage of enterprises with abandoned/suspended innovation is found to be lowest percentage with 6.5% where the actual percentage is 8%.

5 Conclusion

Innovation became one of the most important issues in the success and competitive advantage of nations. Innovation not only affects economic performance, such as profits, growth, productivity and job creation, but also has environmental and social effects. The absence of relevant forecast in innovation potential is often a major obstacle for the design and implementation of science, technology and innovation policies in countries.

In the context of this study, the innovation potential of Turkey was investigated. Since innovation measurements in Turkey have been collected in recent years, there has been a few data for analysis of the innovation potential to be used in future forecasting. Because of the uncertain environment of innovation measurements, instead of conventional methods which have lack of ability for forecasting in such an uncertain environment, grey forecasting approach has been used for the prediction of innovation potential of Turkey where there is only a few bi-yearly data available. Grey forecasting has widely applied in various fields and achieve satisfactory results while constructing the forecasting models with small samples. We believe that grey forecasting approach could successfully be applied in the field of predicting the innovation potential in national and international level. These predictions of innovation potential can be used to evaluate the effects of national and international policies within the country. Moreover, according to these predictions, the national policies should be improved to enhance the country's competitive advantage in terms of innovativeness. As a future work in terms of problem, grey forecasting approach could be used for predicting the innovation potential according to economy activities. As a future work in terms of method, grey forecasting approach could further be improved with the usage of cause-effect relations and fuzzy relationships.

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Evaluation of High Rise Building Sustainability Performance

Ecehan Ozmehmet and Zehra Yuksel

Abstract The demand for high-rise structures is having an increased spillover effect as a result of economic, physical and social needs. Due to their extended size, large impact and area of influence on the urban pattern, these buildings have the potential to improve the quality for living environment through detailed design and urban integration. On the other hand, planning considerations regarding sustainable integration of high-rises need to be considered with more detail and care than with other small-scale structures. This study focuses on the sustainability performance of high-rise building systems in the context of physical and social environmental impacts where these impacts are examined through a case study in Aegean Region, Turkey with a coastal mediterannian climate. The focal sustainability concept provided to be an observational tool to conduct a study on existing or new high-rise structures, from the architectural planning to the urban scale. This paper also examines current construction methods, design and occupancy of contemporary high-rise buildings to understand what impacts on the environment they make and also discovers how renewable energy/energy saving measure are already currently incorporated into high-rise buildings to determine what changes need to be made to build and create high-rise buildings that are more environmentally conscious and ultimately environmentally friendly.

Keywords High rise building · Sustainable indicator · Performance evaluation

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1 Introduction

Building sector has an increasing global effect on social, environmental and economic sustainability. The building sector rapidly growing world energy use and the use of finite fossil fuel resources has already raised concerns over supply difficulties, exhaustion of energy resources and heavy environmental impacts-ozone layer depletion, carbon dioxide emissions, global warming, climate change [1]. This built environment is one of the most resource-intensive sector and sustainable building model is the key factor that is a primary issue for protecting the environment. Sustainability is the main aspect in this context. As a result, there is a global increase on the interest and improvement of sustainable models. It can be stated as Akadiri, Chinyio and Olomolaiye [2] mention that from the three pillars of sustainability, the process-oriented principles overach "*the management of activities through the setting of targets, monitoring, evaluation, feedback and self-regulation of progress. This iterative process can be used to improve implementation in order to support a continuous learning process*."

The first time sustainability was introduced by United Nations Bruntland Report as; "*Humanity has the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs*" [3, p. 16]. Sustainability debate is a social issue as well as an environmental and an economical extent. However, in building sector, economic and environmental indicators are the main targets that are mostly discussed on. Social aspects are usually not taken into consideration during short or long-term planning. On the other hand, the aim of today's building sector focuses on maximizing the utilities and service outcomes and minimizing the total cost of the constructions. Kunstler [4], mentions that the high-rise buildings generate urban pathologies and also demand a large amount of energy and are expensive to retrofit. In other words, maximizing the economic performance of the buildings is the key factor on sustainability performance of the sector.

This study aims at evaluating the building sustainability performance by developing an assessment model approach and discussing the evaluated sustainability indicators on the high-rise building systems. In this context, sustainability performance indicators are defined under the topics of social, environment and economic aspects for a high-rise building. On this baseline, we developed a sustainability performance evaluation model and we analyzed the selected high-rise building according to the selected sustainability indicators as a case study. This evaluation model contains some of the selected sustainable performance indicators, which can be categorized according to occupants, employee, suppliers, building (built environment), services. The primary research questions of this study are as follows; How were the sustainability indicators introduced and optimized in the building identity? Which indicator has a dominant role in the building sustainability performance? While looking for answers to these research questions, this study particularly intends to analyze the relevant topics by literature reviews books, journals, government publications and reliable websites, including similar current examples. Additionally, it also intends to analyze a case study, where relevant data is collected while visiting the building site.

This study has the potential the rise the awareness of sustainable effects of high-rise buildings and built environment and sustainable assessment models in order to provide an environmental, social as well as economic performance. The structure of the paper is as follows; Sect. 2 contains information on the methodology of the study. Section 3 covers the evaluation of the building sustainable performance. Following these conceptual background information, the evaluation of the case study is given in Sect. 4. Finally, the concluding remarks and the discussions on implications on future research are given in Sect. 5.

2 Methodology

This empirical research is based on the evaluation of sustainability performance for high-rise buildings. The resultant criteria are developed identify primary sustainable indicators and strategies through quantitative models. The framework of this study is shown at Fig. 1. This research consists of two main phases and two feedback phases. The main phases include establishing the context and the evaluation of sustainability, whereas the side stages include communication/consultancy and monitoring/control.

In this study, in order to illustrate the applicability of the methodological framework mentioned above, a high-rise structure specifically is considered as the case study because it was the most recently built high-rise building in the area. In this context, the first main phase is to establish and refine the context as the evaluation of high-rise building sustainability performance. Particularly, a systematic extensive literature review related to sustainability, sustainability indicators, sustainable built environment, the concept of the social and environmental, economic impacts of high-rise buildings have been conducted. Some similar case studies were also studied closely in order to find out all the essential topics mainly mentioned. In the second main phase, sustainability is evaluated from different perspectives. For this purpose, interviews and email communication have been carried out with the architectural team, project managers and construction material firms as well as service provider companies and some questions were asked to gather related information. The site of the building structure was analyzed. The appointments with the head of specimen of Construction Company were arranged and some interviews with several questions on the material and products selection and construction process were made. These informations were used to identify the contexts of sustainability for the case study, to analyze the sustainability, where sustainability indicators are discussed and calculated, and finally to evaluate the impact of sustainability. Beside these two main phases, there was also a two-sided feedback from two feedback phases, i.e. communication/consultancy, which ensures the stakeholders evolvement, and monitoring/control, which ensures and eases the system's adaptation to changes in the environment.

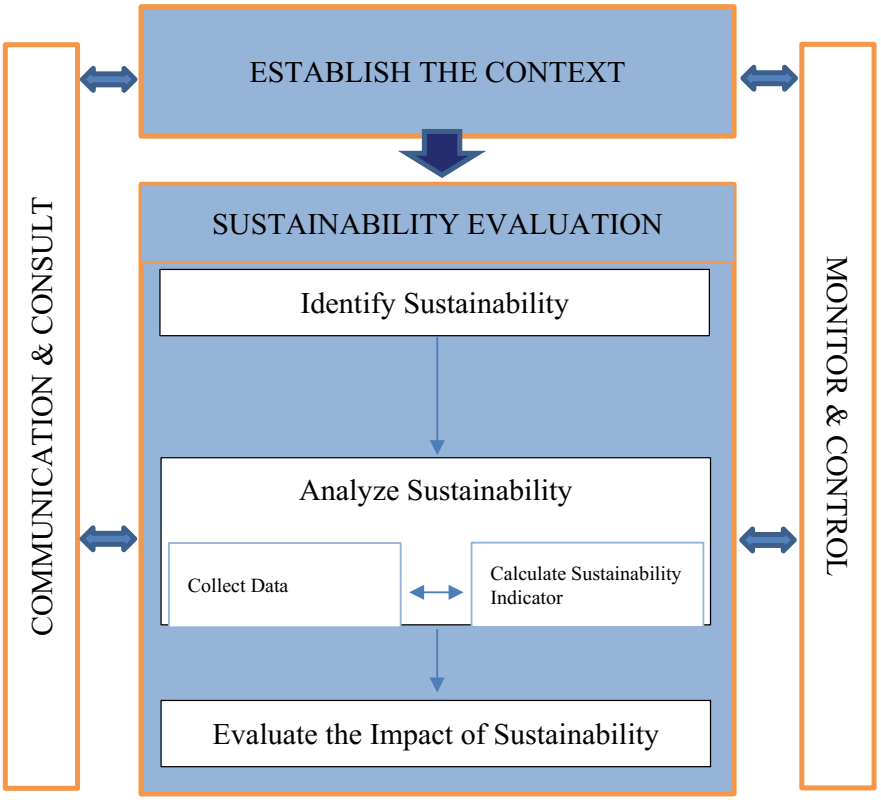

Fig. 1 Framework of the study for evaluation of high rise building sustainability performance

3 Evaluation of Building Sustainability Performance

Building sustainability is one of the main issues in today's world. Models, tools and frameworks as well as rating systems have been evaluated and developed according to different sectors of buildings. Sustainability has three main pillars. These are social, environmental and economic indicators. Furthermore, meeting the needs of environmental, social and economic concerns are separate objectives and the main focus of sustainability is to improve the life quality.

Sustainable systems are described and analyzed according to indicators. Sustainability performance of a process is qualified by calculating/measuring sustainability indicators. There are various kinds of indicator classifications. Different sustainability indicators are introduced to scale performance assessment models. These classifications differentiate according to the assessment systems. Main target of sustainability indicator framework focuses on providing a comprehensive and highly scalable information driven system that is policy related and understandable by the community and that would be helpful to make decisions [5]. The weight of the

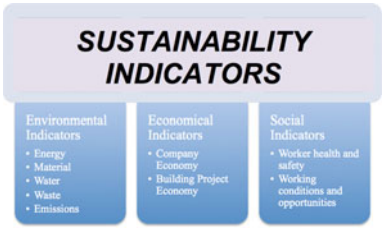

Fig. 2 Classification of sustainability indicators for architectural projects [11]

sustainability indicators differs related with the building type and economic parameters, in the built environment. Also, according to Hill and Bowen [6], sustainable buildings consist of economic, social, biophysical and technical principles. Miyatake [7] proposes building sustainability performance principles as, to minimize the resource consumption as well as maximizing the resources reuse, use of renewable and recyclable resources, while protection of the natural environment, create a healthy and non-toxic environment, and pursue quality in the buildings. Sustainability context is also a competitor understanding for a corporate business identity. According to Kitzmueller and Shimshack [8], if the social responsibility and green corporate branding are smartly used to win more business and achieve a large scale of economic benefit as overall profit. Also, Pettifer [9] focuses on the the business benefits of sustainability and he comes the conclusion that that the benefits are diverse and potentially very significant. According to Ahmad and Thahemm,

> though the concept of economic sustainability in buildings seems fairly simple, the assessment is an intricate process including details such as capital and life cycle cost, adaptability, flexibility, etc. Further, when it comes to the optimization of economic performance of buildings, a number of different variables need to be controlled in order to meet the aspired levels of performance [10 p. 129].

For building systems, sustainability indicators are categorized under these three sustainability pillars. Figure 2 illustrates this categorization, where energy, material selection, water management, waste management and emission were defined under environmental indicators, company economy and building project economy were defined under economical indicators, and worker health and safety, working conditions and opportunities were defined under social indicators. In this study, quantitative indicators are used to measure the high-rise building sustainability performance. Also, performance-based indicators are focused on as core indicators.

4 Evaluation of Building Sustainability Performance: A Case Study

In this section of the study, the high rise multi functional building complex that is located in Turkey is analyzed. This building complex is constructed on 18.392 m^2 site, having a leasable area of 25.600 m^2. With an investment value of approximately

390 million TL it is one of the first mixed used high-rise buildings in 3rd biggest city of Turkey. In regard to the importance of the harmony between the building and the environment, the project has been prepared for the multifunctional construction group-mixed use to be built.

4.1 Sustainability of Built Environment

According to Gonçalves [12], because of the rapid growth in population high rise buildings are increasing in the urban environment with the pressure of high density and globalization. The discussions on building sustainability performance mainly focuses on the development and management of the high rise building complex. As making this study, the importance of taking into account the contextual data as social, economic and climatic values, is reached as the end result. The information about the identified indicators of the global company is collected from employees and annual reports that are published online.

4.2 Results and Discussions

In this section, economic, environmental and social impacts are analyzed. Furthermore, according to environmental impacts the following classifications; i.e. urban microclimate, façade design, materials, water consumption, energy consumption, gas consumption, HVAC systems, waste management, water management, labourers, maintenance and total cost data have been examined in accordance with the above information.

Economic Impact

There are three major economic sectors on world energy consumption; industrial sector, transportation sector and building sector. Approximately 50% of the energy is consumed in the building sector. According to U.S. Energy Information Administration [13], in developed countries, it has been reported that about 35–40% of the overall energy is consumed in the buildings with between 50–65% electricity consumption.

The United Nations Environment Program (UNEP) states that about 80–90% of the energy in buildings is used during the operating phase of a building's life cycle, while another 10–20% is used during the extraction and processing of raw materials [14]. Obviously, from an economic point of view, high-rise buildings have some drawbacks. The construction of these buildings requires an extra cost premium due to the need for advanced foundations, structural systems carrying high wind loads and high-tech mechanical, electrical, lift and fire-resistant systems. Also the economic impact of high-rises vary according to the newly designed traffic routes, commercial areas and this leads the increase in the property values of the neighbour.

Environmental Impact

Urban Microclimate

High rise buildings have a large impact on environment and climate which changing climate factors are wind and solar data. Densely located high-rise buildings mostly are restricted from the benefit of solar exposure, as well as the changing patterns of prevailing wind flow in the urban area. These oversized structures can cause undesirable wind flow in and open and semiopen spaces and pedestrian paths, as well as they can cause avoidance of wind flow in urban scale. Generally, buildings depending on how their exposure to wind flow, create dual effects of wind flow increased or recessed [15].

In terms of the climatic issues and advantages in Izmir, during the months April, May, June, September and October pleasant weather is experienced with a nice average temperature. The hottest season is in June, July, August and September. On average, the most wind is seen in January and the least is seen in August. However, all these climatic advantages of the region were not used in any design approach for natural ventilation, heating, cooling and lighting needs of this high-rise building complex. On the contrary, it has a negative impact on global warming due to the heating and cooling systems. Moreover, the case study building is situated in the prevailing wind direction so this location and orientation interrupt and prevent needed natural ventilation.

Facade Design

The crystallized transparency that has been created by wide terraces, which significantly contribute to the interior life in the buildings, as well as the differentiation of wind and sun breakers on the terraces, contribute to the specificity of the project, and the difference of height between two high building create a positive perception on the urban scale. As the floor number of the high-rise buildings increase, the structured elevation surface enlarges, consequently increasing their yearly energy consumption. Especially when glass is used for a building envelop, energy efficiency has become an even more important issue. To achieve better results, tempered glass is used for the façade of the high-rise. Şişecam Temperable Low-E Neutral (50/33) is used mostly in office and shopping mall projects for its optimum light transmittance (49%) and maximum solar control (33%). Due to its temperable Solar Low-E coating effective thermal insulation in winter is provided and heating expenses are reduced and it keeps cooler in summer and cooling expenses are reduced. It provides clear view from outside to inside and neutral view from inside to outside due to its low reflectance coating. Also, the advantages of the tempered coating meet the safety need of the building complex.

The tilt before turn (TBT) from fenestration systems are used. The Crown Casement Window System creates side or top hung windows and fixed lights as individual elements or as co-ordinated multi-light windows. The system is fully weather stripped to achieve the highest levels of weather performance. All aluminium profiles incorporate polyamide thermal barriers to meet the building U values and window energy rating requirements. The optimum system is the perfect aluminium window for high rise buildings with extremely low air infiltration (0.18 m^3/hm^2), (EU stan-

dards: 1.89 m^3/hm^2). The thermal break technology is used in this product. 40% of the product is manufactured with recycled materials in the UK. The product has low weight, high strength and endless design possibilities. As for coating, GRC (glass reinforced concrete) is used. Hollow rib profiles with a depth of 50–100 mm provide the structural integrity of the components. Being 80% lighter than pre-cast steel reinforced concrete, the applied GRC system plays a positive role on emission reduction. Aluminium joint stick plates were used for coating. In terms of external blinds and shutter, power operated external blind with aluminium construction with antibacterial lead-free finishing and polyester (15%) PVC (85%). FP Line Zip Curtain for sun and wind (Ferrari Sortis 86) curtain was used and tested according to DIN EN 1932 which is a test of the resistance to wind load. It has been reported that the features of the materials are the visibility toward the outside, low emissivity, tear resistance, no sagging, efficient maintenance, flame retardant and recyclable textile which has a protocol concerning the reduction of CO_2 emissions from the building.

Materials

The design of the interior, especially the wet surfaces, has mainly natural stone and ceramic tiles. Except for the mall and fire exit stairs of the office block where only local material (Bergama Grey Marble) was used for surface covering, all the natural stone materials were imported from India, China and Italy. Most of the materials and products were designed and manufactured specifically for the high-rise building complex. As for the kitchen and bathroom top counters, staron acrylic solid surface sheets were placed. As for electronic appliances used in kitchens, Siemens products were ancastered. The floor surface coverings are by 'Massive Parquet', which is a local product, and the kind of parquet is Dendro. As for the paint selection, the responsible company was so sensible about the quality of the products for indoor and exterior. All the products are environmentally friendly. On the other hand, no recycled materials were used for the building. When choosing the materials, no test results for CO_2 and VOC emissions have been taken into consideration the only standard that paid the most attention is fire resistant products. To sum up, the amount of the local products is 25% whereas the rate of imported products is 75%.

Water Consumption

6300 m^3/month water is consumed per month. There is no system for the use of grey water and rain water. Therefore, local water supplies are consumed in all sections of the building. The total amount of water consumption seems too low as, if the local source of water is only used for watering the green areas, this amount must be much more. Especially the green spaces between floors need to be watered as well.

Energy Consumption

The high-rise building complex consumes 360.000 kWh/month electricity at the mall area, 70.000 kWH/month at Block A and 50.000 kWH/month at Block B. This electricity amount is so high that no renewable energy is used in the building instead one of the reasons is that the HVAC system is provided by electrical appliances.

Gas Consumption
Under the analysis of gas consumption issue, except for office building (Block B) and the mall, Block A of the building heating systems and hot water are supplied with natural gas heating. For common shared spaces natural gas heating is used so the consumption is 5.500 m^3/month and 5.600 m^3/month for Block B and 9200 m^3/month for Block A. As the building has separate HVAC systems for heating and cooling, the average a month of gas consumption normally increases.

HVAC Systems
In the building complex, central HVAC system is used for chilling and water cooling at the mall and common areas and at office and residential areas, VRV system is used for cooling. The central heating system works with gas and each residence has radiator available for central gas heating. Outdoor units have built-in noise-reducing features, that also lowers the sound level. Residential applications have the 'night set' mode, that functions over a programmed period of time

Waste Management
The only recycling act was on steel, aluminium and metal wastes which were only recycled. However, other wastes with amount around 3000 trucks load such as concrete, paper and plastic were not recycled at all. As mentioned above, there is no grey water or rain water systems for reuse. There is a separation system of wastes for the mall but for the residences and office blocks no wastes are classified and contained ences and office blocks no wastes are classified and contained.

Labourers
Only 10% of the labourers is local and in total 474 workers were employed and the rest came mainly from Istanbul. This is only because the materials selected were new or not known locally so they could not find well qualified operator in Izmir. The given number of workers is just for the regular worker as the responsible companies brought their own specimen. The labourers who were hired were mainly painters and construction workers. The most importantly, although the number of the locally employed labourers was just 10% of the total number, at the moment the building provides a wide range of employment to the area.

Maintenance and total cost
Periodically, maintenance is provided for all buildings as prevention and precaution by the specimen sent by responsible companies and also specialist staff for the building has been trained specially. As the building complex is newly opened that most materials and products are under guarantee for two years. The responsible company was not able to give any amounts for the expenditure for maintenance.

Social Impact
High-rise buildings have socio-psychologic impact on community. When we take a look into the community, single people and couples prefer more on living on the high-rise buildings than families with children. Also, the living habits people prefer low rise buildings are closer to nature and have community oriented social life than the people that are more focused on the interiors of the densly populated high-rises with a loose of social interaction spaces.

5 Conclusion

Sustainability of the high-rise buildings plays an important role on the sustainability of an urban environment. As a result, this dominant effect is that these buildings are immediately becoming an important part of the urban environment, and therefore there is a particular need to pay attention to issues related to their integration into the environment.

The sustainability context studied in this research provided an emperical platform for the development of high rise constructions and their urban environment. The data collection process of the analyzed construction had many difficulties and limitations, so that this resulted by the selected and limited sustainability assessment model. The evaluation system has been limited according to the intersection points of social and physical attributions of this high rise. From this point on, the developed key sustainability context within this research have the potential to be implemented through similar building typologies.

As for the case study, the building considered does not have a systematic organization that enables to analyse the building in details. All the gained information was received indirectly and a lot of research needed to be done to reach correct data and a lot of face to face interviews, mail communications, telephone calls were made with the representatives of the responsible companies. In consequence, no analysis has been made since the construction so very little comparison can be made. The sustainability rate of the products can be approved but the sustainability of the building in terms of water and energy consumption and waste management is low as no renewable or very few recyclable and recycled products have been selected. It has been said that all the materials and products were selected by the architect and most of them were imported. However, very few of these materials and products are renewable or recyclable. Above all, the building has no green feature despite global warming and no renewable energy is preferred despite the available conditions such the location of the building and local climate. Moreover, it has been declared by the authorities that the HVAC system of the mall stores and the office building has been put in together with the best quality of glazing, insulation and shading systems, but the appliances were not placed instead the users are said to be supervised on the appliances selected, bought and placed by them. This critical policy is not suitable for the sustainability performance and evaluation of the urban environment. In spite of many drawbacks of the analyzed building complex, the only positive concept about the building is the use of light at night. It produces less light pollution at night compared to other high-rise buildings in the same location.

As researchers, we focused on an umbrella approach to the evaluation of high rise building sustainability performance. In the follow up papers, other types of buildings. Furter research directions may also focus on public or private building applications. Management and maintanence of the built structures have a primary role in the sustainability issue. From this point on, future research may be given more importance on these topics to integrate sustainability into management and operational systems.

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Pharmaceutical and Biopharmaceutical Patents: The Opportunity of Pharmerging Countries

Karina Fernandes de Oliveira, Gabriel Guerra da Silva Freire, Igor Polezi Munhoz and Alessandra Cristina Santos Akkari

Abstract Countries with emerging pharmaceutical market (pharmerging countries) has gained prominence in the international scenario because they are identified as the future responsible for the sustainable growth of the new medicines sale. However, there are still few studies focused on these regions, and it is of extreme interest to assess whether these countries are exploring their domestic markets. In this work, a technological and industrial mapping of the pharmaceutical and biopharmaceutical segment were developed through the analysis of patents data extracted from the Derwent World Patent Index platform (Thomson Reuters Scientific) as well as the association of R&D report. In the pharmaceutical scenario, the importance of European and North American industries stands out, mainly Novartis (1,402 patents) and Roche (1,380 patents), which are the pharmaceutical industries that most invested in R&D in 2017, suggesting a positive correlation between R&D and pharma innovation. For biopharmaceutical patents, the importance of Merck and the German company Sartorius Bioprocess Solutions, both with about 74 protections, stands out. The total of biopharma patents refer to only 2.2% of total pharmaceutical protections, suggesting that biopharmaceutical sector still has much to advance in innovation. Also, it was conclude that pharmerging countries, like China and Brazil, are not represented by the companies that most invest in R&D, nor do they currently stand out among the largest holders of pharma or biopharma patents, showing low exploration of emerging market opportunity.

Keywords Pharmaceutical industry · Biopharmaceutical industry · Patent

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1 Introduction

The pharmaceutical industry stands out as one of the most profitable segments of the market and is unquestionable for a movement of the world economy. It is a segment characterized by the great dynamism and constant need for innovation, requiring investment in research and development (R&D) [1]. In addition, the advancement of science and technology, especially in the biotechnology area, has led to the emergence of biopharmaceutical products for the treatment of complex diseases such as cancer, rheumatoid arthritis and other autoimmune diseases [2].

In pharmaceutical and biopharmaceutical segment, an intellectual property, mainly patents, is of paramount importance, since the development process of a new medicine, from the drug discovery until launching of the medicine in the market, requires many years and an investment of billions [3]. Thus, the patents, in addition to being able to protect an innovation, standing out by restricting a competitiveness, barring new entrants in the market and allowing a generation of extraordinary profits for innovative companies, in order to stimulate the maintenance of investments in R&D. Therefore, an absence of a well-grounded innovation system in a country would directly impact innovation effortlessly, putting investments and producing R&D activities at risk [4].

The relevance of emerging pharmaceutical markets is consensus in the literature, but still have few works focusing on these regions. The study of pharmerging countries, based on patent data, can point tendencies and perspectives for the pharmaceutical and biopharmaceutical sector, as well as to direct new public policies of fomentation to innovation. Thus, the development of technological and industrial mappings in this segment is of great value in order to evaluate how the pharmerging regions are exploring this business opportunity, based on the analysis of innovation indicator.

2 Background

2.1 The Importance of Pharmaceutical and Biopharmaceutical Patents

The cost to launch a new drug was US$ 1.5 billion, in 2011, and this estimate considers different variables. The most significant figures on the nature of R&D investment, with strong uncertainty associated with long maturation periods. In fact, it is estimated that every 14 new molecules arriving at clinical trials, which require most of the resources, only one obtains the registration and reaches the market. The long term maturity of the projects is expressed in the cost of the invested capital [1, 5].

The average time for the entire new drug R&D process is approximately 11.5 years. The characteristics of the discovery process and the high cost of drug development

are significant barriers to entry into the industry. These factors, coupled with the safety offered by patents and brand loyalty established by the medical profession, can explain the longevity of pharma companies [6]. In fact, studies point out how patents work differently in segments of industry. For example, in the electronics industry, patents are often shared between competitors through pooling or cross licensing. On the other hand, the pharmaceutical and biopharmaceutical industry is highly dependent on patent protection, since this is the guarantee of the return of the required high investment, showing that intellectual property plays a vital role in the modern economy [3, 5].

Biopharmaceuticals are developed to target highly specific molecules of the immune system and have a high molecular complexity, being about five times more tested than traditional drugs and categorized as high-risk R&D [2]. In fact, biopharma patent protection is so important that threats to reduce the exclusivity period of innovative biological products are increasing industry uncertainty and bringing negative impacts on long-term R&D investment decision making [7].

2.2 Pharmerging Countries

The IMS Health, a global pharmaceutical market audit firm, points 21 countries as pharmerging countries, emerging pharmaceutical market, which together were expected to raise about US$ 187 billion in annual sales between 2012 and 2017, accounting for one third of global pharmaceutical growth. Within these emerging market, Brazil, Russia, India and China stand out among the top 10 for sales value [8].

India and Russia are seen as susceptible to growth in this sector. China is estimated that alone will account for almost half of the growth of the drug market. From this perspective, it is believed that pharmerging countries, especially the BRICS, will be one of the main responsible for maintaining the growth of the pharmaceutical and biopharmaceutical industry, keeping the segment sustainable [5, 7]. It is also worth noting the outstanding position of Brazil, classified in the stratum of level 2, being behind only China, estimating a reach of US$ 87 billion in sales in 2017 [8]. Therefore, a more in-depth and assertive analysis is extremely significant in order to allow the targeting of policies and actions focused on innovation in these regions.

As an example, patents of several biopharmaceuticals consumed in Brazil will expire until 2018, equivalent to a market of US$ 45 billion [8]. This is a great opportunity for national laboratories in terms of business. However, as the national industries do not dominate the biotechnological processes, there is a great challenge to develop technology so that Brazil can produce this type of medicine and generate innovation [3, 7].

3 Research Approach

This work consisted of an exploratory study, integrating bibliographic research and collection and analysis of secondary data. A systematic literature review [9] was carried out and different scientific databases such as Web of Knowledge and Scopus were used. The main fields of research encompassed Intellectual Property; Patents; Pharmaceutical industry; Biopharmaceutical industry; Innovation; and Pharmerging countries. Criteria for inclusion and exclusion of articles, definition of information to be extracted from articles, analysis and discussion were considered as stages of bibliographic review.

According to Frascati Manual, patent-based indicators can be a measure of a country's innovation, with investments and personnel costs related to R&D correspond to the input, while patents can be considered output of the innovation process [10]. Therefore, in the present study, the survey of patent indexes will be used as an indicator of innovation. For the collection of secondary data, the international patent bank Derwent World Patent Index was used as an industrial property research tool produced by Thomson Reuters Scientific. A search for technology and the most innovative companies of the sector was developed, allowing the development of an industrial mapping. In order to investigate whether there is a correlation between the level of R&D investment and the generation of innovation, global R&D reports were studied.

4 Results and Discussion

Using the Derwent Innovations Index database, a search for patent registrations was made using the terms *pharmaceutical* and *biopharmaceutical*, restricting research between the years 1996 and 2018. It was decided to start the search in 1996, since the first industrial property law that allowed the protection of drugs in Brazil appeared in that year. For pharmaceutical industry, the areas with the highest patent registrations correspond to *Chemistry* (188.334 patents), followed by *Pharmacology and Pharmacy* (184.420 patents), *Biotechnology applied microbiology* (93.216 patents) e *Engineering* (53.233 patents), as shown in Fig. 1.

For biopharmaceutical industry, patent records were classified according to area, obtained in a greater number of records in *Chemistry* (705 patents), followed by *Pharmacology and Pharmacy* (614 patents), *Engineering* (523 patents) and *Biotechnology applied microbiology* (463 patents), as shown in Fig. 2.

Although the prevalence in the areas of Chemistry and Pharmacology and Pharmacy occurs in both analyzes, it is interesting to note that in the scope of the biopharmaceutical industry, the Engineering area occupies the third position, possibly referring to process innovation. It is worth mentioning that many patents are classified in more than one area of knowledge.

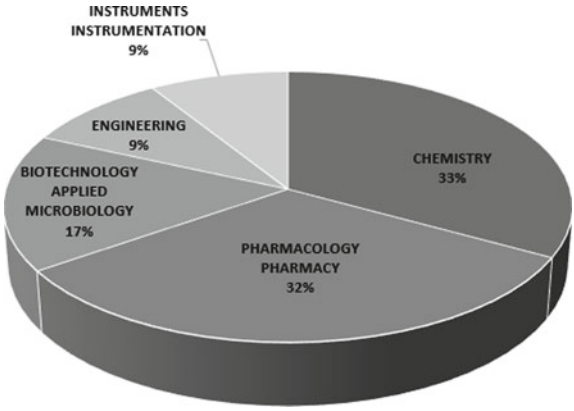

Fig. 1 Main areas of patent registration, considering the search for term *Pharmaceutical*, between 1996 and 2018, according to Derwent world patent index

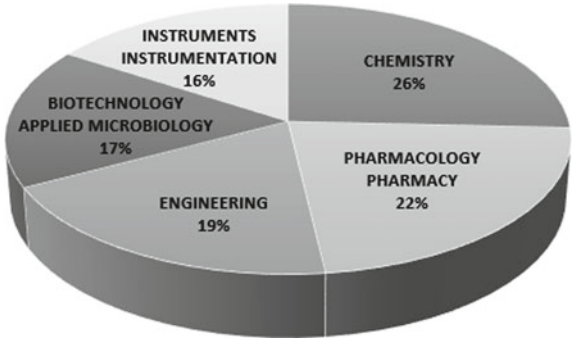

Fig. 2 Main areas of patent registration, considering the search for term *Biopharmaceutical*, between 1996 and 2018, according to Derwent world patent index

Subsequently, the records were classified by depositor, identifying the 15 companies in the pharma and biopharma segment with the highest number of patents, considering the Pharmacology and Pharmacy area, according to Figs. 3 and 4, respectively.

For the pharmaceutical patents, the importance of the European and North-American industries stands out. Novartis is the first in the world ranking with 1,402 protections, followed by Hoffmann La Roche with 1,380 patents, by Bayer with 1,223 patents and finally Merck with 1,192 protections.

It was observed the presence of two Japanese companies (Kao Corp. and Sumitomo Chem Co Ltd.), among the institutions with the highest number of pharmaceutical protections. In fact, Japan has always been recognized as a world leader in the sector. It should be noted that no industry or institution from pharmerging countries was identified among the 15 largest in number of pharma patents. From the comparison with a literature work [3], using the same patent bank and pharmaceutical term search from 1996 to 2014, is observed the loss of Japan's representation in the world ranking, once that to 2014 there were 4 Japanese companies among the top 15 pharmaceutical patent holders. Also, it is noteworthy that by 2014 there was a Chinese research institute (Beijing Guanwuzhou Biological Sci.) among the 15 largest

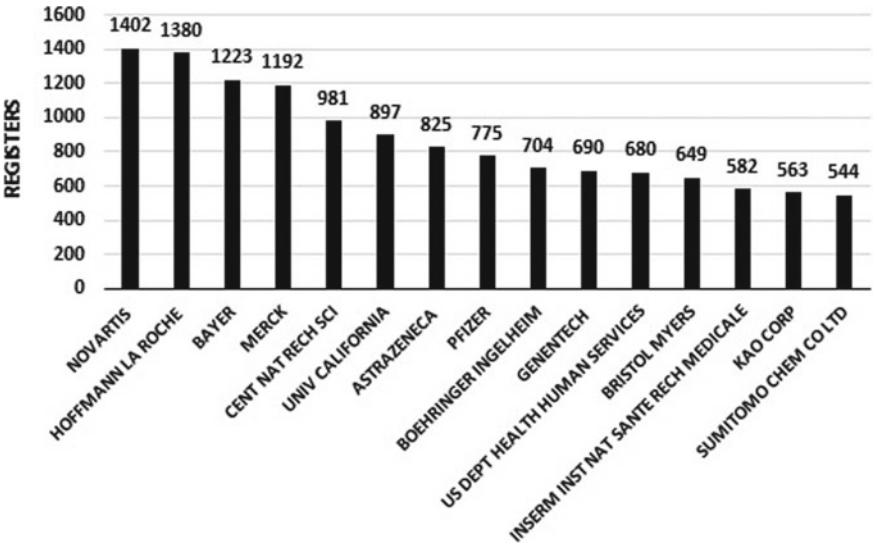

Fig. 3 Top 15 companies with the highest number of pharmaceutical patents granted between 1996 and 2018 in the pharmacology and pharmacy area, according to Derwent world patent index

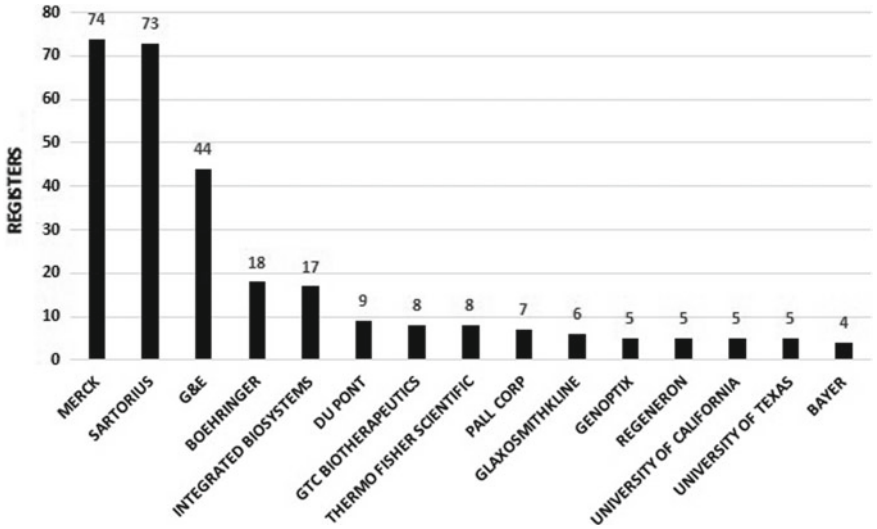

Fig. 4 Top 15 companies with the largest number of biopharmaceutical patents granted between 1996 and 2018, in the pharmacology and pharmacy area, according to Derwent world patent index

pharma patent holders, a fact that did not occur in 2018, demonstrating that China did not get keep up in pharmaceutical innovation ranking according to the Derwent.

For biopharmaceutical patents, the importance of Merck and the German company Bioprocess Solutions Sartorius stands out, with 74 and 73 biopharmaceutical patents respectively. The G&E company occupies the third place, with 44 protections in the segment. Only Merck appears in the world ranking of pharma and biopharma patent and this is due to the fact that in the biopharmaceutical area there are many patents related to new devices and biotechnological processing, highlighting Du Pont and Thermo Fisher. It is observed that there is no representativeness of the pharmerging countries in the ranking of the largest companies holding biopharmaceutical patents.

The total biopharma patents generated by the 15 largest industries (288 protections) refer to only 2.2% of total pharma patents (13,087 protections). This finding suggests that biopharmaceutical sector still has much to advance in terms of innovation and patent protection, pointing out that industries of pharmerging countries gain new competencies to enter this dispute and exploit their markets.

According to 2017 EU Industrial R&D Investment Scoreboard, among the 100 companies that most invested in R&D regardless of the technological field, there are 24 pharmaceutical companies, most notably Roche (1st in the pharma sector and 8th in the general ranking) and Novartis (3rd in the pharma sector and 10th in the general ranking). This finding points to positive correlation, at least for these two large companies, between R&D investment and pharma patent [11].

Therefore, it was observed that pharmerging countries are not represented by the top 100 global companies that most invest in R&D, nor do they currently stand out among the largest holders of pharma or biopharma patents, suggesting a low exploitation of the opportunity of their emerging markets. In fact, since the 2012 report, all the leading pharmaceutical companies were of European, North American or Japanese origin [11].

5 Conclusion

It is a consensus that countries with emerging pharmaceutical markets open a sustainable growth opportunity for the sale of medicines worldwide. The present study pointed out that this market opportunity has not been explored by pharmerging countries in terms of innovation, so no company or institution was observed among the top 15 largest patent holders of pharmaceutical or biopharmaceutical. Taking the example of Roche and Novartis, which indicated a positive relationship between R&D investment and number of pharmaceutical patents, possibly the low investment in science and technology intensive activities is an explanation for the inexpressive innovation index in pharmerging countries. Therefore, it is suggested that countries with emerging pharmaceutical markets adopt more audacious and effective public policies, especially focused on the acquisition of skills in the biotechnology area, aimed at leveraging innovation in the productive sector in order to exploit the market potential.

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Mapping Scientific and Technological Patterns: Hybrid Vehicles

Izaskun Alvarez-Meaza, Enara Zarrabeitia-Bilbao, Rosa Maria Rio-Belver and Itziar Martinez de Alegría

Abstract The hybrid vehicle is a key technology in reducing greenhouse gas emissions in road transport, improving long-term environmental sustainability. The aim of this paper was to evaluate the research status of Hybrid vehicles and identify its industrial and commercial impact. Visualizations have been made from data from WOS (1900–2017) that allow us to understand the field of research of hybrid vehicles. The relationships between main institutions, relevant authors and keywords have been analyzed. Moreover, a very innovative contribution is the analysis of web indicators to quantify the industrial impact of the research. Global results show that hybrid vehicle is rapidly obtaining attention in scientific production. The research concentration is mainly in USA and China, as well as the institutions with more publications. In addition, those institutions are the ones that collaborate the most. The intellectual landscape is formed by very general terms such as electric vehicle and hybrid vehicle, but fields related to battery, energy management, optimization and design, among others, are also being studied. Regarding industrial and commercial impact, the impact on the market of USA scientific research is higher.

Keywords Hybrid vehicle · Scientometric · Visualization · Web indicators · Networks

1 Introduction

Greenhouse gas (GHG) emissions up in 2015 due to road transport and the residential sector. In 2015, total GHG emissions increased by 23 million tonnes (+ 0.5%) compared with 2014. Total energy consumption (and energy-related emissions) increased overall in 2015, driven by an increased use of natural gas and crude oil. The increase in energy use and related emissions was triggered by a higher demand for heat from

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the residential and commercial sectors, and road transport demand, and subsequently road transport GHG emissions, increased for the second year in a row, confirming the upward trend in emissions that started in 2014. In 2015, these emissions accounted for 20% of total GHG emissions, up 1.6% from 2014 [1].

During the last century, the automotive industry revolutionized the society, bringing new technologies to the market that improve their internal combustion engine vehicles, such as, global electric vehicles, which are recognized as one of the most promising alternatives to reducing transport sector contributions to carbon dioxide emissions [2, 3].

The Electric Vehicle (EV) is a road vehicle which involves electric propulsion. With this definition in mind, EVs may include battery electric vehicles (BEV), hybrid electric vehicles (HEV), and fuel-cell electric vehicles (FCEV) [4]. According to Chan [5], HEVs are likely to dominate advanced propulsion in coming years. Hybrid technologies can be used for almost all kinds of fuels and engines. Thus, it is not a transition technology. Therefore, this study only focuses on the HEV and the plug-in option in hybrid vehicles (PHEV). Besides, the report on the Global Hybrid Electric Vehicle Market 2016–2020 [6] predict the global hybrid electric vehicle market will grow steadily over the next four years and post an impressive Compound Annual Growth Rate (CAGR) of more than 37% by 2020.

Despite the importance of electric vehicles as a key factor to reduce GHG emissions in the transport sector, there have been few attempts to analyze data about the worldwide scientific production of these technologies [7]. Assessing trends and the value of research is becoming increasingly important [8, 9]. Scientometric methods in recent years have become an interesting activity to evaluate research activity in the research community. Scientometrics is the quantitative study of research transfer [10]. Hence, its main objective is to facilitate the analysis of emerging trends in knowledge domain [11]; besides, knowledge mapping and visualization is a meaningful field of scientometrics [7].

Patent statistics have been used to define the path of the science assessing scientific and technology activities for a long time. Patents provide a uniquely detailed source of information of inventive activity [12]. According to Griliches [13], patents are one of the most important proxies to evaluate the performance of industry research and development (R&D). Hence, patent citation analysis is considered as a key way to analyze technological development [14] and its counts can be claimed to represent usefulness or relevance to commercial innovation [8]. In order to learn about the knowledge transfer from scientific field to technological field, web indicator analysis based on patent citations makes it possible to explore the influence of research publications on the patents, so webometric analysis has been carried out.

The purpose of this research is to analyze the publications' scientific trends and the market impact of the most relevant country's publications through patent citation analysis of hybrid vehicle research in recent years, in order to help researchers identify the landscape of this technology research, and to predict the future paths of research trends and the impact on technology.

2 Methodology

The analytic process described in Fig. 1 was applied as is clarified in the following sections.

The analysis of scientometrics is achieved according to literature data collection. In this article, the data set of bibliographic registers on hybrid vehicles was recovered from the Web of Science™ (WoS) Core Collection database by using a search query. WoS is a database that merges publications from over 7000 academic and research institutions, including governments and organization in over 100 countries [15]. Because of burgeoning technologies cover different approaches, the definition of the search query is important. The allocation was accomplished through an iterative process whereby different terms and queries were tested by gathering information from databases. In order to build a search query for HEV, we established specific terms that occur within the field (See Fig. 2) according to a previous work done by Gridlogics [16] concerning HEV technologies. Exclusion terms were defined based on manual inspections during query trials.

To delimit the starting year of the information obtained from the database, we identified that the first articles about HEV were published in early 1900. Based on this, 1900 was defined as the initial year for the gathering stage and 2017 as the final year. The main query or Eq. 1 (World) (see Table 1) used in the WoS database retrieved for the defined timespan a total of 15060 articles. Table 1 collects the relative data to the queries, the timespan and the results by countries.

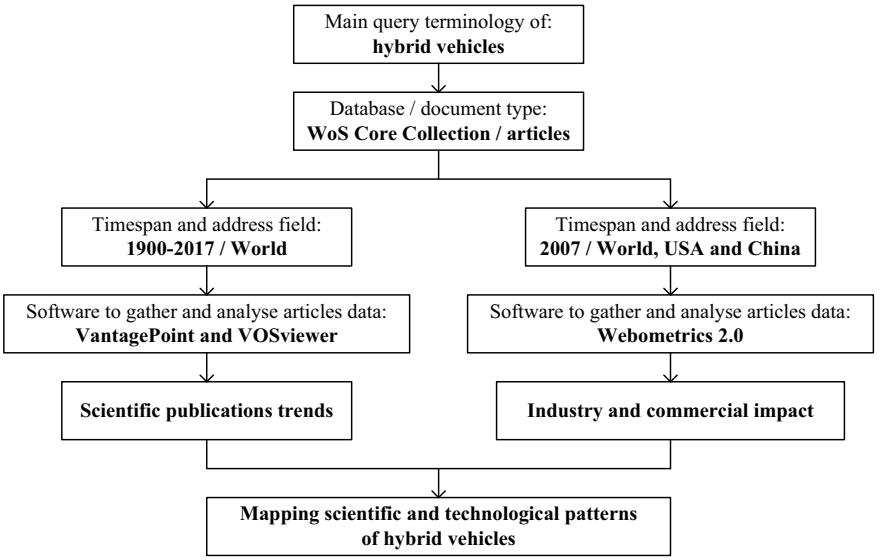

Fig. 1 The analytic flow process of data mining

Table 1 Search query for hybrid vehicles adapted to the Web of Science (WoS) database

Topic	Data
Equation (1) [World]	((TS = ((hybrid* NEAR/3 vehicle*) OR (electric* NEAR/3 vehicle*) OR ("hybrid electric" NEAR/3 vehicle*) OR (hybrid* NEAR/3 car) OR (electric* NEAR/3 car) OR ("hybrid electric" NEAR/3 car) OR (hybrid* NEAR/3 cars) OR (electric* NEAR/3 cars) OR ("hybrid electric" NEAR/3 cars) OR HEV OR PHEV)) NOT (TS = (hepatitis OR virus* OR genotype* OR disease* OR infection* OR allerg* OR "high endothelial venule*")))
Equation (2) [USA]	((TS = ((hybrid* NEAR/3 vehicle*) OR (electric* NEAR/3 vehicle*) OR ("hybrid electric" NEAR/3 vehicle*) OR (hybrid* NEAR/3 car) OR (electric* NEAR/3 car) OR ("hybrid electric" NEAR/3 car) OR (hybrid* NEAR/3 cars) OR (electric* NEAR/3 cars) OR ("hybrid electric" NEAR/3 cars) OR HEV OR PHEV)) NOT (TS = (hepatitis OR virus* OR genotype* OR disease* OR infection* OR allerg* OR "high endothelial venule*")) AND (AD = USA))
Equation (3) [China]	((TS = ((hybrid* NEAR/3 vehicle*) OR (electric* NEAR/3 vehicle*) OR ("hybrid electric" NEAR/3 vehicle*) OR (hybrid* NEAR/3 car) OR (electric* NEAR/3 car) OR ("hybrid electric" NEAR/3 car) OR (hybrid* NEAR/3 cars) OR (electric* NEAR/3 cars) OR ("hybrid electric" NEAR/3 cars) OR HEV OR PHEV)) NOT (TS = (hepatitis OR virus* OR genotype* OR disease* OR infection* OR allerg* OR "high endothelial venule*")) AND (AD = China))
Source	Web of Science
Database	Web of Science Core Collection
Timespan (1)	From 1900 to 2017
Timespan (2)	2007
Document type	Articles
Date of the search	March 12, 2018
Results (1) = Equation (1) + Timespan (1)	15060 articles
Results (2) = Equation (1) + Timespan (2)	257 articles
Results (3) = Equation (2) + Timespan (2)	77 articles
Results (4) = Equation (3) + Timespan (2)	34 articles

Source Own work

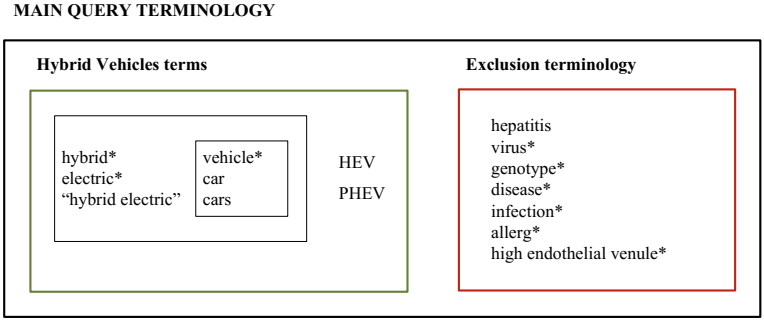

Fig. 2 Main query terminology for different database searches. *Note* Words with asterisk (*) are root words, i.e., these words plus all possible suffixes are contemplated in the query. *Source* Own work based on Gridlogics [16])

The data were imported into Vantage Point^{R} (VP) software, text mining software that help us identify the fields from raw data and show results through a combination of statistics. In a scientometric review, the intellectual landscapes can be represented by a variety of entities such as a network through collaborating authors, institutions, co-occurring keywords, cited references, etc. [17]. In this study, the structure of the intellectual scenarios focuses on co-occurring keyword networks and institution collaborating networks, which provide meaningful information regarding to the intellectual linkages between various scientific concepts [18]. The trends for hybrid vehicle have been identified through frequently occurring keywords and keyword plus. WoS records include two types of keywords: author keywords, those furnished by the original authors, and keywords plus, those extracted from the titles of the cited references by Thomson Reuters [19]. Keywords plus, generated by an automatic computer algorithm, are words or phrases that appear frequently in the titles of an article's references and not necessarily in the title of the article or as author keywords [20, 21]. Garfield [20] claimed that keyword plus terms are able to capture an article's content with greater depth and variety. Thus, the co-occurrence networks were built using VOSviewer software in order to visualize the patterns and knowledge to analyze the evolution of technology.

Additionally, a web indicator analysis is carried out with the intention of measuring the value of the research conducted. The Web indicator analysis is a quantitative method that evaluates web indicators, where a web indicator is a number that is intended to associate with an aspect of research performance or impact, and that is derived from the web and in no way based on counts of citations from academic journal articles [8]. There are many types of web indicators, such as, academic, industrial and commercial, and public engagement impact indicators. In this case, in order to achieve the aim of the research, the industrial and commercial impact is measured from the Google Patents citations analysis (citations from patents to a list of scientific articles gathered) in a specific year, using Webometrics Analytics 2.0 software [22]. We defined 2007 as the specific year to perform the analysis, because it

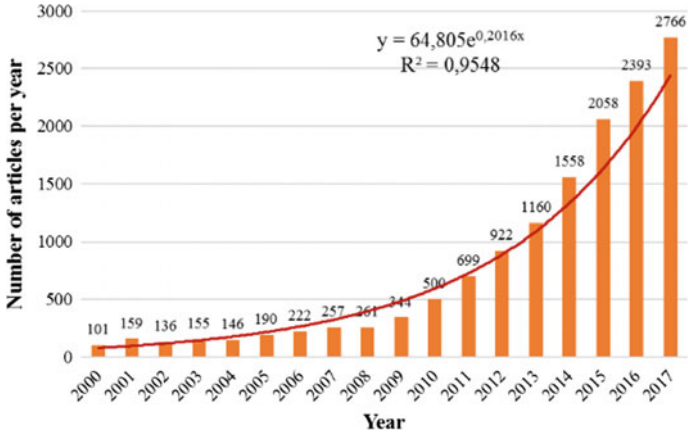

Fig. 3 Annual article publications on hybrid vehicle from 2000 through 2017

is a stage where HEV scientific articles are emerging, and from 2007 until 2017 there is enough time for the collected articles to be cited in patents. Taking into account that, in recent years, China and USA are the main electric car markets [23], the patent citation count is performed and compared between both of them. Thus, we will be able to measure the value of the science research in the technological, industrial and commercial development of the selected countries.

3 Results

In this section, the results obtained through the applied data model are presented.

3.1 Scientific Publication Trends in Hybrid Vehicle

Scientific knowledge production in hybrid vehicles from the results of the WoS analyses from the beginning of 1902 until 2017 was determined: the results are shown in Figs. 3, 4, 5. Global results show that, in the most recent years, the hybrid vehicle is rapidly gaining attention in scientific production, which in turn impacts in R&D. Whereas in 2000 there were only 101 scientific articles related to hybrid vehicles, this number increases to 2766 in 2017, an increase of 2738%. Of the 15060 scientific articles on hybrid vehicles published from 1900 to 2017, 85.7% were published in the last ten years (2007–2017), showing the innovation and increasing interest in hybrid vehicles. An exponential regression was done based on the data from 2000 to 2017. The equation describing the data is $y = 64.805e^{0.2016x}$ with a coefficient of determination $R^2 = 0.99548$ (See Fig. 3).

The affiliations of authors of scientific papers indexed in scientific databases, such as, WoS, are an indicator of which countries and organizations have specific patterns of research concentration and excellence [15]. The most profitable countries in terms of publishing in hybrid vehicle (shown in Fig. 4) are not geographically concentrated. The two predominant countries, by far, with the highest number of publications are USA and China. Almost half the publications are from the USA or China (24% of articles are from USA and 22.5% of articles are from China). The remaining countries in the top 10 published between 425 and 967 articles and they are located in either Western Europe or Eastern Asia, with the exception of Canada and Australia, which hold the seventh position and the tenth position, respectively.

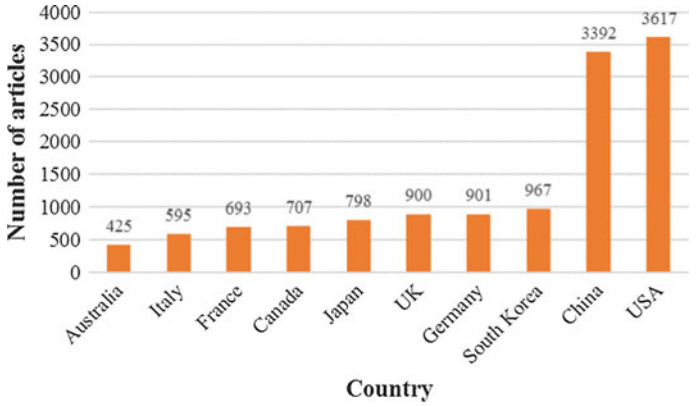

Fig. 4 The 10 most frequent affiliation countries

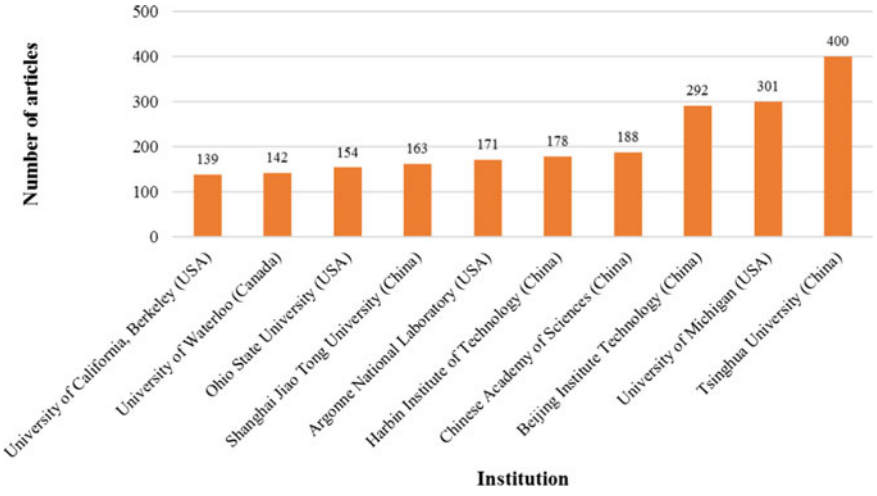

Fig. 5 The 10 most frequent organizational affiliation

The top 10 publishing institutions are highly correlated with the top 10 countries, most of these institutions are Chinese (5) and American (4) (see Fig. 5). The top three publishing institutions are Tsinghua University (China), 400 articles, University of Michigan (USA), 301 articles and Beijing Institute of Technology (China), 292 articles. They publish 46% of scientific articles about hybrid vehicles. Tsinghua University, established in 1911, is one of the most recognized university in China and it has become an important institution for fostering talent and scientific research. In April 2018, it has "14 schools and 56 departments with faculties in science, engineering, humanities, law, medicine, history, philosophy, economics, management, education and art" [24].

3.2 *Visualization of Networks*

Figure 6 shows the co-occurring network of hybrid vehicle of the 100 most cited author keywords and keywords plus generated by VOSviewer. A clusterization of the keywords allows to define the intellectual landscape , showing that "electric vehicle",

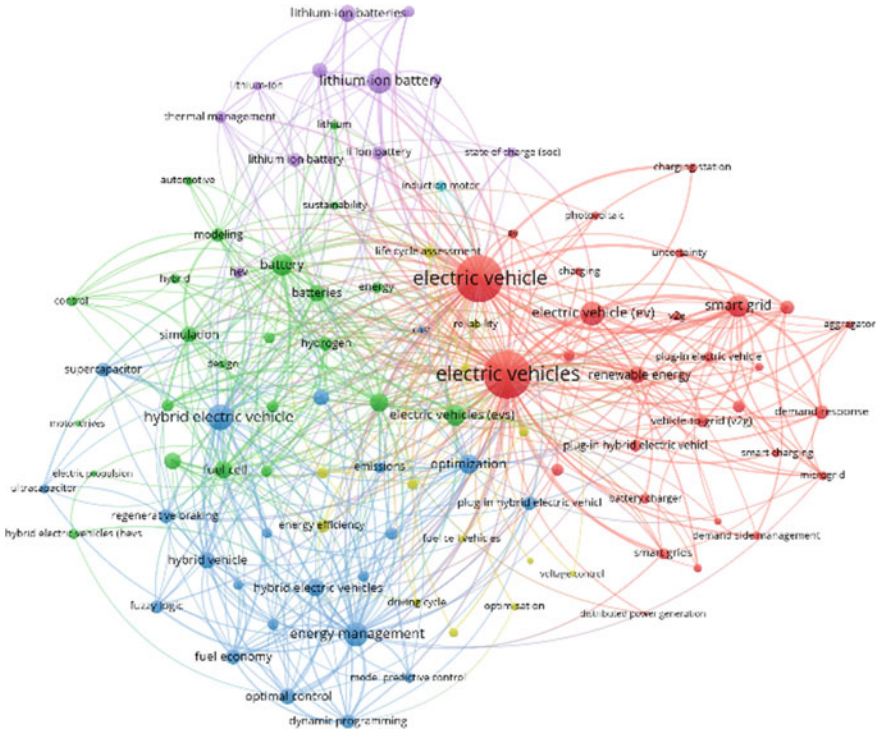

Fig. 6 The visualization map of the co-occurring keywords (author keywords + keywords plus)

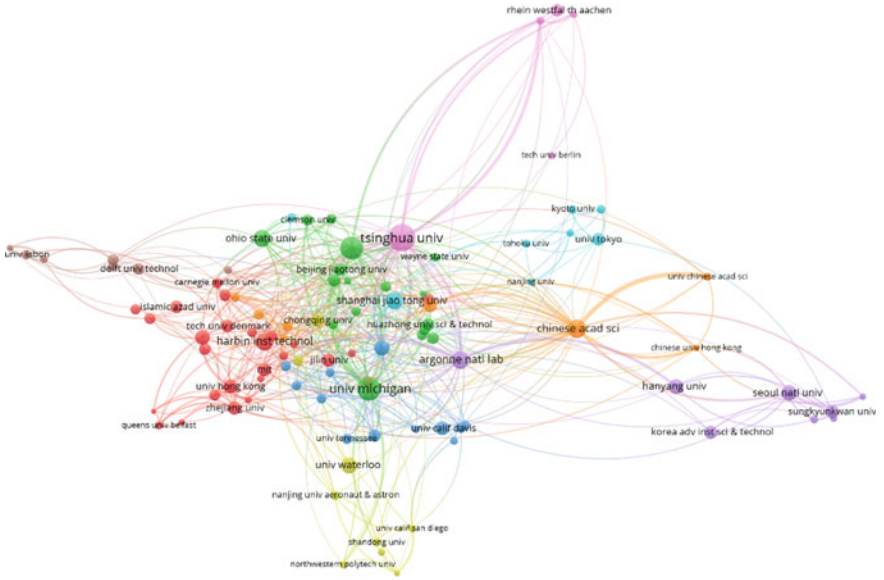

Fig. 7 The visualization map of the top 100 institutions network based on co-authorship relations

"electric vehicles", "hybrid electric vehicle", "lithium ion battery", "energy management", "smart grid", "battery" and "optimization" are the top author keywords and "electric vehicles", "design", "system", "model", "performance", "optimization", "hybrid" and "energy management" are the top keyword plus, which reflect the main hotspots of hybrid vehicle.

Regarding institutions collaborating network, the analysis has been carried out based on the number of co-authorship relations. Figure 7 shows that the top 100 institutions with more co-authorship relations are the Tsinghua University (China) and the University of Michigan (USA), which ties in with the top publishing institutions.

3.3 Web Indicator Analysis

Citations from Google Patents to scientific publications could be used to measure the commercial value or technological benefits of the cited works [8].In this way, the knowledge transfer from scientific field to technological field can be quantified. Taking into account the articles published in 2007, the patent citations count has been carried out addressed in worldwide, in USA and in China. USA hybrid vehicle research has above world average impact, the four indicators are higher. In contrast, China hybrid vehicle research has bellow world average impact. The four indicators are smaller in the case of China (Table 2).

Table 2 Industrial and commercial impact of hybrid vehicle scientific articles

Industrial and commercial impact			
Google patents citation counts			
	Hybrid vehicles—World	Hybrid vehicles—USA	Hybrid vehicles—China
Records	257	77	34
Arithmetic mean (unique domains)	**1.019455**	**1.077922**	**0.73529**
Geometric mean (95%CI) of unique domains	**0.841380** (0.743159, 0.945136)	**0.885554** (0.698297, 1.093459)	**0.636802** (0.443710, 0.855720)
Mean (95%CI) of log(1 + unique domains)	**0.610515** (0.555699, 0.665332)	**0.634222** (0.529626, 0.738818)	**0.492745** (0.367216, 0.618273)
Proportion non-zero (95%CI)	**0.696498** (0.637734, 0.749475)	**0.701299** (0.591506, 0.791961)	**0.676471** (0.508429, 0.808684)

4 Conclusions

We conducted, on one hand, a scientometric study of the patterns of publications outputs, such as, international productivity, both by countries and by institutions, landscape of co-occurring network and institutions collaborating network. On the other hand, we performed a web indicator analysis to know what is the scientific research value in the market.

Global results show that hybrid vehicle is rapidly obtaining attention in scientific production, which in turn impacts in R&D. In the last ten years the 85,7% of scientific articles have been published. The research concentration is mainly in USA and China, as well as the institutions with more publications, Tsinghua University (China) and the University of Michigan (USA). In addition, those institutions are the ones that collaborate the most. The intellectual landscape is formed by very general terms such as electric vehicle and hybrid vehicle, but fields related to battery, energy management, optimization and design, among others, are also being studied.

Regarding to industrial and commercial impact, the value of the USA research is greater than the Chinese research. Therefore, the impact on the market of USA research is greater.

In view of our results that explain the current state of science related to hybrid vehicles, by conducting a patent analysis of this technology, future researches should analyze the technological transfer in industrial applications in order to understand the technological advances in this field, and identify the flow of knowledge through the analysis of patent citations.

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Analysis of Cultural Factors That Can Influence International Research Projects by Brazilian UNIFEI Professors in the United States

Justin Michael Hansen and Carlos Eduardo Sanches da Silva

Abstract Identifying and assessing the influence of cultural factors in international research and projects is a topic that is becoming increasingly relevant as the world continues to globalize. Cultural values that differ across the world have a deeper influence on everyday life than many people are normally aware of. The scientific contribution of this work will be in line with other publications found in the area of management of international cultural projects with a specific aim of what steps can be taken in order to better prepare individuals working overseas and maximize their productivity. The most common country studied in the context of intercultural project development is China. However, the present research aims to establish and develop this knowledge in the context of Brazilian professors doing research in the United States through means of a survey taken by eleven Brazilian professors and one doctoral student answering both open-ended and closed questions with a numeric rubric about their experiences in the US. The results of this project measured cultural factors related to personal life and everyday working issues in order to gain a better understanding of what cultural aspects are having the greatest influence on Brazilian professors conducting research in the US. The data, consistent with much of the literature consulted for this project, demonstrated that among other areas, communication, comfort in one's everyday working and social life, and autonomy in the workplace were considered to be of the most importance areas for Brazilians living in the US.

Keywords Cultural influences · Global market · International research projects

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1 Introduction

Everything from beliefs, morals and norms that represent a group of people to the behavior and habits that form a "complete design for living" is considered in order to have a reference of definition when it comes to culture for the sake of this research. Perhaps it can be said that things such as beliefs, morals and accepted norms of a cultural group are what influence the behavior and habits of that very group. That is to say that a group's morals and beliefs shape what are accepted as the norms for these people which then give way to the behaviors and habits as consequences of a particular belief system. In this way of thinking, the current research seeks to identify how such cultural beliefs, morals, and likewise norms, produce behavioral and habitual routines and actions that affect work output, in this case study. Furthermore, this study will examine how research affected by the consequences of different behaviors and routines influenced by different beliefs intertwines and how such cultural aspects influence the overall outcome of productivity and research achieved.

The first step in selecting individuals to take part in an international project is the screening process illustrated in what is referred to as "Expatriate Selection". This is the process of selecting individuals who demonstrate characteristics of adaptability. One can see this taking mass effect in the global market currently in how employers place an especial importance on the areas such as cultural awareness and international experience on their résumés and in job interviews. Secondly, project management is responsible for providing "Cross-cultural Training" if they want to be efficient in transitioning their employees to life overseas and putting them at ease in order to make productive workers who will contribute effective results to the project. "Cross-cultural Training" is viewed as training that can take place before leaving one's country and on-site in the host country (usually phases of both are executed in order to transition workers in the most effective way possible). This is an involved process which teaches the "selected expatriates" about the norms of the culture of the country where they are going to live and gives them insights on how to cope with the challenges they will potentially face.

Expatriate Selection *During the anticipatory phase, when considering individuals for foreign assignments, the most important organisational factors to be considered are the criteria and the process of expatriate selection* [3]. *This has been substantiated by researchers, who have long been advocating effective recruitment and selection systems for successful expat assignments* [8]. *In spite of this, to date, most organisations continue to rely on technical skills and domestic track record as the criteria for selection* [6].

Cross-cultural Training *Cross-cultural training is an intervention to escalate an individual's aptitude to deal with and perform in an unfamiliar environment* [3]. *Studies* [2, 3, 7] *suggest that comprehensive cross-cultural training is helpful in building an expatriate's cross-cultural skills and competencies. Trained expatriates are able to carry themselves confidently and work efficiently with less supervision* [4] *and have the potential to predict success on international projects* [4].

After the individuals selected to participate in an international project are chosen and go through their initial phases of cross-cultural training, they will go through three major periods of adjustment while living and working in their new country:

Interaction Adjustment

This aspect deals with the comfort levels when dealing or interacting with host country nationals at work and in non-work situations [4]. *It is also suggested that interaction is the most difficult of the three facets of adjustment.*

Work Adjustment

This involves adapting oneself to the new job tasks, roles and environment. Work adjustment is easier if there are similarities between the parent and the host subsidiary in terms of procedures, policies and task requirements [1].

General Adjustment

This second facet deals with overall adjustment to living in a foreign land and adjusting to its culture [3]. *It comprises factors such as housing conditions, healthcare, cost of living, etc.* [1].

As can be derived from this information, things such as comfort and adaptation are at the forefront of the transitional process. Correlation between this and the "Cross-cultural Training" aspect of transition are no coincidence. The "Expatriate Selection" and "Cross-cultural Training" are built upon the research that was developed into these adjustment phases in order to ease such a transition of working internationally.

2 Materials and Methods

The search for the information needed for this research was done through interviews with expatriates (professors and one doctoral student who participated in international research programs in the United States). The interview sought to answer and understand the main theoretical difficulties presented in the literature review and to highlight if the experiences lived by the individual of study correspond to the theoretical proposals presented. This was done in two parts. In the first part of the interview, a survey was applied in which the participants were asked to assign a value to different aspects of their everyday lives while living in the US and conducting research. The second part of the interview allowed the participants to discuss in more detail why they rated the different aspects of their life abroad in the way that they did. This was accomplished through a series of open-ended questions that gave each participant the opportunity to comment openly and add as much detail as they wanted to about a particular area. Figure 1 shows the scheme followed with the main categories and sub-categories of influence.

In the first part of the study, the participants were asked to give a numeric value of 0–10 to rate what they considered the importance level for them in nine categories related to adaptation. The nine categories included: social life; communication; distance from family; alimentation; safety; religion; politics and bureaucracy; laws and rules; and weather (Figs. 2, 3). These categories were strategically selected based on evidence from the literature that each particular area does in fact contribute to

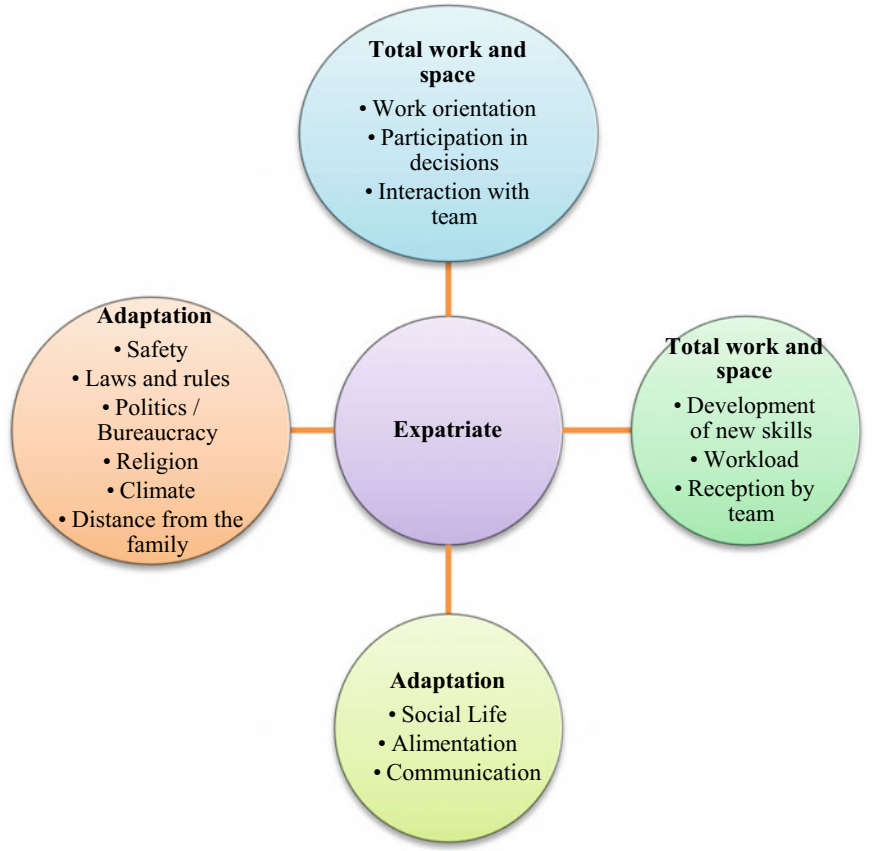

Fig. 1 Scheme showing the factors analyzed in the interview with the purpose of determining the main influence factors in international research projects from the interview of the expatriate teachers/students to the United States. Adapted by Bardin [1]

the overall adaptation process. In addition to this, the given categories were also chosen as they naturally reflect different facets of culture and thus can facilitate the categorical measure and analysis of culture and in what areas it is having the most impact.

3 Results

Data was collected from a total of 12 subjects, of which 8 were male and the remaining 4 were female. This ratio comes as a consequence of the demographical distribution of male and female professors at UNIFEI being predominantly male. The age

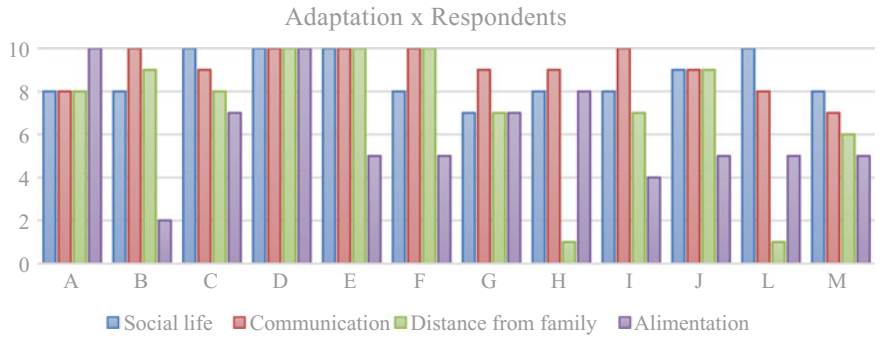

Fig. 2 Adaptation graph showing the primary factors (social life, communication, distance from family and alimentation) for adaptation

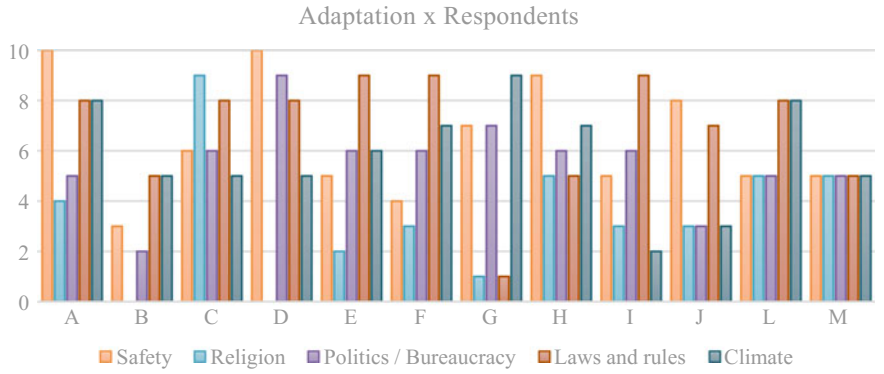

Fig. 3 Adaptation graph showing the primary factors (safety, religion, politics/bureaucracy, laws and rules, climate) for adaptation

distribution of the sample studied was as followed: 17% in the range of 21–30 years old; 25%, 31–40; 25% 41–50; and 33% 51 and older. Half of the participants were native to the state of Minas Gerais while among the other half, 4 were native to the state of Sao Paulo, 1 was native to Espirito Santo and 1 native to Rio Grande do Sul. When asked about civil state, 75% of the participants reported that they were married while 2 more replied single and only one reported to be divorced. Ten of the 12 participants identified as white while the remaining checked "*pardo*" on their survey (a term used in Brazil to identify those of mixed blood and generally darker than white skin). In terms of religion, 58% of the participants identified as Catholics while 25% considered themselves Spiritists and the remaining 17% were atheist. However, of the 7 participants that self-identified as Catholic, only 4 considered themselves to be devout practicing members. Similarly, 2 of the Spiritists considered themselves practicing.

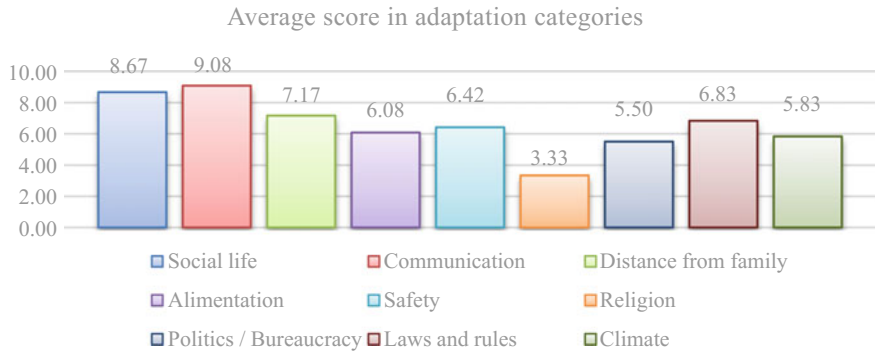

Fig. 4 Adaptation graph showing the average of all categories applied

Between the two graphs, what is shown is the numeric value that each participant assigned to each of the nine categories. The communication category resulted in the highest average at 9.08 (Fig. 4). This is perhaps the strongest result from the closed-question section of this study as it is consistent with what was seen throughout the literature related to comfort and trust being of the utmost importance and depending greatly on communication in the context of people living and working abroad.

Religion had an average score of 3.33, giving it the overall lowest average. The highest score, which was a 9, came from a participant who confirmed being a practicing Catholic. The next highest score in this category was a 5 being appointed by just two individuals. This suggests that, religious and practicing or not, Brazilian professors do not tend to be very concerned with this characteristic of living abroad, at least in the case of the US. This data does not eliminate the possibility that a Brazilian could be concerned about this or even run into problems while in the US but it does seem to demonstrate a relieving tendency of this aspect in terms of what workers and researchers should concern themselves with in order to better prepare for living and working experiences overseas.

A category that had scores ranging from as low as 1 all the way to a high of 10 was the distance from family category. In this case, further contextualization of which of these participants lived with their families in the US and which lived alone at a distance from their families in Brazil must be considered in order to make complete sense of, and validate the consideration for this data. In this regard, results tended to be consistent with the idea that those participants living abroad without their families tended to give this category a higher score while those who had a spouse and/or their kids with them tended to place less importance on this. However, there were exceptions.

Safety consistently ranked relatively high in importance among participants of this study with an average score of 6.42. This was especially true among female subjects with the exception of one outlier who placed a value of just 4 on safety while the other three candidates appointed scores of 10, 10 and 8 respectively. As for the men, excluding one participant's score of 3, this category received no less than a 5. Aside

from the two low scores, safety being considered of high importance is consistent with prior observations made in the literature review that when residing and undertaking employment abroad, participating workers, or more specifically researchers in the case of this study, have reported that they need to feel safe and comfortable in order to produce effective results in their work. This should be no different in the case of Brazilian professors taking on research projects at universities in a foreign country such as the US as is consistently demonstrated, save for the exception of two outliers.

The category of social life was another high-ranking category among participants in this study receiving no lower than a score of 7 and receiving as many as four scores of 10 and another six scores of 8 with one additional score of 9. Given that culturally speaking Brazil is a very social country that tends to place a high value on social interaction and participation, this was not surprising. As was reported very consistently throughout the literature, those who live abroad place a high importance on their comfort and attribute positive and negative results of living abroad directly in part to whether or not the person was able to feel comfortable in their living environment. For this very reason, social life was an area of interest in this study in order to evaluate the overall comfort level that the subjects felt not only in their work environment but in general in the US as working hours may be limited but living hours are always in effect. Thus, the first part of gathering this data required a measure of how important subjects considered this aspect. Results were consistent with suggestions from the literature that social life is potentially as much of a factor in determining one's comfort while abroad as is comfort in their work environment in some cases.

Alimentation received generally modest scores across the board with the exception of one participant contributing a low score of 2 and two participants indicating an importance level of 10. The two highest scores both came from female participants. This suggests that in terms of preparation for Brazilians and potentially other nationalities around the globe, perhaps food can be more of a concern for women than it would be for men. The overall average in this category was 6.08 suggesting no significant concern among participants of this study. As the US is a country with ample varieties of food throughout its different regions, this data also comes as no surprise.

Participants of the study varied in their responses regarding the importance of climate. All but two responses were indicative of climate being a 5 or higher. The only exceptions to this were one participant giving a 3 to this category and another participant giving an even lower score of 2. Contrary to this was the high score of 9 given by just one individual. Climate fits into the adaptation and comfort realm in terms of why it was included on the survey and how and to what extent it will be analyzed. Region is of particular importance in the analysis of climate as this is one aspect that varies greatly throughout the US. Also important to consider is the difference of climate in each of the four seasons, something of which the intensity can also vary drastically depending on the region. The highest score came from a subject who participated in international research in both Indiana and Massachusetts, both of which, although known to have warm summers, are even more known for their brutally cold winters. This response is suggestive that the level of importance

related to climate tends to have a correlation with the specific part of the US where the participant resided. Giving additional support to this analysis is the fact that the two participants that both gave the second highest score of 8, were also in cities in regions known for having extremely cold winters (Troy, New York and State College, Pennsylvania respectively).

Politics and bureaucracy scores ranged from a low of 2 to a high of 9 while 6 was the most frequent score appearing 4 times and 5 appeared three times resulting in an average of 5.5. The two highest scores of 9 and 7 were both given by female participants and the lowest score was given by a male suggesting that perhaps women tend to place a higher importance on this category. With the exception of one female participant indicating a 3 in this category, no other women gave this category a score of less than 6. As political influence and policies can vary greatly depending on the presidency in place at the time each participant spent in the US, it is also worth analyzing this data for patterns suggestive of correlations between the time period and political situation current to that time. The female candidate that gave this category a 3, for example, was the only female candidate to have spent time in the US during a presidency of the Democratic Party. This particular participant did research in the US for the first time during Clinton's Presidency in the 1990s and for the second time during the Obama Administration. During both of these Presidential Administrations, national and international security measures along with bureaucracy for foreigners and immigrants were at a relatively lower point when compared to the Republican Presidencies in recent times of both Trump and Bush. The highest score from female candidates came from a participant who has conducted research in the US since the Trump Administration has taken office. Trump's Presidency, being widespread in international news and media as a racist and misogynist administration, could indeed have everything to do with this.

In the category of laws and rules, three participants indicated a score of 9 while four more gave a score of 8 and one marked a 7 in regard to the importance of this aspect. These high scores were a mix of both male and female candidates leaving no defined indication that one sex considered this category more important than the other. With the exception of a low score of 1, no single participant gave a score of less than 5 in this category resulting in an overall average of 6.83. Being that this was the fourth highest average of the nine categories, it can be seen that Brazilians generally place a reasonably high level of importance on laws and rules when living in another country.

Much like the adaption factors section where each participant was asked to place a numeric value on what they considered to be the level of importance for each of the areas, the work-related factors of influence section also measured six unique aspects of the work atmosphere and work life by means of a numeric assessment.

In this section, importance of each category was not measured but rather each participant was asked to rate how good or bad they felt this area was in their experience doing research in the US. For the purpose of comparing the scores given by each participant, 0 signifies that the participant felt that this area was not effective to some degree or that they were displeased by the overall condition and or conduct in this

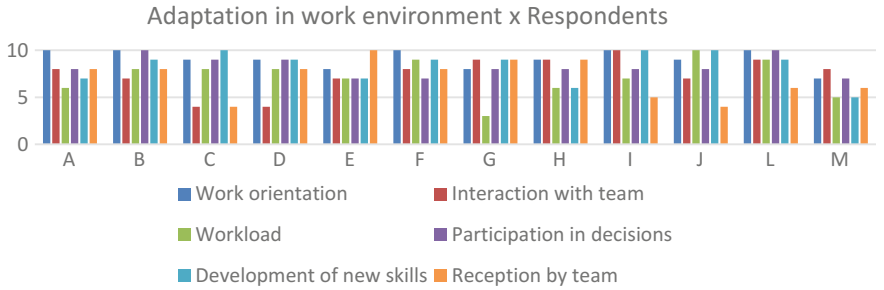

Fig. 5 Adaptation graph related to work environment

area while 10 means that the participant was very pleased with their experience in the given area.

The six different categories measured related to the work atmosphere and work life were the following: (1) orientation of work/assignment; (2) workload—amount of hours worked/expected to work; (3) development of new abilities; (4) interaction with work team; (5) participation in decision-making process; and (6) reception by the team and colleagues (Fig. 5).

These categories were specifically thought out and selected in order to create a profile of what each participant felt about their experiences abroad in terms of their work life. Categories such as participation in decisions and reception and interaction with the team were designed to better understand the involvement and participation of each participant in their work environment whereas orientation and workload categories were selected so as to gauge the professional side of expectations and productivity in each case. Finally, the development of new abilities measures both of these aspects and is a final means of determining how well the participants felt that they were able to grow from the experience and gain new skills that they can consider professional development in their careers as researchers.

With the exception of one score of 3 and another of 5, workload scored consistently high among all participants with scores ranging from 6–10 and an overall average of 7.17 (Fig. 6). As will be seen in more detail in the open-ended question section, many of the participants felt that their workload was pretty standard and that it was comparable to what they experienced in Brazil, making this aspect an easy adjustment (if any adjustment at all). Some participants also commented on the fact that their workload was left for them to decide and that they did not necessarily have a required minimum number of hours, but rather a set of expectations in terms of what was to be achieved and as far as how those expectations were met was left for them to manage. Generally, this aspect was reflected on as a positive characteristic of the participants' experiences in the US. In the literature, it was observed that structure and/or lack of structure relative to one's customary working style, can cause a disruption in one's working habits thus creating a less productive work environment and order of operation for the individual. For this reason, such a question was placed on this survey and analyzed with the intent of seeing if this aspect had an effect in the case

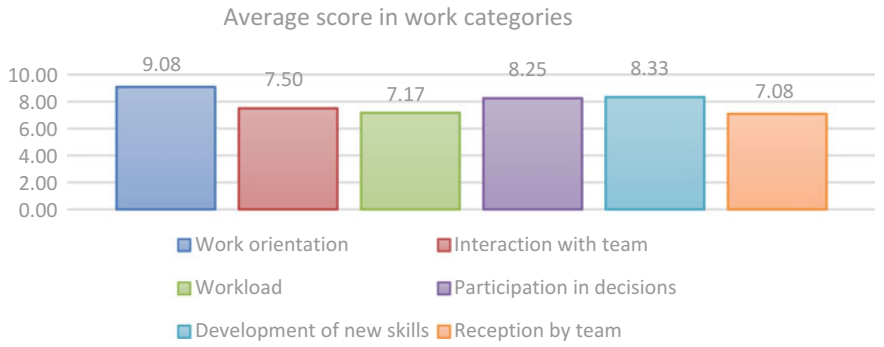

Fig. 6 Adaptation graph related to work environment showing the average for the categories

of Brazilians doing research in the US. Seemingly, there is evidence that for some that are more accustomed to a more structured work environment, this can in fact influence their productivity in a negative manner. However, what seemed to hold more true was the idea that in the case of Brazilians, a more open and "free-to-choose" workload and work schedule can allow people to structure their own schedule and become increasingly more productive.

In the area of reception by team, not all participants gave such high marks. Two scores of 4 were seen in this category along with one score of 5. The two scores of 4 came from one male and one female giving no strong indication that one sex was more dissatisfied in this area than the other. Likewise, the rest of the scores ranging from 6 to 10 were mixed in terms of the sex that indicated them furthering the aforementioned notion. In this area, as can be seen in the open-ended questions part of the survey, participants seemed to express that they felt a lack of reception in terms of friendliness and extension of openness to them. This again furthers previously referenced ideas about Americans having a tendency to be purely professional in the work place and not as friendly necessarily as they have more of a "work is for work" attitude. Brazilians, on the other hand seem to have a tendency of expecting more friendliness and warmth in the work place as this is culturally more appropriate and common.

Interaction with the team was a category that generally received high scores but at the same time received more than one score below a 5. Based on the open-ended questions that supplement this information, this seemed to be directly connected with the freer work schedules and liberty for participants to choose their own hours and be solely responsible for managing the progress of their work. Thus, it can be noted that along with the benefits of a more autonomous work schedule and freer structure of work, comes with the potential cost of social interaction within the team members. The negative scores received in this section draw attention to the fact that in the case of at least some Brazilians, this was something that lacked or in some way affected their work dynamic and atmosphere. Perhaps in this case, being used to a more interactive team as opposed to a work environment structured and

focused on independent and individual work was an aspect to which Brazilians did not necessarily anticipate having to adapt. However, at the same time as having some critical feedback in this area, most of the participants gave the category a score above a 7 suggesting that the overall experiences were generally positive in this area. Still, these low scores cannot be over looked as the point of this research is to identify such gaps in order to work toward improving them in the future.

In the participation in decision-making category, participants showed favorable, positive results with scores ranging from a low of 7 to a high of 10 and an overall average of 8.25. As discussed above, the participants of this study did not always feel that they had the best interaction with their work teams on an everyday social level. However, the positive results in the participation in decision-making category demonstrated that Brazilians were encouraged to participate and did have an opportunity to participate and interact with their team on more professional matters such as making group decisions about the research and projects in which the team was involved on a group level. Perhaps this is also related to the general differences in work habits and structures of respective work environments.

Orientation for work was a category that received a low score of 7 with all other participants indicating a value in between 8 and 10 in this category resulting in the highest average of the work-related factors at 9.08. Overall, this demonstrates satisfaction among the participants of this study and demonstrates that the orientation process for their work was effective. As seen throughout other areas measured in this study related to both social life and the work atmosphere, there seems to have been a theme of communication and interaction in general with American counterparts as being direct and professional. Perhaps in the case of orientation, this is also true and consistent with this tendency. At any rate, this result is significant in demonstrating the importance of communication in the work place and especially so in the case of being oriented in a new work environment. This is also consistent with findings in the literature that feeling comfortable and having a clear understanding of one's work assignments and responsibilities is essential to one's ability to produce effective results.

With the exception of one score of 5 and another of 6, the development of new skills category received scores ranging from 7 to 10 giving it an overall positive outcome and an average of 8.33. In the context of this research, this demonstrates that there is a lot to be gained from international work being performed throughout the world. As work orientation results were positive in this survey as well, it is suggestive that work orientation in the host country is a vital aspect that allows for participants to maximize the potential of what can be gained from their experience overseas. Further relating the results of this category to the outcome of other categories, it can also be suggested that things like more autonomy in the work place and more participation in the decision-making process encourage skills development as these could be new areas where participants have more room to grow when given the chance. In the case of having work autonomy in the work place, some participants commented in the open-ended questions section that they felt growth in this particular area in that they were forced to be more organized and responsible in managing their own research projects. Likewise, having more influence in the decision-making process

encouraged participants to develop more skills in areas such as communication and teamwork as was commented in the open-ended questions by some participants.

4 Conclusions

Important factors that had the most influence on the participants' productivity were those related to comfort, such as aspects of food, social life and contact with family whether living with their family or living at a distance. Flexibility in work hours and having more autonomy to not only choose one's work hours, but be more independent in managing one's own project also came through as positive aspects of cultural differences observed by Brazilians living in the US. When it came to participating more in decision-making processes as collective groups, Brazilians demonstrated that this was an overall positive part of their experiences and gave good feedback regarding the idea of being included more in this facet of their work lives. Other, more uncontrollable factors such as weather and politics also had a measurable influence on the participants of this survey. Weather influenced the comfort level of those participants who had lived in colder regions with more severe winters while a correlation was seen between level of comfort and concern, and political party of the US president at the time of stay. The most consistent data seen throughout the responses of all of areas measured in this survey pointed at the theme seen throughout the literature that communication is vital for someone working and living overseas. This was observed in both sections of the survey related to everyday life and questions specifically regarding aspects of the participants' work lives. For future research, one could interview more researchers in order to have more data to compare and analyze. It would also be of interest to interview Brazilian professors that have done research in other countries besides the United States to compare the results with those of this study.

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Acknowledgement of Consent The participants in this study have all given their consent in writing that the contents of this article to be published are known and consented by each of them and that their names will not be mentioned.

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Causes of Food Loss and Waste: An Analysis Along the Food Supply Chain

Vanessa S. M. Magalhães, Luís Miguel D. F. Ferreira and Cristóvão Silva

Abstract The waste of food represents a missed opportunity to feed the growing world population. This is the main reason why member states of the European Union are committed to halve the food loss and waste by 2030. To reach this goal, researchers and practitioners are working to find solutions on the level of prevention of food loss and waste. However, to adequately tackling the problem, researchers and relevant stakeholders need to understand the origins of food loss and waste for the different stages of the supply chain. To help with that, this paper reviews the main causes of food loss and waste for each stage of the supply chain. In conclusion, the most urgent causes of food loss and waste to tackle seem to be the demand forecasting, the handling and operational bad practices, the specifications set by retailers regarding weight, size and colour, and the decay of the products quality. Therefore, since these are common to almost all stages of the supply chain, researchers and practitioners should form multi-disciplinary teams to develop solutions for food loss and waste prevention, based on concepts of supply chain cooperation and coordination, seeking to improve the organization and the visibility of information along supply chains.

Keywords Food supply chain · Food loss and waste · Causes

1 Introduction

Some studies predict that global food production will have to increase roughly 70% by 2050 to meet the growing demand of food by the world population [1–3]. Yet, approximately one third of the food produced today is lost or wasted [4]. This waste of food represents a missed opportunity to feed the growing world population. With this in mind, the member states of EU agreed to "take measures to promote prevention of food waste in line with the 2030 Agenda for Sustainable Development" and made

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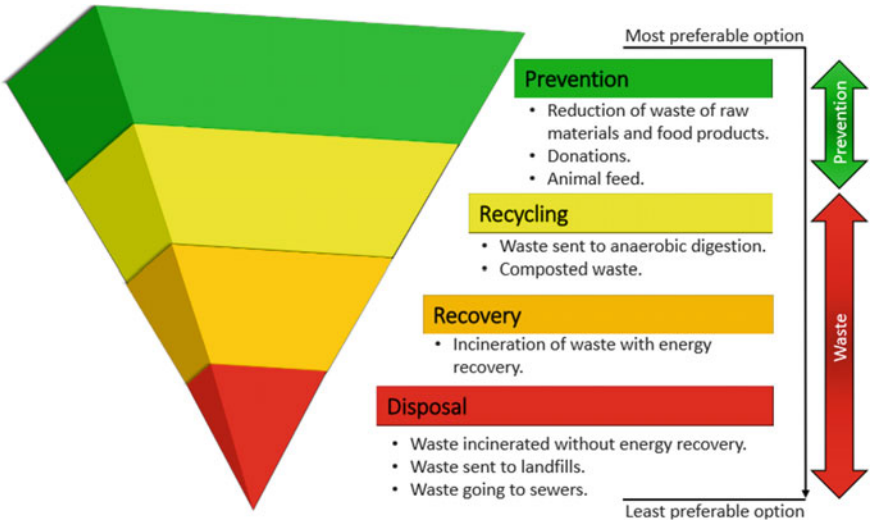

Fig. 1 Food waste hierarchy, based on [16]

a commitment to "halve per capita global food waste at the retail and consumer level and reduce food losses along production and supply chains including post-harvest losses" by 2030 [5]. Therefore, researchers and practitioners should strive to stop food products from becoming waste and work on the level of prevention, according to the food waste hierarchy (Fig. 1) [5].

The FUSIONS project (the first to quantify food loss and waste at a global scale [6]) defines food waste as "any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed, but not including food, or inedible parts of food, sent to animal feed or used for the production of bio-based material/biochemical processing" [5]. When this food waste occurs at the upstream stages of the food supply chain it is usually called "food loss", when occurs at the retail and consumption stage it is denominated food waste [7]. Although reducing food loss and waste has gained greater attention in recent years, its pattern and range along food supply chains is not yet well understood [8]. This is why some of the recommendations of the FUSIONS project, in 2016, include the improvement of the knowledge on "food waste drivers and on their environmental, social and economic impacts", since they considered it crucial for the "design and implementation of effective prevention policies at EU, at national and local level" [5].

Therefore, this paper aims to contribute to this discussion through a review of the main causes of food loss and waste along supply chains. To the best of our knowledge, only a smaller part of the researchers has tried to classify the causes of food loss and waste by stages of the food supply chain [e.g. 4, 9–14]. However, the results are difficult to be compared because of the disparity of the stages considered. We add to the body of knowledge by analysing the ten main causes of food loss and waste identified in the literature for the different stages of the supply chain. The

publications here reviewed were selected from a wider collection of publications, retrieved from SCOPUS and Web of Science regarding the problem of food loss and waste for another work [15], and only the publications that had a significant contribution to the study of the causes of food loss and waste were considered.

2 Food Loss and Waste

By definition, the food supply chain (Fig. 2) is the "connected series of activities used to produce, process, distribute and consume food" [5], and, contrary to what one may think, food loss and waste is evident in all stages of the food supply chain and does not happen solely at the consumers end. Before the products reach the shelfs of the supermarkets, they undergo a mix of different processes, like transportation, processing, and packaging, which changes their original form and contributes to part of them being lost or wasted in the process [9]. Therefore, in the present section, the ten most cited causes of food loss and waste identified in the literature for the different stages of the supply chain are listed and evaluated.

2.1 Agricultural Production

The first stage of the food supply chain is the agricultural production stage and includes the activities preceding and including the harvest of crops or the slaughter of animal-based organisms. Here, the main causes of food loss relate to: (1) Management issues—like the overproduction and the inadequate demand forecasting; (2) technical inefficiencies—like poor operational performance and inadequate handling or the lack of infrastructures and technical skills; (3) intrinsic characteristics of the product—such as the non-conformance to retail specifications, because of the weight, size or colour of the products, or even the deterioration of products quality; and (4) factors that cannot quite be controlled—like climate change and seasonality.

Fig. 2 Stages of the food supply chain

Table 1 Causes of food loss in the agricultural production stage of the food supply chain

Cause of food loss and waste	References
Overproduction and excessive stock	[4, 13, 17, 18, 19, 20]
Inadequate demand forecasting and product ordering	[10, 11, 13, 17, 21]
Poor operational performance and inadequate handling	[4, 10, 11, 13, 14]
Climate change and weather variability	[10, 19, 21, 22]
Non-conformance to retail specifications	[4, 11, 13, 17]
Product quality (deterioration and diseases contamination)	[10, 14, 21, 23]
Lack of infrastructures and technical/managerial skills	[19, 20, 24]
Not-harvested products due to unprofitable prices	[4, 13, 14]
Seasonality	[18, 22]
Short product shelf-life	[10]

The ten main causes of food loss for this stage of the supply chain are summarized in Table 1.

2.2 Post-harvest Handling and Storage

This stage includes activities of handling, sorting and storage of the food products at the farm level. Some of the causes of food loss and waste in this stage are identical to the ones in agricultural production (see Table 2). Management issues continue to greatly contribute to food losses, due to overstocking because of take-back agreements or order cancellations. So, do the technical inefficiencies, where most of the top ten causes belong to, with poor operational performance, the lack of storage facilities, the spillage of product, the poor accommodation of products in bins and the storage at wrong temperatures. The remaining causes of food loss relate to intrinsic characteristics of the products.

2.3 Processing and Packaging

The processing and packaging stage refers to activities that include the reception, sorting and storage of raw materials in the processing facilities, the pre-processing and processing treatments and the packaging and storage of processed products that

Table 2 Causes of food loss in the post-harvest handling and storage stage of the food supply chain

Cause of food loss and waste	References
Poor operational performance and inadequate handling	[4, 13, 14, 22, 23]
Lack of storage facilities	[19, 20, 24, 25]
Non-conformance to retail specifications	[4, 13, 21]
Spillage	[13, 14]
Short product shelf-life	[11, 22]
Poor stacking, filling and cushioning in bulk bins/crates	[26]
Storage at wrong temperatures	[14]
Product quality (deterioration and diseases contamination)	[4]
Inadequate or defective packaging	[4]
Overstock due to take-back agreements and orders cancellation	[4]

Table 3 Causes of food loss in the processing and packaging stage of the food supply chain

Cause of food loss and waste	References
Inadequate or defective packaging	[10, 13, 14, 19, 20, 21, 26]
Improper handling and storage at wrong temperatures	[10, 13, 22, 26]
Poor processing and storage operations	[10, 11, 13]
Inadequate demand forecasting and product ordering	[10, 11, 13]
Non-conformance to retail specifications	[10, 11, 13]
Overproduction and excessive stock	[11, 13]
Short product shelf-life	[10, 11]
Product quality (deterioration and diseases contamination)	[10]
Inadequate inventory management	[10]
Wrong labelling	[10]

will wait for transportation to the wholesalers and retailers. Here, the main causes of food loss have roots in: (1) technical inefficiencies, like inadequate packaging, improper handling and storage, poor processing operations, or even wrong labelling; (2) management problems, such as inadequate demand forecasting, overproduction and inadequate inventory management; and (3) intrinsic characteristics of the products, like non-conformance to specifications regarding the weight, size or colour of the products, the products short shelf-life and deterioration of products quality. These causes are presented in Table 3.

Table 4 Causes of food waste in the wholesale and retail stage of the food supply chain

Causes of food loss and waste	References
Expired or near expiry products	[13, 14, 17, 25, 28, 29, 30, 31]
Non-conformance to retail specifications	[13, 28, 29, 30, 31]
Storage at wrong temperature	[4, 10, 13, 17, 29]
Inadequate demand forecasting and product ordering	[4, 10, 13, 29, 30]
Pricing strategies and promotions management	[4, 10, 29, 30]
Inadequate or defective packaging	[4, 28, 29, 30]
Supply chain inefficiencies (lack of coordination and information sharing)	[10, 29, 30, 31]
Product quality (deterioration and diseases contamination)	[4, 10, 14, 29]
Inadequate handling by retailers and consumers	[10, 13, 29]
Inefficient in-store management	[10, 13, 29]

2.4 Wholesale and Retail

This stage includes all activities from the moment the product leaves the processing facilities until the moment a consumer buys the product. The transportation between different stages can be of international or regional nature. The ten main causes of food waste at this stage are summarized in Table 4. The most pressing causes of food waste are the ones related to the products intrinsic characteristics, such as products that are near expiry or expired or the non-conformance to the retail own specifications regarding the weight, size or colour of the products or even the products quality deterioration. The management decisions, like the inadequate demand forecasting, the pricing and promotions strategies and the inefficient in-store management, also generate waste. Lastly, the remaining causes of food waste are technical inefficiencies, except for the supply chain inefficiency. That one relates to the characteristics of the supply chain itself.

Since not one of the previous roots of food waste is related to the transportation of food, and since this activity of the supply chain contributes to the decay of the food products quality [27], consequently contributing to food waste generation, we decided to summarize the top five main causes of waste related to this activity (Table 5). These causes of food waste relate mostly to the inadequacy or lack of infrastructures (e.g. roads or cold chain facilities) and to the large distances to travel.

2.5 Public and Household Consumption

The public and household consumption stage is the final stage of the food supply chain and takes place in food service locations (e.g. restaurants, pubs, hotels, healthcare institutions, etc.) or at private homes.

Table 5 Causes of food loss and waste related to the distribution of food products

Cause of food loss and waste	References
Inadequate transportation systems	[10, 13, 14, 23, 25, 26]
Transportation at wrong temperature	[10, 13, 14, 24]
Lack of cold chain facilities	[13, 14]
Lack of infrastructures	[23]
Distance travelled	[10]

Table 6 Causes of food waste in the public and household consumption stage of the food supply chain

Causes of food loss and waste	References
Oversized meals in food service and at home	[4, 13, 14, 19, 20, 25, 30]
Mismatch with consumers needs	[4, 11, 13, 14, 24]
Over-purchasing	[13, 19, 20, 24]
Poor storage management	[4, 13, 14, 25]
Poor skills in meal planning	[4, 13, 25]
Expired products	[14, 30]
Consumers high cosmetic standards expectations	[13, 24]
Lack of skills for food preparation	[4, 13]
Confusion about date labels	[4, 13]
Inadequate demand forecasting in food service	[4, 11]

In this stage, the scenario is completely different from the previous ones. The reasons why food is wasted move away from management decisions and technical inefficiencies to reasons regarding the consumer's behaviour and decision-making capabilities. The main reasons of food waste (see Table 6) relate to: (1) inefficient planning—of the size of the dishes, of the purchasing process, of the meals themselves or of the demand; (2) mismatch with consumers needs and cosmetic expectations; and (3) poor consumer skills—in food adequate preparation or storage; leaving food past the expiration dates and not knowing how to interpret different date labels.

2.6 Discussion

Some similarities between the classification of the causes of food loss and waste are visible for several stages of the food supply chain. Indeed, the causes of food loss and waste until the retail stage refer mainly to management issues, to technical inefficiencies and to the characteristics of the product. When it comes to the con-

Table 7 Common causes of food loss and waste along the food supply chain

	Stages of the food supply chain				
Causes of food loss and waste	AP[a]	PHS[a]	PP[a]	WR[a]	PHC[a]
Inadequate demand forecasting	✔		✔	✔	✔
Overproduction and excessive stock	✔	✔	✔		
Poor handling and operational performance	✔	✔	✔	✔	
Storage at wrong temperature		✔	✔	✔	✔
Inadequate or defective packaging		✔	✔	✔	
Non-conformance to retail specifications	✔	✔	✔	✔	
Product quality	✔	✔	✔	✔	
Short shelf-life or expired products	✔	✔	✔	✔	✔

[a]AP: Agricultural Production; PHS: Post-harvest Handling and Storage; PP: Processing and Packaging; WR: Wholesale and Retail; PHC: Public and Household Consumption

sumption stage, the causes relate more directly to the consumer's behaviour and its decision-making capabilities.

In Table 7 are show the main causes of food loss and waste that are common to several stages of the supply chain. Even though there are some causes of food loss and waste that are specific to each stage of the supply chain, these common causes are the most pressing ones to be tackled since they impact different stages of the food supply chain, involving different stakeholders, and therefore are most complex problems to solve. Short shelf-lives and expired products is the only cause of food loss and waste recorded for every stage of the supply chain. This is not a surprise since food supply chain management emerged has a hot topic in the field of supply chain management precisely to deal with the perishability characteristics of food products and the complexity of this supply chain [32]. The food supply chain also shares the remaining causes presented in Table 7, even though these were not included in the top ten of one or two stages.

Consequently, to actively fight the problem of food loss and waste, researchers and practitioners should establish multi-disciplinary teams. The work of these teams should be based on concepts of supply chain cooperation [33] and coordination [34] and seek to improve the organization of the supply chain and the visibility of information along its different stages [17], to develop integrated and holistic solutions for the prevention of food loss and waste.

3 Conclusions

This work identified the top ten main causes of food loss and waste for each stage of the food supply chain.

In conclusion, for every stage of the supply chain, with the exception of the consumption stage, the causes of food loss and waste can be attributed to management issues, to technical inefficiencies and to the intrinsic characteristics of the product. In the consumption stage, the causes relate more directly to the consumer's behaviour and its decision-making capabilities. This review also leads to believe that the causes that contribute more to the food loss and waste problem are: (1) the short shelf-lives and expired products; (2) inadequate demand forecasting; (3) poor handling and operational performance; (4) storage at wrong temperatures; (5) non-conformance to retail specifications; (6) the product quality; (7) overproduction and excessive stock; and (8) inadequate or defective packaging. Since these causes are common to larger parts, or the totality, of the food supply chain, then future work in this field should focus on holistic solutions to the food loss and waste problem that incorporate notions of supply chain coordination, cooperation and visibility.

Everyone should keep in mind that food loss and waste represents not only an economic loss for stakeholders but also an environmental burden for our planet and a social problem for the growing population.

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Load Areas-Sorting Methodology to Aid Maintenance on Power Distribution Networks

Flavio Trojan and Danielle Costa Morais

Abstract To perform maintenance, the prioritization of sectors on power distribution networks still has been a challenge for managers and maintenance engineers. It should consider relevant aspects of the sectors, such as population density, the number of hospitals, and the number of schools, among others. In order to guarantee facilities reliability, this paper presents a proposal for this problematic by developing a Load Areas-sorting methodology to improve maintenance decisions on power distribution networks. It uses multi-criteria approach; characterizing criteria and weights. The initial phase of the methodology was concerned with defining of relevant operational criteria, suggested by the literature, as well as admitting new criteria that the decision makers may be deemed necessary in each scenario. The main objective was the obtaining comparison parameters to determine critical Load Areas by the occurrence of failures and allocate these areas in priority classes. An application was performed by collecting data from an electric power company in Brazil. For this application, the classes suggested were: High, Medium, and Low priority. Thus, each Load Area was allocated in a priority status regarding its importance to the company and community. The multi-criteria method used in this phase was ELECTRE TRI. With this development, it was possible to know the most critical area equalizing the decision maker's view and operational indicators. Thus, the maintenance developments can be updated with this methodology, providing sustainability in electricity distribution by adjusted maintenance actions.

Keywords Power distribution networks · Load Areas-sorting · ELECTRE TRI method

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1 Introduction

Over the time it is notorious that people's quality life and countries progress are directly related to the availability and sustainable electricity production. The efficient electric system operation and the correct application of maintenance modes become important factors to promote the progress for present and future generations. Thus, it is necessary that the power distribution is performed efficiently, at the same time considering specific features in each scenario for places and process. In addition, it is inevitable that failures will occur throughout of this process operation, whether caused by natural (environmental) means, or by technical failures. When these failures occur, maintenance requires efficient action plans so that consumer units run out of power down for only a short period of time.

As highlighted by [1], several new optimization methods had been proposed to solve problems regarding electricity distribution networks, but the complexity of this combinatorial issue is high in large systems and the classic optimization methods are failing to address the problem reasonably.

In this sense [2] proposed a general formulation for a Load Area in electricity distribution system, exploring a model introducing an approximation to improve the accuracy of the Load Area representations, and also the relevant reduction of the required information to describe the network. In order to maintain the attendance to electricity demand, the maintenance practices should be the most appropriate as possible. In a city or country, the electricity distribution service is essential to maintain life quality and continuity of operations on organizations. Consequently, the reliability level of these services must be high. Thus, the fractionating is a common technique used to manage services in distribution networks in general, because it is usually used to generate lower tariffs and improvement in the quality of maintenance service. However, there is still a gap related to prioritization of these areas and services demanded. Besides that, in distribution control centers, there is a necessity to fractionate circuits to equilibrate the load demanded. The proposal developed by [3] investigated the possibility of grouping part of a network for monitoring purposes and in another work developed by [4] was introduced an approach which makes a distribution networks modeling in a way similar to the transmission. In this connection, it becomes essential to recognize the elements strictly necessary for the correct and compact electrical system representation. Figure 1 illustrates an example of fractionating Load Area in electrical networks, suggested by [2]:

The Load Areas concept was detailed by [5], and it involves the participation of inhabited areas features and public services, connected to a low voltage grid on the power systems.

The prioritization of maintenance service orders is usually performed considering only one main criterion, which may be: the flowing of entries, emergency conditions or yet another non-technical reference. However, it is necessary to exploit criteria which relate effects on power supply interruptions and the importance of Load Areas.

In [6] was applied a dynamic inoperability input-output model (DIIM) to 101 sectors, including households, of the Scottish economy in 2009 to explore the direct,

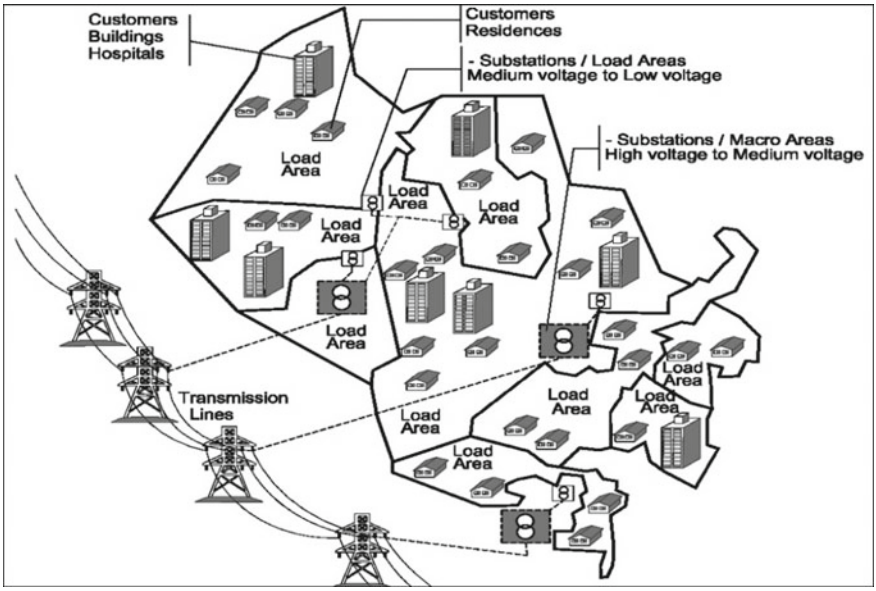

Fig. 1 Distribution system organized in macro and Load Areas. Adapted from [2]

indirect, and induced effects of supply interruptions. It estimated the **Societal Cost of Energy not Supplied** (SCENS) due to an interruption. The theme related with Load Areas becomes important to be studied because it implies in social and economic aspects that reflect in customer's satisfaction and performance measurement of powers companies around the world. It is a decision which impacts in a huge amount of people, their life quality level, and the economy.

To reinforce that, several authors in the scientific literature have been presented discussion and models, involving studies which regard inhabited areas features, public services, and performance. Among them we can cite:

The work carried out by [7] had the purpose of evaluating the electric power company's productivity to detect the least efficient ones. The technique based on Probabilistic Evaluation of Productivity was used, together with two indicators, defined by [8]—SAIFI (System Average Interruption Frequency Index), and SAIDI (System Average Interruption Duration Index). The results identified the power companies with lower values of productivity.

The multi-criteria analysis was used in [9] as a tool to select a power supply system for coastal rural properties located in Rio de Janeiro, Brazil. It was used criteria of different natures, such as equipment cost, environmental impact, useful life, continuity of supply, the useful area available, installation and maintenance, and system efficiency. The areas adopted for the study were residences nearby, distant and in an intermediate position of the network. It was concluded that the further away the residences are from the conventional distribution network, more viable the use of renewable energy sources, otherwise, the use of the conventional grid is more viable.

In [10] were proposed multi-criteria models to support water distribution network maintenance decisions in order to reduce costs and losses. In one of these models, the flow areas were sorting according to their criticality, so that there was a reduction of water loss. The used method to sorting areas was ELECTRE TRI, through data collected by an automated system. As result, it was possible to have a better perception of the most critical classes and the maintenance sector used this information to act speedily in situations that required priority maintenance, consequently reducing water losses and costs. In [11] was studied a model to prioritizing areas, regarding the number of criminal occurrences in a city. The multi-criteria method SMARTS was used in this prioritization model. After the methodology application, it was possible to observe some divergences between the result of the model and the police occurrences records. But, despite this, the model studied did help police officers to act or even show that measures and investments should be taken for public safety. In [12] also was used a multi-criteria model seeking to prioritize tasks in the preventive maintenance area. With this, it was possible to reduce by 80% the divergence among opinions in the maintenance group.

Thus, is evident that multi-criteria tools present efficient results in cases where subjectivity and specific features are present, as well as several factors, that needing to be observed simultaneously, and present conflicts each other [15].

The present work shows the developing of a multi-criteria Load Area-sorting Methodology, which aid to improve assertive maintenance decisions in power distribution networks. In this methodology was structured an elicitation process to collect information from experts on power systems in order to know technical and strategic power company preferences, as well as an opening to include criteria taking to account each scenario, where the methodology could be applied. Also, it was exploited a characterization of each Load Areas to perform the classification.

This development is closer with the digital transformation and Industry 4.0 when it can be incorporated in the automated system of the power companies and providing automatic aid to maintenance occurrences which can be visualized and controlled in the SCADA (Supervisory Control And Data Acquisition) system.

2 Methodology—Developed Methodology

In the framework presented in Fig. 2 is shown the methodology arrangements for this work, presenting steps and interconnections among issues combined in this problematic. In it is possible to visualize the important questions that must be answered and tasks to be performed directing to achieve efficiency for its utilization.

In sorting problematic, each action is considered independently from the others in order to determine the categories to which it seems justified to assign it, by means of comparisons to profiles (bounds, limits), norms or references. Results are expressed using the absolute notion of “Assigned” or “Not Assigned” to a category and sorting problematic refers thus to absolute judgments [15].

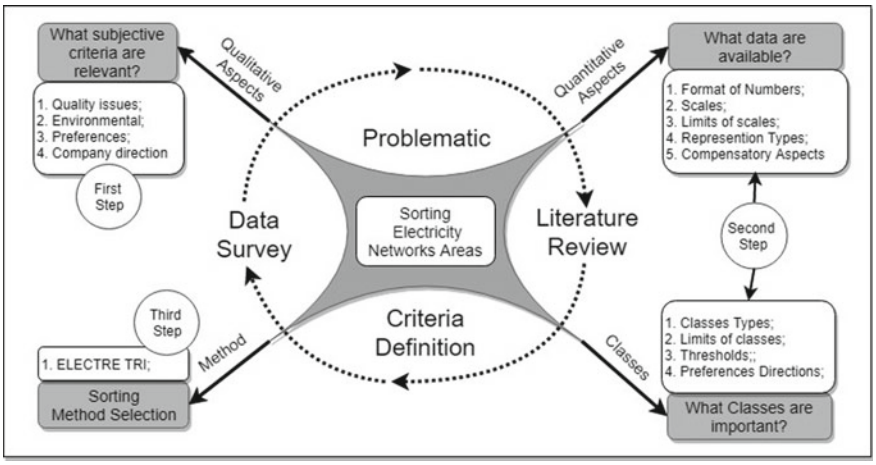

Fig. 2 Framework of the proposed methodology

The **First Step** of the methodology was directed to the criteria definition. It encompasses general criteria; but it is possible to restrict them at the time of use by employing only those that satisfy the decision maker's preferences. There are the qualitative and the quantitative aspects involved, which can be measurable. The aspects for qualitative criteria could be basically energy quality questions, environmental issues and also the company objectives, according to the decision maker preferences.

When assessing the quantitative criteria it is necessary to take into account several factors, such as the format of the numbers chosen. What would that be? Number formatting is basically characterizing the collected data in a way that can be compared between them.

In a **Second Step** was considered the determination of the scale limits, classes, thresholds and normalization of data.

In a **Third Step** was oriented to choosing of sorting method. The ELECTRE TRI method has a non-compensatory aspect, so it is necessary to make this evaluation among the criteria before selecting them for the application. Thus, each criterion will receive a weight orienting evaluation to the sorting procedure. After all these definitions for the criteria, it is necessary to define the types of classes and also the limit among them.

2.1 The ELECTRE TRI Method

As developed by [13] ELECTRE TRI is designed to assign a set of actions, objects or items to categories. This method has been used in a several applications involving allocation alternatives in predefined categories, considering a multi-criteria evalu-

ation with weighted criteria or not. This allocation results from the comparison of each alternative with defined profiles of the limits from the categories.

In this work the ELECTRE TRI method was used with the purpose of Load Areas allocation in classes which represent prioritizing features for technical and social preferences. This method is detailed as follow:

Phase One: Categories definition.
In ELECTRE TRI the categories are ordered; from the worst (C_1) to the best (C_k). Each category must be characterized by a lower and an upper profile. Let $C = \{C_1, \ldots, C_h, \ldots, C_k\}$ denote the set of categories. The assignment of a given action a to a certain category C_h results from the comparison of a to the profiles defining the lower and upper limits of the categories; b_h being the upper limit of category C_h and the lower limit of category C_{h+1}, for all $h = 1, \ldots, k$. For a given category limit, b_h, this comparison rely on the credibility of the assertions aSb_h and b_hSa [13].

Phase Two: Concordance, Non-discordance and Credibility indexes calculation.
This method presents outranking relations S, which validates or invalidates the assertion that aSb_h and (b_hSa), whose meaning is "a is at least as good as b_h". Two conditions must be verified to validate the assertion aSb_h:

Concordance: for an outranking aSb_h to be accepted, most of the criteria should be in favor of affirming aSb_h.

Non-discordance: when in concordance condition is not satisfied, none of the criteria should be opposed to the assertion aSb_h.
In the construction of S it is used a set of veto thresholds $[v_1(b_h), v_2(b_h), \ldots, v_m(b_h)]$, used in the test of inconsistency $v_j(b_h)$, which represents the smallest difference $g_j(b_h) - g_j(a)$ inconsistent with the statement aSb_h. The indexes of partial concordance $c_j(a, b)$, concordance $c(a, b)$ and partial discordance $d_j(a, b)$ are calculated by the Eqs. (1) (2) and (3), [13]:

$$c_j(a, b_h) = \begin{cases} 0 \; if \quad g_j(b_h) - g_j(a) \geq p_j(b_h) \\ 1 \; if \quad g_j(b_h) - g_j(a) \leq p_j(b_h) \\ \dfrac{p_j(b_h) + g_j(a) - g_j(a)}{p_j(b_h) - q_j(b_h)}, \text{ otherwise} \end{cases} \tag{1}$$

$$c(a, b) = \frac{\sum_{j \in F} k_j c_j(a, b_h)}{\sum_{j \in F} k_j} \tag{2}$$

$$d_j(a, b_h) = \begin{cases} 0 \; if \quad g_j(a) \leq g_j(b_h) + p_j(b_h) \\ 1 \; if \quad g_j(a) > g_j(b_h) + v_j(b_h) \\ \in [0, 1], \text{ otherwise} \end{cases} \tag{3}$$

Still, it is calculated an index $\sigma(a, b_h) \in [0,1]$ $(\sigma(b_h, a)$, respectively, which represents the degree of credibility of the assertion in which aSb_h, $a \in A$, $h \in B$, as shown in Eq. (4).

$$\sigma(a,\ b_h) \ = \ c(a,\ b_h) \cdot \prod_{j \in F} \frac{1 \ - \ d_j(a,\ b_h)}{1 \ - \ c(a,\ b_h)} \tag{4}$$

where: $\bar{F} \ = \ \{j \ \in \ F : d_j(a,\ b_h) \ > \ c_j(a,\ b_h)\}$.

After calculating the indices $\rho\ (k,\ b_h)$ *and* $\rho\ (b_h,\ k)$, it is used a cut off level $\lambda \in [0.5,\ 1]$ to determine the preferably relationship with the condition: $\rho\ (k,\ b_h) \geq \lambda \Rightarrow a_k S b_h$. Thus, the higher the value of λ, the more severe are the subordination conditions of one alternative over the border. So with ELECTRE TRI, mainly used in alternative classification problems, it seeks to assign the performance of the alternatives in one of the of predefined performance classes. Two assignment procedures can be evaluated: Pessimistic procedure and Optimist procedure [13].

Phase Three: Classes assignment.
Pessimistic procedure: compares successively with b_i, *to* $i = p,\ p-1,\ \ldots,\ 0,\ b_h$, starting with the first profile such in which aSb_h says to the category $C_{h+1}\ (a \rightarrow C_{h+1})$.

Optimistic procedure: compares successively with b_i, *to* $i = 1, 2, \ldots, p, b_h$, starting with the first profile, such that "b_h is preferable to a " says C_h for category $(a \rightarrow C_h)$. The b_h is the first threshold value such in which $a_k S b_h$ assigns the alternative a_k to class C_{h+1}. If the values of b_h and b_{h-1} are the lower and upper limits from class C_h, this procedure gives to a_k the highest class C_h, such in which a_k makes the value $b_{h-1}\ (a_k S b_{h-1})$. Moreover, the optimistic procedure compares the performance of a_k successively to b_i, $i = 1, 2, \ldots, p$. Being b_h the threshold value such in which $b_h P a_k$, must assign a_k to the class C_h. This procedure assigns to a_k the class C_h, but lower, in which the upper limit b_h is preferred to $a_k\ (b_h P a_k)$ [13].

3 Model Application

3.1 Phase One: Purpose, Criteria and Alternatives Definition

1. *Number of Residences*: equivalent to the number of households fed by the company's low voltage power lines, measured in residential units;
2. *Population*: similar to the number of individual dwellers contained in the delimitation of each Load Area, measured in number of inhabitants;
3. *Area*: represents the area in Km^2 of the sector to be represented. This criterion was considered with the intention of delimiting the physical space where the feeding circuits are contained.
4. *Demographic Density*: represents the urban concentration of residents, relating population with area to physics that represents the Load Area sector;
5. *Affected Consumers*: This criterion shows the number of consumers that were affected within each Load Area, during the referred period, due to maintenance stops, related with SAIFI and SAIDI indexes, measured in number of inhabitants;

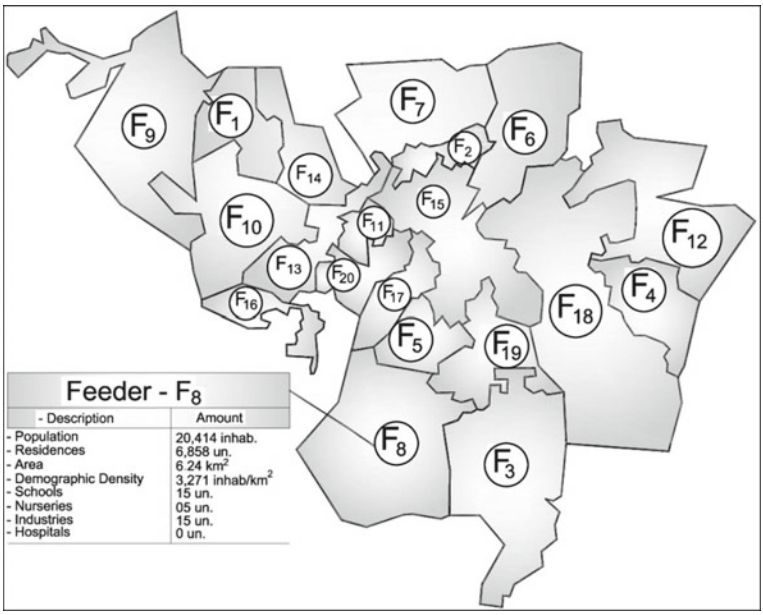

Fig. 3 Thematic map of the studied areas: **Feeders = Load Areas**

6. *SAIDI*: Equivalent Duration of interruption per consumer unit, expressed in hours and hundredths of an hour. Represents the average of the interruption times, necessary to carry out maintenance in the period;
7. *SAIFI* = Frequency Equivalent interruption per unit Consuming, expressed in number of interruptions and hundredths of the number of interruptions. Represented by the average interruptions per consumer unit in the period studied.

Figure 3 illustrates the explored areas from studied case in a Thematic Map:

3.2 Phase Two: Concordance, Non-Discordance and Credibility Indexes Calculation

The data was collected from a Power Company and are presented in Table 1 is the base for ELECTRE TRI indices calculation, related with the defined criteria (g_n), and following guidelines from [14].

Table 1 Data collected from power company in Brazil

Load Areas Feeders	g_1 Residences (units)	g_2 Population (Inhab.)	g_3 Area (Km^2)	g_4 DemDensity (Inhab/Km^2)	g_5 CustomersAff (Inhab.)	g_6 SAIDI (minutes)	g_7 SAIFI (units)
LA_1	1,000	3,000	461.54	6.50	71	128.4	3
LA_2	979	2,936	440.84	6.66	15	24.9	1
LA_3	7,915	24,779	68.86	359.86	1	1.7	0
LA_4	1,034	3,102	517.00	6.00	0	2.0	1
LA_5	2,760	7,548	3.78	1,996.40	239	7.9	1
LA_6	4,640	13,107	3.44	3,812.49	358	2.0	1
LA_7	7,738	24,968	16.62	1,502.24	931	38.5	3
LA_8	6,858	20,414	6.24	3,271.78	565	26.1	1
LA_9	295	886	161.09	5.50	21	18.3	1
LA_{10}	1,505	4,514	186.58	24.19	6	6.1	0
LA_{11}	6,338	12,325	2.34	5,265.87	539	33.3	3
LA_{12}	7,243	22,211	9.17	2,422.09	170	81.2	3
LA_{13}	9,132	28,386	12.89	2,201.90	1,775	52.4	3
LA_{14}	6,680	19,656	4.57	4,296.53	1,121	40.1	3
LA_{15}	7,778	22,393	12.67	1,767.81	1,055	8.3	2
LA_{16}	5,168	16,639	12.18	1,366.27	559	38.8	2
LA_{17}	3,173	9,229	3.11	2,967.95	461	32.4	2
LA_{18}	15,087	44,450	16.42	2,706.92	7,881	73.9	3
LA_{19}	2,815	8,545	3.40	2,514.17	114	2.6	1
LA_{20}	7,159	23,166	17.86	1,297.20	1,189	121.6	3
Sum	105,297	312,254	1,960.6	37,798.33	17,071	738.5	36

3.3 Phase Three: Class Assignment

According to the necessities of the company, were pre-established classes called: High Medium and Low priority. It was performed in accord with the decision maker (an expert of the company), which defined the better way to analyses these establishments in their point of view. Each class represented the orientation for a set of actions that will be performed in accord with the sorting results. Table 2 shows each class with their respective limiting profiles. Table 2 present the criteria weights definition, through an elicitation process.

All the directions of preferences were considered with maximization objectives by the fact that the Load Areas allocated in High-priority class must have maximum values in every criterion even Customers Affected, and SAIDI/SAIFI indices, in order to concentrate efforts in maintenance improvements.

Table 2 Parameters for the boundaries between classes

Classes/ Boundaries			Criteria						
			g_1	g_2	g_3	g_4	g_5	g_6	g_7
CL_1	High	b_1	7,000	20,000	70	4,000	1,500	40	1
CL_2	Medium								
		b_2	5,000	15,000	50	2,500	500	25	0.5
CL_3	Low								
		b_3	3,000	5,000	20	1,000	300	10	0
Weights			0.10	0.10	0.10	0.15	0.15	0.20	0.20
Preferences directions			↑Max	↑Max	↑Max	↑Max	↑Max	↑Max	↑Max
Limits	*Preference*		2,000	5,000	20	1,200	300	10	0
	Indifference		1,000	2,500	10	600	150	5	0

In the alternatives comparison with the limits, the judgment in a peer comparison matrix of a single alternative a_k to each limiting profiles was performed based on the data of each alternative as shown in Tables 1, 2. To the application of ELECTRE TRI method it was used the software ELECTRE TRI 2.0a, available in Lamsade (Paris-Dauphine University, Paris, France).

4 Results, Analysis and Evaluations

The comparison was carried out in pairs with the value of each alternative and the limiting profile of each class by ELECTRE TRI software. Thus, class assignment was done, using the pairwise comparisons of the alternatives and the class boundaries. The obtained classification is shown in Fig. 4.

The results compared with the illustration in Fig. 3, denote the possibility of balance in the maintenance power system by the Load Area allocation, while the maintenance actions can be focused in important Load Area, providing a solution for priority maintenance problems. At the same time actions can be focused on priority events and the constant evolution on the identified middle classes, which need improvements.

Thus, the alternatives that presented high complexity in maintenance proceedings, a high concentration of residences and population, as well as high indices SAIDI and SAIFI, were allocated in High-priority class.

For the cut level index used in the method was adopted 0.5, which explain the similar results in the pessimistic and optimistic procedures. If it is necessary a more severe subordination conditions of one alternative over the border, this cut level could be changed. It was that found the results shown in this application were coherent with the reality of the company operations.

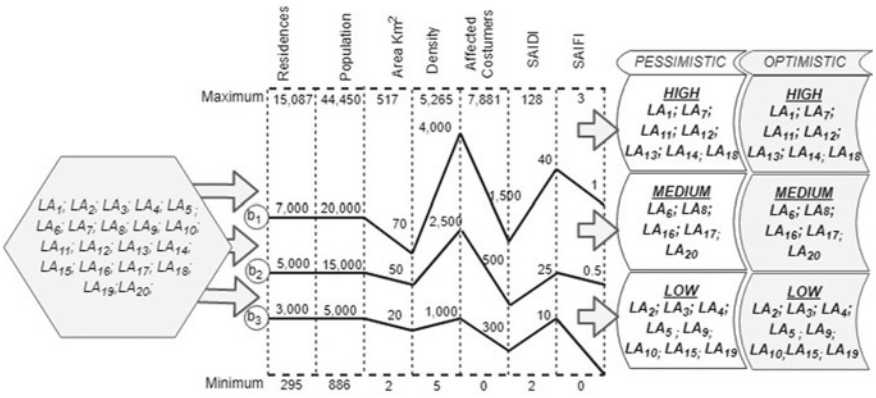

Fig. 4 Results of Load Area-sorting application by ELECTRE TRI method

5 Final Remarks

This study provides improvement on performance to the maintenance management on power companies. It complies with the goal of building a sorting model of allocating alternatives with quantitative aspects at the same time to assist in decision making on maintenance of distribution networks in a power system.

The proposed model reached relevant results in a complex situation of maintenance on power distribution system, in which multiple failures can be occurring. This model can certainly support the maintenance decision-maker, when present a sorting of Load Areas in classes of maintenance priority, allowing reducing problems in power systems distribution, such as: high frequency of failures, execution of correct maintenance actions, automation lacks, monitoring systems, among others. With this support the managers can make more assertively decisions, as there is the tendency for goals to be met in a more appropriate way.

This developed model allows the immediate visualization of priority classes and gives support to the Load Areas maintenance using this information to act quickly in situations that need to meet the priorities of maintenance. The results found in application shown that the areas classified met expectations. The fact of making the preliminary classification of the priorities for Load Areas participation expedites maintenance immediately after the occurrence of leaks or situations that require immediate maintenance on the most important areas from the perspective of the decision maker's preferences.

This study provides a contribution on maintenance management developments related to a new methodology for systems on power companies. Therefore this work complies with the goal of building a classification model of priority alternatives with quantitative aspects at the same time to assist in decision making on maintenance of distribution networks in a power system.

For future works, this methodology could be incorporated in the SCADA (supervisory system) of the power companies in order to orient prioritized actions for maintenance. This classification is a construct to support decisions in maintenance operations and can be controlled by automated systems following closed with some concepts of the Industry 4.0.

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Using System Dynamics for Simulating Mechatronic New Product Development

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Abstract This research aims to propose a model for predicting the time performance of a mechatronic new product development. The proposal consists in a System Dynamics model to support the planning and execution phases of projects by simulating the influence of product complexity and team seniority on project times for a previous defined quality requirement. The proposed model adopts seniority and complexity as the variables to relate time and quality demands of mechatronic projects. To demonstrate the applicability of the proposed model, we tested it on a development project of a medical product: a Retinography device. The results of applying the proposed model made it possible to foresee the development time with a success rate of 100%. Thus, using the model, a given company could use complexity and seniority parameters, based on the project team composition and a list of product components for accurately foreseeing the time a product development project would take.

Keywords New product development · Mechatronics · System dynamics · Project management · Predictive model

1 Introduction

To deal with that increasing complexity of new product development (**NPD**) projects, the knowledge, experience, and capability of team members are positively associated with the innovation dimension of technical performance [15]. In addition, senior project managers are also "an essential determinant of the success of a project" [25]. Complexity has a moderating role in the relationship between functional diversity, team stability and transactive memory system, and performance measurements [12].

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Particularly in new product development projects, the team composition has an influence on project development because of skills developed, educational qualification and professional experience that contribute to the delivery of a high performance product [2, 13, 27].

In this study, we are particularly interested in using System Dynamics to gain an understanding of how future performance is affected by the results of past decisions. System Dynamics is "a perspective and set of conceptual tools that enable us to understand the structure and dynamics of complex systems". It is also a "rigorous modeling method that enables us to build formal computer simulations of complex systems and use them to design more effective policies and organizations" [23]. Moreover, we aim to understand the mitigating effect of team composition in dealing with project complexity.

Mechatronic product development is a vast process of combinations involving many designers, inter-dependent components, and combining hundreds of product development tasks. Given the complexity of the design and development process, it is highly time-consuming [1]. Usually most of the central activities for mechatronic product development are present in the technical planning phase during which the decisions made involve examining the feasibility of the estimated project timeframes and costs, and whatever sub-contracting may be needed. In addition, this phase also consolidates product conceptualization, the abstract models (product architecture), and the analysis of software requirements [3, 4].

In this context, this research aims to model project complexity, team composition in terms of seniority (experience and educational background) and project performance. We proposed a System Dynamics predictive model applicable to the technical design phase of a mechatronic product development process. We tested it by applying the model to the mechatronic product projects of a medical equipment company. The model simulation was compared to the company's actual project data.

We organized the paper as follows. The second section presents the theoretical background followed by the third section presenting the proposed model. Section 4 presents the research design for testing the proposed model's applicability, presented in Sect. 5. Finally, the sixth section presents our discussion and conclusions.

2 Literature Review

2.1 Mechatronic Product Development

The multi-disciplinary field of mechatronics integrates and interconnects Mechanical engineering, Electrical engineering, Control engineering, and Software engineering. Authors suggest that understanding the interconnections of those fields is the basis for conceiving successful products [6]. This approach to systems design and product projects aims to create cheaper products with a certain degree of "intelligence" and "flexibility" to be launched on the market in the least possible time.

In mechatronic product development, designers must fully understand the interdependencies and exchanges of information that occur among the different technical domains and complex dependencies to foresee how the process will respond to future alterations [1].

Barbalho and Rozenfeld [4] developed the Mechatronic Reference Model (MRM) based on phases, each one characterized by a flow of activities that include value aggregation, inputs, outputs and decisions. The phases are defined by the results they generate and involve many activities and specific tasks. The phases are: (1) Defining the strategic objectives to be achieved for each line of products; (2) Defining the product portfolio for each line of products; (3) Defining specifications for each product; (4) Creating the project plan; (5) Conceptualizing the main components and the solution-finding principles for the product's main functions; (6) Elaborating details of the Project Plan based on the defined concept; (7) Elaborating the Technical Design containing technical solutions, components and parts associated to the product's main functions; (8) Optimizing details, analyzing solutions for the product's secondary functions and testing for enhanced robustness and reliability of the product; (9) Verifying the product manufacturing and assembly capabilities; (10) Validating and certifying the product; (11) Launching the product on the market; (12) Monitoring the results obtained with the product and managing any modifications made to the initial production configuration.

The technical design stage in the actual differentiation among a mechatronic development process from NPD for other kinds of products. During it, product designers reach, test and verify technical solutions. As it is a process, MRM requires a verification of activities needed at each stage. It is materialized by means of subprojects that are planned using traditional project management methods such as Work Packages, Gantt Charts, Critical Path Method, sensitivity analysis etc. [21].

2.2 Product Complexity and Team Seniority

Projects involve complex, non-repetitive, technically or logically interdependent activities and must follow a specific pre-determined sequence in order to ensure the achievement of the objective for which the project was created and be in due alignment with the specifications [28].

Project complexity can arise from different sources, the product design or the Project Management (PM) processes [7]. The literature also suggests other sources: technological (integration of the parts, level of maturity), market-based (user needs, competition, regulatory structure), marketing related (user education processes, distribution channels, prices), developmental, organizational or inter-organizational.

In the product perspective, there are three aspects to consider concerning complexity in product development. First, the complexity of the product itself, which concerns the number of product components/parts and the extent of their interaction [17, 1]. Pugh [22] considers the number of components of a product as being the main drive of the complexity of its development. The complexity of a new product devel-

opment project consists also of the number of disciplines involved [16], the degree of innovation embodied in the product, the number of technologies employed and the complexity of integrating the number of technologies involved in the creation of new products [11]. Finally, the customer interface complexity [8, 27], and the degree of interdependence between the product and the technological process, and between project innovation and its organizational development [26] are important issues.

In the 21st century, the problems have become increasingly multidisciplinary and complex. The effectiveness of the problem-solving cycles depends on combinations of hard and soft abilities [7]. The literature also underscores the importance of those two kinds of abilities especially in upstream-downstream integration along the course of the product design [8, 27]. Research has shown how problem-solving capacity is strongly associated to personal qualities such as resilience and sturdiness [10].

Professionals with a so-called T-shaped profile [5, 9, 13] are the category considered as the best suited for short-cycle problem solving. The educational aspect is very important in the reduction of the problem-solving cycles.

Consequently, seniority is another aspect that strongly influences project progress. Seniority means the set of varied qualifications held by the project developer; the capabilities, knowledge and experience that make it possible to distinguish highly capable professionals from those with only average capability, in a given function [13].

Atman et al. [2] compared senior and freshmen engineering students' and observed that senior students have better problem solving abilities spending time more efficiently than freshmen. Classic literature on new product development strongly emphasizes senior product designers as technical leaders of successful projects [18]. Seniority-based research intends to determine what processes and activities distinguish novice designers from expert ones. Research has shown that engineers do not simply progress step-by-step through the design process but instead iterate through cycles of proposal, testing and modification.

2.3 Modelling Using System Dynamics

Forrester [14], and after Sterman [23] and colleagues specially from Massachussets Institute of Technology (MIT) have developed System Dynamics (SD) methodology for modelling and simulating complex systems with a focus in understanding organizational and social problems. According to Forrester [14], System Dynamics can be defined as a study of the characteristics of industrial activities' information, and feedbacks and shows how the organizational structure, amplifications (through policies) and delays (in decisions and actions) interact to influence the success of a venture. System Dynamics is a knowledge field that seeks to identify the general characteristics of systems with dynamic complexity, based on the behavior patterns among the parts of the system and the structure that determines those patterns [23].

Based on General Systems Theory, system dynamics is a methodology connected to systemic thinking that seeks to understand the structures of social and organi-

zational systems by means of representations of the causal relations among their elements and by studying their evolution in the course of time [14]. It seeks to explain the behavior of a given system based on the interactions among the various parts that compose it [14, 23].

It there are two possible approaches available for modelling in SD: Causal Loop Diagrams/Models (soft modelling) represent qualitative relations that occur within a complex system and make it possible to infer the system's tendency to grow or shrink; and Stock and Flow Diagrams/ Models (Hard modelling) represent quantitative relations [14, 24]. Pidd [19] explains that, although it may be interesting to develop diagrams, they are often just one of the steps in an investigation of the dynamics of a system. To move such an investigation forward, someone need to transform diagrams in such a way that they can be calculated as a set of equations and hence a dynamic simulation can be based on them.

Sterman [23, 24] proposes for hard modelling a language made up of just four elements: stocks (levels) which represent the accumulations of a resource; flows, which are activities that lead to stock increases or depletions; converters, which process information regarding stocks and flows or represent sources of information external to the system; and connectors, which are nothing more than information links that describe relations among stocks, flows and converters.

This paper suggests a predictive model based on system dynamics theory for estimating timeframes of development projects for complex products by means of a post mortem evaluation of projects of a given company. Next section presents the methodology to achieve that end.

3 Methodology

This study emerged based on the application of the hypothetical-deductive model or method. Popper [20] proposed that the route of this methodological trajectory should embrace the stages of the study of existing expectations and theories for the formulation of problems associated to theoretical and empirical issues. After, we propose solutions consisting of a conjecture and deduce the consequences in the form of propositions suitable for testing the investigated phenomena. Then, we must did falsifiability tests embracing efforts to refute the hypotheses created in regards to the phenomena under investigation by observation and experimentation and other means.

Based on the literature presented in the previous section, we constructed a logic model relating complexity, seniority and project performance according to the system dynamics theory. We simulated it theoretically for delimiting its contexts to gain an understanding of how the output variables behave in relation to inputs. After that, we applied the model to a real case of mechatronic product development. We gathered the necessary data on complexity and seniority from a company that supplied its personnel control records and those of the product structures of the equipment analyzed in this research. Data analysis and validation made use of interviews with the person

who was the project office manager at the time the product development. The request to supply data was made to the directors of the Research and Development Department. Other project members involved in the development of the analyzed product were contacted to validate information supplied by the office manager whenever it was considered necessary.

The Vensim®PLE software was use of to develop the proposed model and data analysis used Matlab and Scilab 5.5.2 software.

4 Proposed Model

An analysis of the reference model for developing mechatronic products [4] shows that the technical design phase is the most complex and time-consuming stage as it has to produce technical solutions for the product's main functions. During it an assessment is made of the engineering design's primary functions to ensure they comply with the product specifications and it may be conducted either in the sphere of the main product development process or of its sub-systems, according to the complexity of the design.

Figure 1 presents a more detailed model of this stage developed. In this model there is an input point (1) defined by the project's technical specifications and by the project's technical plan. There may then be some incorporation of new technology (2) to product design or an existing technology (3) may be used to develop the product's basic engineering design, the control system design, communication and micro-processing design, electronic design and the high-level software design. Once the designs have been specified, off-the-shelf materials and components are acquired (4) to then develop and test the Alpha prototype of the product (5). After completion of all those steps comes verification of the technical design results (6) and finally due documentation of the technical solutions (7).

One of the most important stages in the technical design phase is stage (3) dedicated to developing the mechatronic product design. In it, some important aspects of the project need to be done. The basic engineering design of the product, which sets out the details of the product concept for its main function, and the control system design, which integrates the control design with the control system. The communication system is also implemented by means of the electronic design which in turn, depends on the control strategy that is adopted. The control systems are implemented by means of the software components of the micro-processor/micro-controller; and the high-level software design produces the codes that implement the functions that were defined by the software requirements analysis, especially those concerning the product-customer user interface.

Figure 2 displays the stage three of the technical design in detail. It should be noted that there is a simultaneous engineering cycle for each project developed in the stock. All the projects need to be finalized in order for the flow to proceed and pass on to the next stage of the stock (4) which is that of acquiring off-the-shelf materials and components.

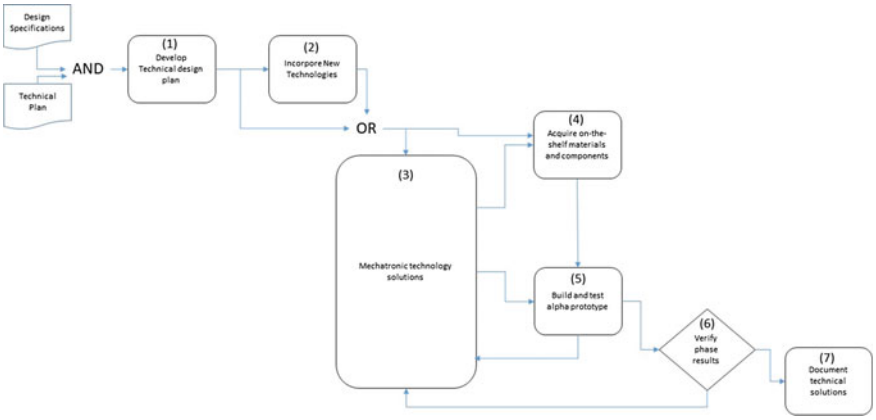

Fig. 1 Model of the technical design phase

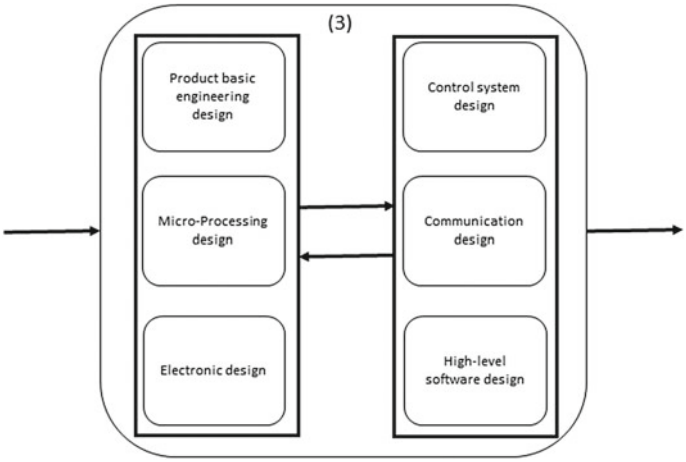

Fig. 2 Simultaneous design cycles: stage 3 of the technical design phase

A basic assumption we did is that complexity of the mechatronic product leverage NPD timeframes in technical design phase more than in any other activity of the project as a whole. And the cycles represented by Fig. 2 are the seed of all NPD complexity of these products. As the literature review revealed, in addition to the simultaneous cycles, two variables—complexity and seniority—strongly influence project execution. Many projects are highly complex and require a high level of seniority in order to develop them in less time and in compliance with the desired quality standard. Therefore, a model that involves complexity and seniority as critical components in technical design phase will have predictive potential for the results of the project.

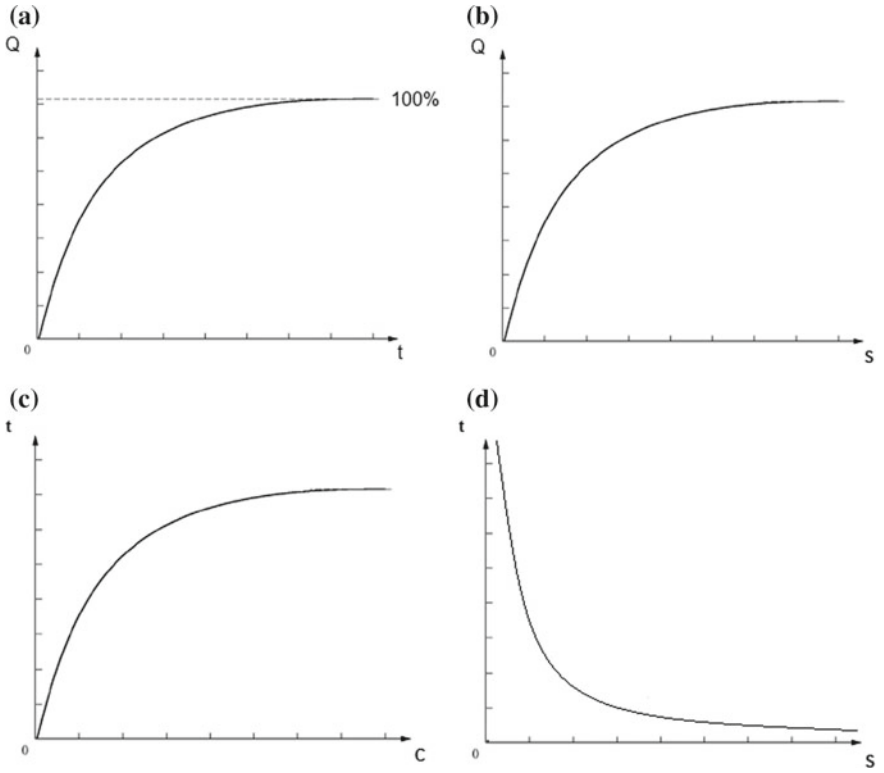

Fig. 3 **a** Quality as a function of time. **b** Quality as a function of seniority. **c** Time as a function of complexity. **d** Time as a function of seniority

Based on previous discussion, we can state that the time needed to achieve a given project quality standard is directly proportional to the complexity and inversely proportional to the seniority for any given time of execution. That is to say, the greater the complexity of the product, the more time needed to achieve the specified performance standard. On the other hand, the greater the seniority of the design team, the faster that standard will be achieved.

In general, the time-quality relationship in a project can be described by the mathematical relation that Sterman [23] calls "goal seeking" in which positive feedback loops generate growth, amplify diversions and reinforce changes whereas negative loops tend towards equilibrium and the negative feedback loops have the effect of bringing the system closer to a given goal or desired state. Our model suggests that, having the detail illustrated in Fig. 2 as a black box, if we have product complexity and team seniority of a specific new product effort, these variables can be helpful for understanding mathematically the relation between quality and time in a project.

Figure 3 illustrates the mathematics that Sterman [23] suggests for "goal seeking", which shows the impacts of the variables in discussion here on the project results.

Figure 3a exhibits the relation of Quality (Q) to project time (t). The more complex the design, that is to say the stricter its quality requirements are, the longer it will take to be executed. Figure 3b shows the relation of quality to seniority (S). The greater the degree of the design team's seniority, the higher the quality standard that will be achieved in a given period of time. Figure 3c illustrates the time versus complexity (C) relation: the greater the project complexity, the more time will be needed to conclude it for a given team and quality standard. Finally, the graph in 3d shows the relation between time and project team seniority. The higher the seniority level of the professionals involved in project development, the less time the team will consume to achieve a specified product quality standard.

Analysis of the graphs shows that it is possible to achieve excellence in less time even when the degree of design complexity is very high. Addressing that issue requires that the professionals involved in design execution should have a high level of seniority.

Based on the definitions set out in Sect. 2 of seniority (S) and complexity (C) and on the modelling of the "goal seeking" based on the first order system response equation for a step input, defined here as being the desired quality standard, we have:

$$c(t) = 1 - e^{-\frac{t}{\tau}}, \text{ for } t \geq 0 \tag{1}$$

where τ is a constant. Initially for $t = 0$, the answer $c(0) = 0$. On the other hand, $t \rightarrow \infty$ implies that $c(t) = 1$. In $t = \tau$, $c(\tau) = 1 - e^{-\frac{\tau}{\tau}} = 1 - e^{-1} = 0.632$, that is, $c(t)$ attains 63.2% of its total value. It can be seen that the lesser the value of the constant τ, the faster the system responds.

Thus, we can write an equation for stage 3—Simultaneous phases of the Technical Design—in which the quality of the design is described as a function of the time of execution:

$$Q\ (t) = 1 - e^{-\frac{t}{\tau}} \tag{2}$$

In this Eq. (2), project quality is defined as a function of its time of execution. The time (t) is measured in months and the constant τ is defined by:

$$\tau = \frac{C}{S} \tag{3}$$

where C is the complexity and S the seniority.

5 Application of the Model to a Real Case

We test the model for one mechatronic product of a company that manufactures products for the fields of medicine, defense and space. The company was founded in 1985 and is a reputable High-Tech manufacturer located in a technological pole in

Table 1 Normalization of seniority

Seniority value	Qualification level	Seniority value	Experience
25	Technical Diploma	25	1–5 years
50	Degree	50	5–10 years
75	Masters	75	10–20 years
100	Ph.D.	100	Over 20 years

São Paulo, Brazil. Its trajectory began in the University of São Paulo as researchers and technical personnel of the Physics Institute founded it. Currently it has over 300 employees distributed among its headquarters and four sites in Brazil and United States.

The product analyzed were the *Retinógrafo ADS* (ADS Retinography device) a piece of equipment that enables the doctor to photograph the patient's retina in order to diagnose eventual lesions or detachment of the retina, macular dysfunctions of the optic nerve or even glaucoma.

The complexity of the system was calculated as the quantity of components in its bill of materials. To specify seniority, a system of awarding points was used to specify degrees of qualification and professional experience for each person (designer) working on the project, taking into account Dyer et al. [13] proposal that there is a considerable difference between the professional with an average capability and the one with a great capability, when they are allocated to innovative project teams. The maximum points attributed to an individual never go beyond 200 points even when all the elements of academic qualification and experience accumulated over the years are taken into account.

We calculated the value for seniority for applying to the model as the simple arithmetical average of the total seniority. Table 1 shows that normalization of the seniority values used in the research.

The results of applying these calculi for complexity and seniority to the product being analyzed were: for complexity—basic engineering parts, 601 components; control systems—240; communication only parts—9; microprocessing control—14 elements; hig-level software—31 pieces of software. The whole complexity was summed 895. For seniority, the following data was gathered: five designers ranging from 1–5 years to 5–10 years, and from graduate degree on engineering to a master engineering degree. The sum of seniority were 450, and its average were 90. We obtained the Graph displayed in Fig. 4 by applying these values in Eq. 2, with the help of Scilab 5.5.2 software.

To plot them, the value of τ, given by $\frac{C}{S}$, was calculated for the Retinography device based on the data set out in Eq. 3, as follows: $C = 895$ and $S = 90$, thus, $\tau = 9.94$.

The respective values from Eq. 2 under these values show that we achieved 100% of the goal-seeking model on 53 months, the exact value gathered from company to the real product development effort, considering its launch time from the beginning of the project.

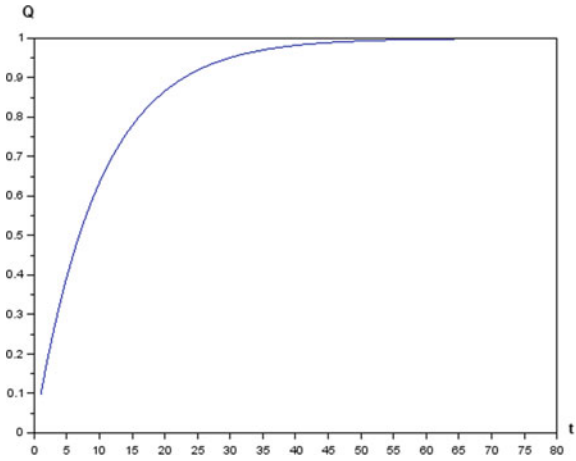

Fig. 4 Relation of quality to time for the retinography device

6 Conclusion

This study contributes to the prior literature by proposing a research model relating project complexity, team seniority and project performance, applying System Dynamics modelling, specifically a first-order linear system, according a "goal seeker" behavior. Only one application was did, but its results made it possible to foresee the development time with 100% success.

More research must be done, but these results suggest using the model, a given company could use complexity and seniority parameters, based on the project team composition and a list of product components for accurately foresee the time the NPD project would take.

This study incorporates limitations and require more in-depth studies in the future. The model was only calibrated for a single company and a single product. We find more products must be analysed to verify if these results persist in the Company. Finally, more companies must be analysed for understand the differences between the model results among them, or verify if the model maintain its good results.

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Lean Manufacturing Application Analysis in the Inventory Management of a Furniture Industry

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Abstract The current context of the furniture industry is represented by a competitive and demanding consumer market and the consequent need for modernization and implementation of methods and tools that contribute to a lean and efficient management, cost reduction and an increase of quality and productivity. This research aims to analyze the results obtained with the application of Lean Manufacturing in the inventory management of a furniture industry. A qualitative research strategy was adopted, in two phases, initially a literature review, followed by a case study in a Brazilian furniture company. The use of Lean Manufacturing principles, techniques and tools such as Value Stream Map, organization of productive process with *Kanban*, levelling of production with *Heijunka*, and percentage of inventory accuracy calculation helped significantly the company to identify and eliminate waste that was affecting process performance. Results were positive with an eight times reduction of the finished product inventory (almost 88% reduction) and lead time two and a half times smaller in the administrative management flow of inventory, even with addition of processes and people.

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Keywords Lean manufacturing · Inventory management · Cost reduction · Waste elimination · Furniture industry

1 Introduction

The Brazilian furniture industry remains competitive in the domestic market. In recent years, its production showed positive performance [1], with alternating periods of growth and decline. The globalization of markets, increased competition, greater need of products diversification, constant improvement of operational efficiency and high competitiveness have made companies, producers of goods or services, to seek for new alternatives to ensure their survival in the markets in which they operate [2].

In this context, companies in the furniture industry are seeking for new work techniques to guarantee quality, greater productivity and lower costs. Waste in companies generate bad consequences for business, that is, when more resources than necessary are spend in the production of goods or for the supply of a service, the competitiveness and financial health of the organization might be harmed.

This situation can be avoided if the business considers sustainability governance, a mechanism that aligns strategies with stakeholders's expectations, focused on economic, environmental and social aspects, which are translated into processes and/or projects to assign and fulfill responsibilities within the organization [3].

Therefore, the application of techniques that aim to improve processes plays an important role, such as Lean Manufacturing, a management philosophy inspired by practices and results of the Toyota Production System, created to meet the needs of an industry automaker seeking to increase productivity and efficiency, avoiding waste. It is a knowledge whose essence is the ability to eliminate waste continuously and solve problems in a systematic way. There are few studies dealing with the application of Lean specifically on inventory management of companies in the furniture sector, which reinforces the importance of this work, whose aim is to complement the scarce available literature, describing the good results achieved by a Brazilian company in the furniture sector, which adopted lean manufacturing in inventory management.

2 Material and Method

In contrast with research strategies that are based on data collected at first hand (experimental, surveys, field studies), the available data researcher mines second-hand information [4]. This study adopted a qualitative approach, using available data, starting with a systematic literature review in four steps, based on the PRISMA [5] method (Table 1), filtered for "articles or reviews" until April 30, 2018.

In addition to the 6 studies from scientific databases, 4 books used by one author during her production engineering specialization course were also included in the literature review, totaling 10 sources of information, presented in the next section.

Table 1 The four steps of the PRISMA method

Database	Search sentence	1. Identify	2. Screening	3. Eligibility	4. Included
Exclusion criteria			Duplicated registers (# 1)	Text, method or authors not available (# 4)	Full-text not aligned with this work (# 0)
Scopus	Lean AND furniture AND inventory	6	10	6	6
Web of Science		3			
SciELO	Lean AND furniture	2			
	Total	11			6

The second work stage was developed in the company, through a case study, whose main features are [6]:

- Selection of a single case of a situation, person or group of interest or concern;
- Case study in this context;
- Collection of information through a variety of data collection techniques including observation, interview and documentary analysis.

The collection of information was accomplished through informal conversations with managers at their job site, in addition to ERP database queries and reports analysis of the company. From the information gathered, it was defined that the area for applying Lean Manufacturing would be the inventory management of finished product, specifically the administrative management flow and not on the factory floor.

Then, the current state of the value stream map (VSM) was drawn including all involved processes, with the aid of employees from the company. In sequence, after analysis and identification of opportunities for waste elimination, a VSM of the future state was developed, to be deployed with the application of Lean Manufacturing principles, techniques and tools. Results measurement was accomplished through performance indicators and testimony of those involved in the process.

3 Background

3.1 Inventory Management and Furniture Industry

The inventory is composed of assets acquired or produced by the company in order to market or use in its productive activities.

For agile production it appears essential that an on-line, real-time data capture system provide the status and location of production lots, components, subassemblies

for schedule control. Current status of all material inventories and work in process is required to develop schedules with frequent changes [7].

In general, the products of handmade wooden furniture are manufactured in order of arrival. The companies have a certain amount of raw material in their inventory as safety stock. The fact that companies do not have inventories control, among others, is considered a weakness. In addition, there is not measurement from indicators of quality, flexibility and value. The importance of "buying or having only what is necessary, at the moment it is necessary", is mentioned by [8], the aim is to eliminate intermediate manipulations and reduce inventories. Several companies of the furniture industry benefits from high levels of inventory, to confront a crisis period without having the need to make investments in the production of most of its products. In this way they can dispatch the product requested by the client, with adjustments of small pieces of products, through exchanges between volumes with similar characteristics. In these cases, the high level of inventory is seen as a benefit, and can be turned into revenue to increase the capital of the company and keep it running.

3.2 Lean Manufacturing

Lean manufacturing is an approach that allows to improve the way how the company organizes and manages the relationship with customers; the supply chain; the development and manufacture of its products, seeking to generate higher outputs with fewer resources [9].

Lean, a management philosophy focused on creating customer value while eliminating waste, can help small enterprises improve their performance [10] in lead time, on-time delivery, inventory turnover, cost per unit and sales per employee. Lean is practiced by leading companies in the wood products and furniture industry [11].

Waste reduction brings the following benefits [12]:

- Increase or improvement of flexibility, quality, safety, ergonomics, employee motivation and ability of innovation;
- Reduction of cost, need for space and job requirements.

Value stream map (VSM) is a tool of Lean Manufacturing, which contributes to reduce lead time of the production process, and minimize waste time and raw material in the furniture manufacturing process [13].

The concept of Kanban is the 'operationalization method of the pulled planning and control system', by performing the control of materials transfer between the different stages of the production process [14]. The word Kanban, of Japanese origin, means card [15], because Toyota uses cards to manage the flow of materials in the factory. The Kanban system is the closest to Just-In-Time (JIT), because it pulls the production, which is released after being authorized, depending on the conditions of the factory and product demand. One JIT oriented company continually tests the production system with smaller lot sizes per kanban and fewer kanbans cycling

through the operations [7]. This drives the Work in Process (WIP) inventories down, reduces the floor space required and encourages continuous improvement in the processing, movement and quality of the products.

Uniform factory load is an element of JIT that incorporates two thoughts "cycle time", which refers to the rate of production and the "level load", which refers to the frequency of production [8]. Heijunka is the leveling of production in volumes and mix, with the goal of creating stability, basis for flow analysis, standardization, use of Kanban and better quality control. The goal is to dampen demand changes to enable the more regular as possible manufacturing environment, with the production of various models, in amounts that meet the requests. Heijunka alleviates the 'bullwhip effect', where a small change in customer demand can trigger major changes in suppliers. The adoption of Heijunka requires the company to rethink how it should buy from the supplier, how to design the machines and tools, how to develop work processes and how to plan teams, creating flexible processes.

4 Case Study

4.1 Productive Process Context

The company, object of this study, hereinafter referred to as Brazilian Furniture for reasons of secrecy, is a traditional furniture industry of a city in the interior of Minas Gerais, Brazil, created by a cabinetmaker in 1980. With a development policy based on reinvestment of capital in the own company, it grew, expanded markets and also its product line, presenting solutions to meet the needs of its customers in Brazil and abroad, currently producing furniture for kitchen and bedroom.

The company operated for a long time with high levels of inventory, raw materials/inputs and mainly finished products, focus of this research. It currently works with product inventory following the pushed production principle, but intends to adopt pulled production. Inventory levels are still considered medium for some products of greater demand, to respond more quickly to customers' orders with products that have more turnover. As the demand for a certain product reduces, its production will be reduced on account of production leveling (Heijunka) until when it becomes obsolete and so out of line, with very low or zero inventory.

Brazilian Furniture has modern equipment with structured production in six sectors, being shipment responsible for the finished goods inventory, object of interest of this study. The production process of the finished product inventory management begins through Production Planning and Control (PPC) with the generation of the production need, where the used Enterprise Resource Planning (ERP) runs a process that identifies the demanded items to production from the equation:

Demand items = *inventory* + *open production batches* – *requests* (1)

The system suggests the quantity to be produced from parameters placed inside the product register, such as minimum and maximum inventory. From this analysis the

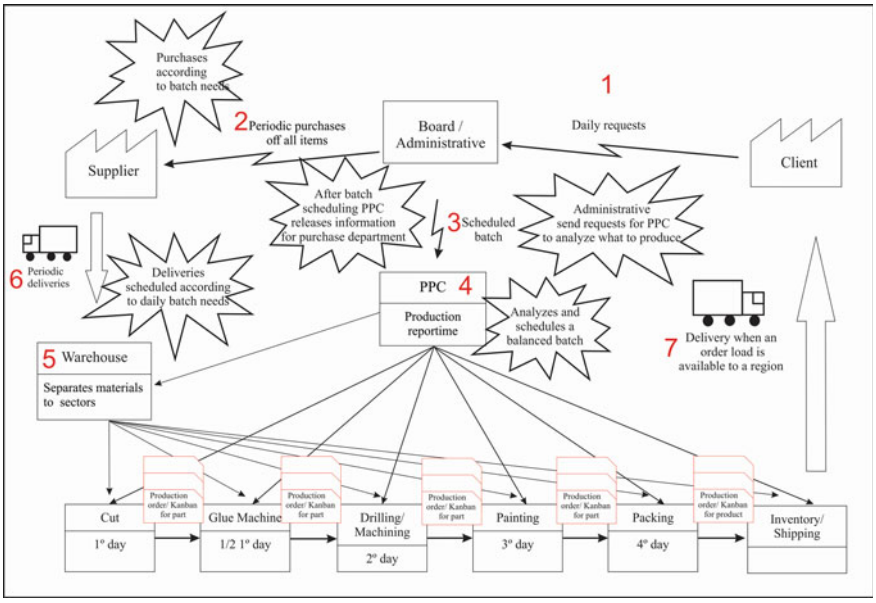

Fig. 1 Value stream map of Brazilian Furniture—current state

Manager makes the decision of what will be produced, always leveling production and trying to keep low inventory. Once started, the production follows by sectors that will receive its production orders and Kanbans to perform the batch always with minimal waste and with organized processes for optimization of the whole.

Initially, the proposal of application of Lean Manufacturing tools at Brazilian Furniture will be presented, based on a literature review, followed by an analysis of the results between January 2015 and October 2017.

4.2 Results and Discussion: Application of Lean Manufacturing Tools

Value stream mapping. In order to identify waste in Brazilian Furniture, the Value Stream Map (VSM) of the current state was initially drawn (see Fig. 1), showing in the same diagram the client, suppliers and main processes involved, as well as improvement opportunities in 'kaizen explosions'. The 'overproduction' has been identified as the main waste, which brings as largest consequence an increased inventory of finished products. The VSM of the future state (see Fig. 2) shows the improvement proposals for elimination of the identified waste.

Table 2 presents a comparison between the current and future state of the administrative management VSM of Brazilian Furniture's inventory.

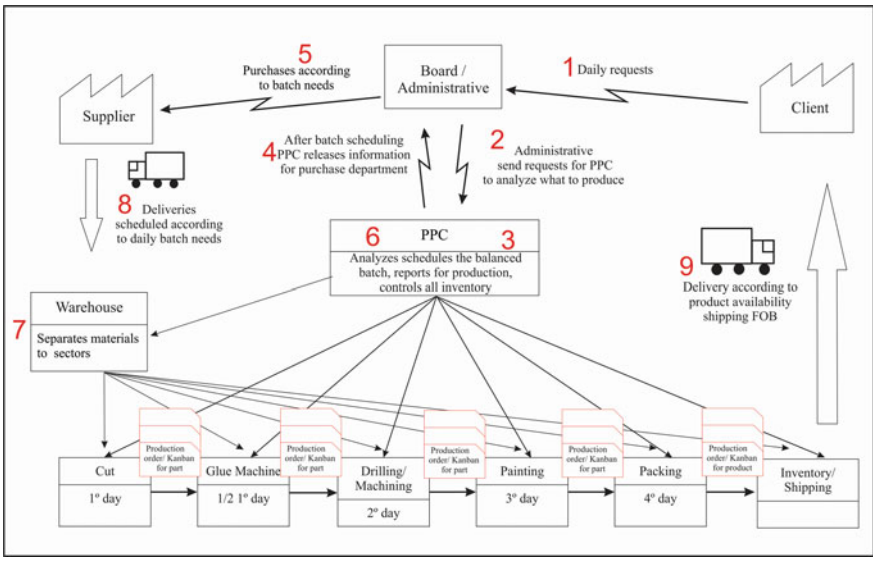

Fig. 2 Value stream map of Brazilian Furniture—future state

Table 2 VSM comparison of inventory management

VSM	Processing time (hs) value-add	Wait time (hs) not value-add	Lead time (hs)	Complete & correct flow (%)	# Process	# People
Current	6.5	1524	1530.5	76	7	5
Future	7.5	600	607.5	84	9	6

It is interesting to note that despite the increase in processing time of the administrative management of the inventory in 1 h, adding 2 more processes in the VSM and 1 more person, there was a big drop in the wait time (waste) and, therefore, the lead time (reduction of 2.5 times), as well as an increase in the effectiveness of the stream (% correct and complete). This is particularly important because it shows a finding contrary to common sense, that Lean usually leads to a work force decrease.

Identification of Waste. As a result of a history of high demand products, absence of restrictions like low inventory of raw material and immediate availability of resources to acquire it, the choice was always to produce to have no problem with shipping loads, in order to meet customer demands more quickly.

Production anticipation is one of the causes of the 'overproduction' waste, i.e. producing to store products with high demand in an attempt to maintain high levels of customer service, operating the plant with a maximum capacity of use of resources and anticipating the future demand in the form of inventory. No efforts are developed to balance the capabilities or to eliminate the variability, because the interest is to operate all the time at maximum capacity. In this case, the pace of production is

dictated by the excessive capacity of the first process that pushes the production towards the successive processes, resulting in higher inventory than necessary.

Most customers are shopkeepers who buy products for resale to final consumers, thereby increasing the distance in Brazilian Furniture's value chain to the final consumer. This makes the company to suffer from the so-called 'bullwhip effect', with high levels of inventory based on demand variation. When the final consumer give signs that doesn't want more a type of product, the retailer stops buying the product because it isn't having output in his store. If the plant inventory is high and there isn't time for this inventory to dissolve, the plant will suffer with a high level of inventory of a product that is no longer current, a given product determined obsolete by the shopkeeper client, the one that buys the products of Brazilian Furniture.

A consequence of this overproduction is the unnecessary use of resources such as raw materials, space in the factory shed, man hours, machine hours, resources that could be destined for other functions, such as investments, benefits, between others. The anticipation of materials and services purchase is one of the consequences of overproduction. Even not representing revenue and profit for the company, a new value needed to be assigned for these purchases, which at a time of financial crisis in the country and specifically in the furniture sector, was pretty hard to get.

Pulled system, Kanban and inventory management. Considering that Kanban is a system that pulls the production, targeting control to ensure just-in-time production, it was proposed the application of the production Kanban card containing information about type and quantity of the product, work center (also called operating station) to perform the operation, code and description of the part/product with their necessary materials. The production process steps of the batch are: (1) Reports generation; (2) Cutting plan preparation; and (3) Printing of production orders (production Kanbans).

The definition of the batch to be produced starts the generation of reports for the entire factory to carry out the process: the operating station orders report (parts list which the operating station must run) and the materials report (grouped list of all raw materials needed to produce the product group contained in the batch) to be separated by the warehouse and delivered to each operating station. These reports contain pre-established information from each product registration in the Enterprise Resource Planning (ERP) in order to eliminate waste.

With the information generated by the Production Planning and Control (PPC), each sector receives the report group that it will use to perform the batch, separated by the equipment contained therein. The cutting sector receives, in addition to the report of parts to run, the cutting plan and the production orders or production Kanbans, as referred to in this study, which will accompany the pieces across their path in the production until they reach the packaging sector. The packaging sector receives production Kanbans of finished products, which will be formed on the fourth day when the component parts arrive to the sector. With the product Kanbans, the parts are gathered and product volumes are assembled. After properly packaged and identified by labels, they are directed to the warehouse where the barcode labels are read to give input on physical inventory and in the system.

Table 3 Proposed indicators for inventory management

Indicators	Description
Demand attendance	Percentage of satisfied demand for a inventory supply cycle (time it takes to produce the same product again and replenish its inventory), obtained by analyzing the amount of requests that arrived and were not immediately met
Inventory turnover	Number of times the capital invested in inventory is retrieved through sales. On physical analysis, means the amount of times the average inventory was sold or consumed and needed to be reset, i.e. its turnover
Inventory accuracy	The physical values of inventory should be the most like possible of their records in the system. The use of the system indicates the degree of precision of the inventory in meeting the demands, it's the quality and reliability of the existing information in the Enterprise Planning Resource (ERP) control system versus the existing inventory in the physical space where it really is. It can be calculated from the analysis of the physical inventory count through the barcode with collectors, contrasting with the info on the inventory in the system. The accuracy is calculated from the amount of differences in the amount found of inventory (tool available in the company's ERP). The closer to 100%, better is the percentage of certainty in the inventory

Using indicators in inventory management. The ideal inventory control is one that balances the minimum size required to meet the demand of the item on time, on site, in the desired quantity and without inventory shortages, having cost of obtaining, maintenance and preparation of orders at an optimum level of service. The inventory can represent 20–60% of the assets in the balance sheet [16], i.e. fixed assets that generate waste and saddled the financial health of the company. The proposal for Brazilian Furniture was the use of indicators (Table 3) to analyze, measure and track results, correct any deviations and improve its inventory management process.

Production leveling and inventory management. The Heijunka technique of production leveling by volume and mix was proposed to be applied in Brazilian Furniture, in order to be able to meet customer demands without having to increase the inventory of product and/or raw material. Every time a production batch with large volume of a product was placed, a high demand of the necessary raw materials was generated, forcing the company to always have large amounts of materials stored in the warehouse, i.e. stopped money. Due to a large and varied portfolio of products, some with similar production characteristics (usually products of the same line) and others less so, the company had difficulty to produce a varied mix in a single batch, which often caused the placement of volume instead of product variety in the batch.

The normal procedure of the company was to make the analysis of the production necessity every day through the management system. The proposed change was in the analysis of 'what' to put in the batch and in which 'quantity ', with the goal of producing only what is necessary for that moment and doing next day a new point-in-time analysis. In this way, the day requests would be served every day, without generating delays for the client, without elevation of the inventory nor need of large

Table 4 Waste, problems and proposal of Lean Manufacturing tools

Waste	Problem	Recommended lean solution
Overproduction	• Large production batches • Production anticipation • Bullwhip effect • Unnecessary resources occupation • Materials purchase anticipation	• *Kanban* (pulled production) • *Heijunka* (production leveling) • Value stream mapping (VSM) • Quality tools (use of indicators)
Inventory (in excess)	• Unnecessary resources occupation • Occupation of storage space • Cost of working capital, commitment of financial resources to stay 'stopped' • Risk of obsolescence/damage	• *Kanban* (pulled production) • Value stream mapping (VSM)
Inadequate processes	• Need to monetize efforts that don't add value	• *Heijunka* (production leveling)

raw material purchases. Table 4 shows the relationship between waste, problems and the proposed Lean Manufacturing tools for inventory management improvement.

4.3 Results Obtained with the Implementation of Lean Manufacturing

The preparation of production batches remained daily, however, with the attendance of orders demanded every day, combined with the use of Heijunka technique, production has changed in mix with least amount of each product daily, reducing the inventory. The inventory of finished product decreased its level daily and the inventory of raw materials was replenished with more frequency according to the demand of each production batch, avoiding to generate major investments to keep inventory for big productions, i.e. the process became more balanced. With the use of production Kanbans, the organization increased, with less waste, since the materials began to come out of the warehouse in their correct amounts for the batch and each piece went on to be accompanied during the productive flow by Kanban, avoiding runtime error in the process. The packaging sector reduced to a minimum the number of parts errors in the packages and labeling errors, using packing orders following with the volumes until they get their proper labels. The entry in the inventory of the Enterprise Resource Planning (ERP) system started to occur instantaneously with the reading of barcodes contained in the sales package, at the time of entry into the physical inventory, always maintaining aligned the physical and system inventory.

The analysis of results achieved through the application of Lean Manufacturing tools can be measured by the proposed and adopted performance indicators, which

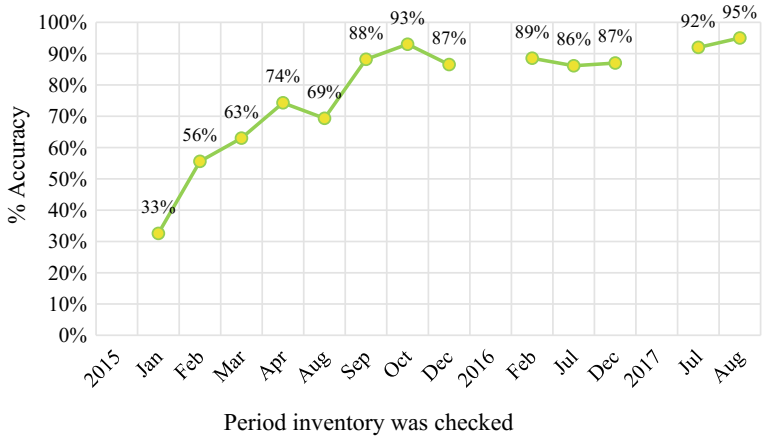

Fig. 3 Historic of accuracy percentage of finished product inventory in Brazilian Furniture

can be drivers for monitoring company's performance evolution and serve as a reference for the decision-making process, as well as for the creation of strategies for continuous improvement. Figure 3 presents the historical evolution of the accuracy percentage of the finished product inventory in the company. The accuracy indicator was calculated by comparing the actual inventory, one that is physically in place, with the inventory that is registered in the company's ERP system.

It is observed that in early 2015, the company had only 33% accuracy, that is, this was the percentage of certainty that everything that existed in the system inventory was in the physical inventory. In this case, analyzing the indicator, it is observed that the company could suffer with customer service issues if programmed to respond to a request with products that actually were not reflected in its physical inventory. It can be realized that there is no periodicity in the analysis of this indicator, the information is available in randomly spaced periods, despite the company having determined a monthly verification of the finished product inventory, what stopped to occur after the fourth month. While there was monthly tracking, the accuracy presented a growth and at the first month (August 2015) after a period without comparing physical inventory with the system inventory, a fall happened.

The Lean Manufacturing deployment job started to be held at the beginning of 2015, when the company had 542 tons of finished product inventory in the month of February for a daily production of 25 tons, that is, it had on its inventory the production of 21.7 working days.

Over time the inventory was being reduced, as well as the daily production, and currently there is about 67 tons of finished product inventory, about 1/8 of the highest value registered in February 2015 (87.64% reduction in relation to the original weight), equivalent to 13 working days (October 2017).

4.4 Challenges in Implementing Lean Manufacturing

The application of Lean Manufacturing brings many advantages, but it also presents challenges. The new routines for the company operation generated a dependency from the Production Planning and Control (PPC), since it starts the entire process, along with the need of constant functioning of the Enterprise Resource Planning (ERP) system, if there is any failure, the process is compromised.

With respect to the supply chain, suppliers need to answer quickly the production orders and purchase orders, because the deadlines are shortened. The barriers encountered in the implementation of Lean Manufacturing are mainly related to people and their resistance to change, contributing negatively to the development of the work, as in the case of the accuracy monitoring.

5 Conclusion

This study showed the importance of the Brazilian furniture industry to adopt new ways of working, to tackle the crisis in the country that, after a period of growth, led to a retraction of industry indicators from 2014 (gross added value, number of companies and working people). Lean Manufacturing, 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 a furniture company located in Minas Gerais, Brazil, and it was possible to demonstrate how the implementation of Lean principles, techniques and tools can bring benefits in reducing the inventory. The value stream map in the current and future state allowed the identification of waste, which were attacked by organizing the production process with the use of Kanbans, leveling batches in accordance with daily requirements (Heijunka) and adopting indicators (demand attendance, inventory turnover and inventory accuracy) to measure results.

A reduction of raw material costs was obtained and at the same time the demand and supply to guarantee customer satisfaction was achieved. Lean Manufacturing has contributed significantly to the main objective, which was the reduction of finished product inventory, reaching a reduction of eight times (87.64% in 33 consecutive months) and the dilution of this reduction in financial returns to the company, avoiding stopped capital in inventory, which was transformed into revenues, contributing to the working capital of the company, at a time the country faces a financial economic crisis. Despite the advantages and benefits, challenges were identified, especially regarding the resistance of people to change, noting that the successful implementation of Lean Manufacturing is proportional to the commitment of the stakeholders involved in the processes, a theme for future research.

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Scheduling Operations and SMED: Complementary Ways to Improve Productivity

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Abstract In most real cases the problem of scheduling operations are sequence dependent, that is, the setup time depends on the sequencing of tasks/batches in the machine. Given the current industrial manufacturing trends and requirements such as high variability, customization and reduction of product life cycles, organizations seek to implement new methodologies to adapt and respond with more flexibly to new demands of the global markets. Thus, this work sought to analyse, inspired by a real case of the textile industry, how production scheduling can be understood as a complement to SMED in order to achieve productivity improvement. In the case under analysis we presented the problem of scheduling tasks in uniform parallel machines with sequence-dependent setup times. The main objective of this work was to minimize the total production time. To this goal, optimization heuristics were used, in this case, simulated annealing algorithm, that demonstrated how the use of heuristics can be an advantage to reduce setup times when associated with other methodologies such as SMED.

Keywords Uniform parallel machines · Scheduling · Simulated annealing

1 Introduction

With increasing global competitiveness and constant evolution of customer needs, a company's ability to respond quickly to the market can be a matter of survival. According to [1, 2] during the 1980s, a trend emerged to increase the production of multi-products and flexible production lines. This greater differentiation of the product, due to changes in consumer behavior, has led to a proliferation of products aimed to meet the specific desires of customers, this trend is known as mass customization

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[2]. To survive in this environment, manufacturers need to balance the challenges of remaining highly flexible and responsive to adapt much better to the market turmoil while avoiding the high unit costs usually associated with small volume production [3]. At the same time, the recently emergence of Fourth Industrial Revolution or Industry 4.0 has been discussed worldwide. Industry 4.0 encompasses a set of disruptive technologies, such as cloud computing, Internet of Things (IoT), Cyber-Physical Systems (CPS), big data analytics and artificial intelligence (AI) [4] linked to the Internet to provide solutions to making production systems more flexible and collaborative. At this regard, the introduction these new collaborating computational entities at the shop floor open a broad range of opportunity to consider with a different perspective: taxonomy, design, maintenance, supply chain management, operating rules and process planning [5, 6]. For today's leading manufacturing paradigms, such as Lean Management, mass customization and Industry 4.0, production flexibility is an imperative requirement in customer-oriented approaches. Although in Lean environments any adjustment in processes, cycle times or inventories can increase the complexity of the processes, the flexibility requirement does not decrease in these environments, since the success of this approach is due in large part to its high efficiency in reducing the complexity by eliminating or reducing activities that do not create value [3].

In this context, setup time reduction is the key initiative of lean manufacturing [7], as well as for mass customization. As the production of small batches, or in some cases, unit batches, will require a greater frequency of changes between different products, production will only be viable if the setup times can be reduced [3, 8]. Therefore, it is widely accepted that a rapid changeover ability has an important effect both in providing rapid responses to the external environment and to internal customers. The authors [9] examined the factors in a production environment that has the greatest influence on performance and concluded that, regardless of the production system in use, simultaneous reduction of setup times and batch sizes is the most effective way to reduce inventory levels, as well to improve customer service. According to [10], this is a key resource to increase the utilization of production capacity and hence productivity while raising the level of flexibility of the plant in terms of volume and variety of products. To this author [10], the total setup time reduction can be achieved by reducing the time required to perform each product changeover and decreasing the number of setups required to satisfy a demand level. The author also identifies three approaches to managing and reducing individual product time changeovers: Traditional approach: those looking to avoid setups by using lot production; Lean approaches: these approaches are mainly applied by shop floor staff and look incremental improvements using kaizen methodology or SMED tool and Strategic Approach: this approach seeks to eliminate the changeover mainly through product, process or equipment design.

The most known of these methodologies is SMED. Methodology from lean manufacturing, developed by Shigeo Shingo for Toyota, the SMED (Single Machine Exchange of Dies) system is a theory and a set of techniques that allow performing equipment setup and changeover operations with less than 10 min [11]. In manufacturing industry, SMED is considered one of the many lean tools to reduce waste

and increase quality. However, despite SMED have allowed Toyota to reduce its lot sizes, adding flexibility to its production system [12] and seems to be applicable to any process that requires flexibility and personalization [13], this tool has physical and technological limits in terms of implementation and acquisition of more flexible equipment, which are not always feasible solutions due to the necessary investments.

By contrast, a second alternative, which is almost never referenced in terms of Lean approach, but it already starts appearing related to the solutions of Industry 4.0 is to decrease setup times through the job scheduling. At this regard, the intelligent perception and connection of manufacturing resources into the cloud platform using IoT technologies [14] allow that a large volume of data about resource status can be collected and monitored in real time. This creates a transparent environment for scheduling in cloud manufacturing [4]. Especially, when setup times are sequence dependent, the importance of scheduling on effective capacity utilization increases, making sequence-dependent setup time is one of the most significant issues to be handled when reducing setup times [8]. In addition, a sequencing and scheduling approach possibility the costs efficient running of the manufacturing system through minimizing operational costs that include setup costs (times), which are very important in many manufacturing industries, such as printing, textile, paper, chemical and automotive industry [8].

Taking into account the above-mentioned types of manufacturing systems, a problem of scheduling tasks in uniform parallel machines with sequence-dependent setup times is presented in this paper. This kind of problem should be considered an operational planning problem and it is found in different types of industries, namely, in the textile industry. As this industry is characterized by strong seasonality and the fashion factor, producing to respond to a large quantity of different products, which makes the concept of product changeover an important determinant of operations productivity, as well to provide a better customer service.

Thus, the main objective of this work is to minimize the total production time. Despite the extensive published literature on the sequencing of parallel machines, the literature on uniform parallel machines is scarce [15]. Moreover, because of their complexity, often these problems cannot be solved by exact methods. Therefore, we tried to analyze, using a real case in the textile industry, how the use of optimization heuristics [16] can be an advantage when associated with other methodologies such as SMED. To this goal, we developed a heuristic to find sub-optimal solutions to the problem, which is based on the simulated annealing algorithm. Heuristics based on this algorithm have been used to solve different combinatorial optimization problems whose resolution by the use of optimization methods is not possible.

2 Problem and Results

The problem under investigation was inspired by the textile industry, weaving in particular, where n jobs are sequenced on k machines. The tasks have sequence-dependent setup times. Equal tasks sequenced in the same machine are joined in

Table 1 Tests performed

Scenarios	Zm	Z0	((Z0-Zm)/Zm)*100
1	12790	12790	0.00
2	37910	49995	31.88
3	79027	164908	108.67
4	50739	50739	0.00
5	62160	66910	7.64
6	55345	74071	33.84
7	61550	73585	19.55
8	70445	80925	14.88
9	248494	318428	28.14
10	2053181	2273021	10.71

batches, so the setup time between equal tasks is zero. The demand is deterministic for the planning horizon.

To solve this problem, we utilised a simulated annealing algorithm. The simulated annealing (SA) algorithm is a non-deterministic local search technique that is used to find solutions in combinatory optimisation problems. This technique establishes an analogy between the minimum state energy of a physical system and the minimum cost in a combinatory optimization problem [17]. Simulated annealing is an extension of the local search algorithm and is based on a possible initial solution.

The goal of this solution is compare the results with the heuristic developed by the company to scheduling operation. The Heuristic developed by the company is represented in Table 1 by the cost of initial solution *Z0*. Thus, tests were designed, keeping in mind the structure of the identified problem. Ten scenarios with increasing complexity were created, with the last one corresponding to the practical case being analysed. For each of the scenarios, a significant number of tests have been done. Scenario 10 concerns the practical studied case that consisted of scheduling 5828 tasks distributed into 232 batches. These batches were distributed to 48 machines.

From the analysis of the results, the authors concluded that the algorithm performance was strongly related to the structure and the dimensions of the problem. It should be emphasized that in analysed industrial environments, the methodology used to schedule operations is the initial solution in the presented work.

For the smaller problems, scenario 1 and 4, the best solution was obtained in the initial solution. In these cases, the solution developed by the algorithm equals the initial solution so this is the optimal solution. In other scenarios, there is a significant improvement in the value found through the simulated annealing algorithm when compared with the value of the initial solution.

In this table, *Zm* represents the best obtained performance, *Z0* represents the initial solution and ((Z0-Zm)/Zm)*100 represents the percentage of improvement in the solution related to the initial solution.

3 Conclusions

The intense pressures of global market have been forcing companies to use and develop new capabilities to remain competitive. Due to the changes in consumer behavior in the latest years, the acceptance of the products and services by the market, depends not only on price, but also on several factors which are considered important from customer perspective, such as quality, delivery time, variety, flexibility of volume, etc. In this context, one of the major challenges that industries face is how to make the production systems already installed more flexible and responsive to meet better the customer individual needs, as well improving its competitiveness.

As a result of those efforts, in this paper we have introduced a problem of scheduling tasks in uniform parallel machines with sequence-dependent setup times, applied in a real case in the textile industry. To solve this, we used a meta-heuristic known as the simulated annealing algorithm to obtain "nearly optimal" solutions for the problem. It was not possible, given the size of this type of problem to guarantee an optimal solution, however, it was found that the results obtained, when compared with the sequencing methodologies used in the companies, presented significant advantages.

Considering the type of industry studied, the results show the clear importance of a structured approach to improve the efficiency in the problems of scheduling operations and point to the integration of a set of practices aimed at minimizing equipment downtime. In the real case study, the developed heuristic allowed for an improvement of approximately 10%. From a more conceptual perspective, though this type of problem should be considered an operational planning problem, the work presented also provides significant advantages in terms of tactical planning. The study identified a planning philosophy in the textile industry based on their Material Requirement Planning (MRP) that generates production needs from the backlog. It is expected, although difficult to quantify that, if the material requirements are generated from the nearly optimal sequence obtained with the developed program, additional gains beyond the direct gains demonstrated in the work will exist in the upstream production sections because it is a system-dependent demand. It also seems important to associate Lean practices, namely SMED with mathematical modeling of problems, using heuristics at the level of sequencing to reduce total production time.

For future research, there are many approaches that may be followed. So that, it is possible this work is extrapolated to other industrial environments, besides textile industry, it may also bring significant benefits. Secondly, studies could be taking into account the implementation of industry 4.0 solutions, such as IoT, Big Data and Cloud Computing that provide increase of available information and massive computing power. As technologies linked to the internet and as more advanced automatic machines are used on the shop floor, data can be exchange in real time, which becomes manufacturing processes more visible and monitorable, allowing setup times to be drastically reduced. The real innovation of the introduction of the CPSs and IoT concepts inside the shop floor it is not only to collect and analyse production data from

the sensors but their interconnection ability for instantly communicating between them [18].

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"Quality Box", a Way to Achieve the Employee Involvement

Cláudia de Sousa e Silva and Carolina Sousa

Abstract Employee involvement is considered as an active quality management (QM) principle, once: it is related with a key asset of organizations—the human resource; it is the base to implement the other QM principles; and it is linked also with the customer satisfaction. This paper discusses this QM principle, since it definition, the relationship with the others principles and the TQM fundaments, putting the focus on real context practice that could be promoted to implement it in a systematic and efficient way. Was developed a case study, an intrinsic study, in an automotive Original Equipment Manufacturer (OEM) where was performed a project designated Quality Box (QB). The research has as main contribution to support the QB implementation project, in a real case context, highlighting the bridge between industry and academy. Contributes, also, to the dissemination of real good set practices integrated in the QB project, which could inspire other organizations. The originality of this work is justified by the relation that is established between the implementation of QM principles with the quality management approaches and its dimensions. Focusing the importance that all activities related to quality management, need to know, understand and integrate a multiple approach of quality. The work also highlights the relevance of employee involvement in the Digital transformation era, concluding that more automated processes require more "humanized" workers.

Keywords Quality management principles · Employee involvement · Quality dimensions

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1 Introduction

In the organizational context, the concept Quality is often referred in a simplified way, since that is implicit is the concept of Quality Management (QM), obtaining a dimension of business management. In this dimension, Quality Management has an active role from strategy, business plan, operational management, supply chain, promoting a culture of continuous improvement that seeks high levels stakeholders' satisfaction.

Quality Management can be defined as a set of organizational practices that lead to better performance results, through the implementation of quality programs, which certainly differ from organization to organization. However, the principles of Quality Management are a common denominator in any quality management system.

The evolution of this systemic perspective, as it involves the entire business of quality management, culminated in the development of Total Quality Management (TQM). Some researchers advocate the ISO 9001 as the first step towards further implementation of TQM [1] and consequently for business excellence [2].

TQM has quality as the central point of an organization's business, disseminating it in all activities and to all employees, regardless of their function. Its main objectives are to guarantee customer satisfaction and promote teamwork, looking for the involvement of entire organization [3]. All employee at all hierarchical levels should participate in the development and sharing the vision, mission and plans for continuous organization improvement [4].

This participation requires efforts to acquire knowledge and skills to solve daily problems, avoiding wrong decisions.

The TQM fundaments are [4]: process thinking; customer satisfaction; total employee commitment; team work; strategic and systematic approach; integrated system, decision based on facts; continuous improvement; effective communication and training. To reach a successful implementation of TQM, these ten principles must be followed together. A study performed by Thamizhmanii and Hasan [3] points out that TQM principles are implemented in the range of 25–30% in the organizations that started their practice. Considering these results, the question arises: How to increase the compliance with the principles defended by TQM? Will they be promoted and encouraged by a set of practices in a systematic and continuous way?

The main objective of this work is to present a case study where a set of practices was developed to stimulate a concrete principle of TQM: the commitment and involvement of all employees.

Employees are recognized as the most important asset of organizations, being an essential resource for it competitive advantage. They are also a differentiating factor of organizations, dedicated and innovative workers allow greater productivity and improve the quality of organizations. Thus, in this context the involvement of employees has been achieving a significant role, being an important factor for the survival of organizations [5].

This study aims to describe the main steps for implementing the principle employee involvement and exemplify with a set of concrete initiative structured

in a project management, called Quality Box. It highlights the need for dynamic and systematic actions to implement the QM principles. It also intends to establish a relationship between the principles of QM and the dimensions of Quality.

But the final reflexion is, will it continue to be relevant and important the Employees involvement in a context in which the digital transformation era is imposed, characterized by the replacement of human resources by new information technologies?

2 Literature Review

In daily life the concept of quality is used in different situations. For the customer, the concept of quality is often employed in the sense of product or service excellence.

To define quality and understand its intrinsic quality concept is not an easy task due the preconceived idea that quality is something subjective and intangible. However, if the quality is to be managed, it must first be understood.

2.1 Quality

An important contribution to the understanding and definition of the Quality concept was given by Garvin with the explanation of quality approaches [6]:

- **Transcendent**: Quality is an "innate excellence" that can only be recognized by the customer through its own product experience.
- **Product-based**: Quality is a measurable and precise variable that can be found in the set of product characteristics and attributes.
- **Value-based**: quality is a function of the product conformity level at an acceptable cost. This ties the consumer's needs to manufacturing requirements.
- **Manufacturing-based**: Quality depends on compliance with the requirements as set by the product design.
- **User-based**: Quality is defined by meeting customer needs and conveniences. This is subjective because customer preferences vary.

Related with these approaches, the same author [7] defines the eight dimensions of product quality: Performance; Features; Reliability; Conformance; Durability; Serviceability; Aesthetics; Perceived quality. It's important knowing and understanding the dimensions of quality to develop an inclusive quality program. However, all actions for the quality promotion should be led by a set management quality principles.

2.2 Quality Management Principles—Employee Involvement

The implementation of the principles of quality management has been referenced, in several research projects, such as Quality Management practices [8–10]. The ISO 9001:2015 [11] determines seven quality management principles: Customer focus; Leadership; Employee involvement; Process approach; Continual Improvement; Factual approach to decision-making; Relationship management.

Although several classifications of the quality management principles were found, in a more general way those can be divided into two main groups: Soft (infrastructure) and Hard (or core) [12].

The soft practices are often characterized as people-oriented, including management commitment, customer focus; employee involvement and the relationship with suppliers [9, 10, 12]. By analysing both the principles of quality management and the pillars associated with TQM, there is a common factor, employee involvement is emphasized in the implementation of Quality Management.

The success the implementation of TQM is very dependent on changes in the attitude and activities of all employees.

Employee involvement refers to the involvement degree of the employees in the activities of the organization's strategic degree [14], which can be implemented through the participation of employees supported in the information process, decision making and problem solving [15].

Was performed a study in a total of 113 employees before the implementation of TQM, and a subset of 73 employees after the implementation of TQM has been done. The results obtained point to significant improvements in: job satisfaction, work involvement, organizational commitment and increased profits [3].

Sila [16] confirmed that performance results from human resources management have a direct positive impact on the organization's efficiency. Lawler, Mohrman [17] demonstrated that 84% of Fortune 1000 Companies implemented empowerment programs. Showing that the results were enhanced when these programs were implemented in conjunction with the TQM.

2.3 Relationship Between the Principles and Impact on Quality Management Performance

It was mentioned that all principles must be present and implemented, however by the results presented only a small percentage of organizations demonstrates their total application As an aid to the fullness of its implementation, it becomes important to realize how these principles are related, realizing how they impact one each other.

The author Bakotić and Rogošić [13] argues that subtly the literature assumes that employee involvement may be the soft key practice that determines the implementation of core practices. Kaynac [18] developed the interdependence model of QM

Table 1 Soft and hard principles [13]

Soft QM principles	Hard QM principles
Costumer focus	Process approach
Leadership	Relationship management
Employee involvement	Continual improvement
	Factual approach to decision-making

practices, where he demonstrated the importance of training and employee involvement in the implementation of TQM.

Roca-Puig, Escrig-Tena [19] demonstrated that a people-oriented quality management perspective has positive affects in the management process.

A study developed by Bakotić and Rogosic [13] concluded that the employee involvement promoted by different initiatives such as the training, communication, empowerment, rewards and recognition, has a positive impact on the process approach, management systems supported in the process approach, continuous improvement and factual criteria to support decision making.

The same authors developed a quantitative study to analyse the impact of each soft principle has on the hard of QM principles, arriving at the conclusion that of all the soft principles defined in Table 1, only the principle of employees involvement had an impact on all hard principles. The results did not surprise the authors, the organizational success depends on the skills of its employees to solving problems, drive their action to be innovative in developing new products, new methods and new processes. This study is corroborated with a set of empirical studies which demonstrated that the employee involvement is the QM principle with the greatest impact on the remaining QM principles. The employee involvement improves responsibility and the development of employees, which directly improve the efficiency and success of the organization. The authors recommend that the quality managers must maintain a high level of employee involvement in order to achieve a significant improvement in the technical aspects of the QM [18].

Whenever quality principles are implemented through a set of effective practices, it can be concluded that the principle of employee involvement impacts on the following principles: process approach; system approach management; continuous improvement, factual approach to decision-making and relationships management [13].

In the same line is the study developed by the Andrade and Mendes [20], where they concluded that involvement and empowerment is a vital aspect of quality management.

2.4 *Practices to Implement the Employee Involvement Principle*

According with Evans [21] the development of actions that promote the implementation of a QM principle cannot be understood as the collection of new tools or the dissemination of a set of slogans, but rather as a way of change of thought that leads to new kind of work. It involves the internalization the added value of the actions developed.

Lakhal, Pasin [22] defined that training and participation have a significant statistical effect on information, analysis and improvement of the quality system. Tarí and Sabater [23] developed a study that correlated practices such as: training; recognition and communication, with the TQM techniques and tools.

The main practices that have been developed to implement the Employee involvement have been through:

- Training [24–27] is clearly identified as a major component of the work force because it allows reach skills, rules, concepts and attitudes that result in greater compatibility between the employers profile and the necessities required by organizations. Corollary these findings are studies that indicate that this compatibility promotes the employee involvement [18] However, training must be implemented on a continuous basis, allowing employees to see the contribution of their work across the production chain and the company's overall objectives [28].
- Communication [18, 25, 29]: Communicating is sharing information among one or more elements or groups to achieve a common understanding about certain information. Thus, the intervener trade and share information influencing their attitudes, behaviours and understanding. It is crucial to make the organizations' mission, vision, culture and goals known. It is a strong opportunity for employees have a participatory attitude in decision-making at various levels, enhances participation in decision-making, enhancing employee involvement [30, 31] Achieving these goals, communication enables employee involvement to move to the next level: Empowerment (employee + power), recognizing the value of employees and delegating sufficient decision-making power and responsibility in their performance and duties [32].
- Awards and Recognition Strategies [33]: these practices are recognized as highly effective ways of motivating employees [34]. They are often referred to as tangible methods that lead employees to realize that their individual or team performance is important. They are usually developed by linking premium policies to corporate objectives, with special attention to quality objectives, thus achieving a dual function: employee involvement and reaching strategic business objectives.

2.5 Employee Involvement in Digital Transformation Era

The nature of work in organizations is changing. Companies expect the technological advances bring more productivity, with processes increasingly automated and therefore reducing the number of workers.

But on the other hand, news technologies bring changes in organizational structures, especially in the communication area. There is much more information, processed more and more quickly and therefore the need to many decisions making, effective and in a short time [35]. Malone [36] argues that it is necessary to cultivate a leadership style to promote coordination, collaboration and participation of all human resources. This requires new mindsets and new skills, both for managers and for workers.

Industries have become more knowledge-based, the employees should work collaboratively with more emphasis being placed on a variety of team-based structures. Organization will need greater commitment and engagement of staff in order to remain competitive [35].

3 Methodology

The development of this work was supported in qualitative research methodologies with the development of a case study. This methodology was chosen since the main objective of the research is spread a set of concrete practices applied in a real context.

Flyvbjerg [37] argues that we use case studies not in the hope of providing something, but rather in the hope of learning something. Also, Yin [38] argues that the development of case studies is an adequate methodology when it is intended to describe the intervention in the real context where it occurred.

The research was developed in an automotive industry where quality management systems are crucial to the success and sustainability of an organization in this industry. Due to the safety and reliability requirements associated with a vehicle, the automotive industry has always shown interest in quality management systems. In the automotive industry, technological advances and the progressive competitiveness have had the effect of increasing the demand quality levels of cars coming to customer. So, the development of quality management strategies has played a key role in the continuous improvement in this sector [39].

The selection criteria of the organization is based on the fact that one of the researchers are currently doing a research there, integrating a work team for implementing the project described in section four, being an intrinsic study [40].

The selection of the principle employee involvement is justified by the fact that it is common both the principles referenced in ISO 9001 and the TQM fundaments.

On the other hand, due its importance, without employees there are not organizations, employees are a key factor for any organization, and if these are not involved in the organizations strategies, hardly can be implemented [41].

One of the researchers belongs to a multidisciplinary team, compose by the following areas: Quality Management, Geometry, Electricity and electronics, Mechanics and Noise; Degradation of appearance. This work team, based on an existing solution, aims to develop an updated solution of a project that allows the employees to be involved and thus achieve better results, concretely in their external performance.

The methodology followed was based on the knowledge of project management, identifying and scheduling the following main steps: Phase 1—Diagnose needs for project construction; Phase 2—Draw up a comparative balance of the several ideas; Phase 3—Decision of the actions to be developed; Phase 4—Training. These steps were duly planned in the Gantt diagram, the final step is expected to be completed by the end of May 2018.

4 Case Study and Discussion

The company is a multinational group that manufactures cars and motorcycles. In 2012, the company developed a project called Quality Box (QB): materialized in a physical area, intended for all employees. It was divided into four stages, where were performed training actions during 20 min in groups of 6 people.

The first step, designed reception, was intended to explain in a general way how QB was structured and its main objectives. In the second stage, this one more dynamic, reverted to awareness of good practices through photographs of sensitive operations (operations that cause more defects). The third stage, the execution of the game "Detects defects", where the employee was supposed to take the place of the customer and identify if the defects in the appearance level. The vehicle was arranged centrally with about 24 defects in appearance. Finally, in the last stage, the trainees would go through a final frame where they would be presented with the mascot and asked each to register their commitment.

It was created with two main objectives: the awareness of employees and the eradication of behaviours that cause repetitive internal defects related to aspect degradation.

The records of Quality results given by the company, allow to state that in terms of aspect degradation there was a significant improvement, achieving in 2016 the objectives defined for this indicator. This leads to the conclusion that the actions developed with the first version of QB were effective, have been able to increase the involvement/empowerment of the operators with regard to aspect degradation.

The problem arises in client quality results, they are good, but this organization set a goal to decrease the percentage of defects arriving at the client, which have not yet been internalized by the company. This problem may be justified by the fact that it is related to the user-based quality approach, specifically in the perceived quality dimension, with a higher subjectivity compared to the other dimensions discussed in the literature review. On the other hand, because it combines a set of defects occurred in the several manufacturing workstations.

Following the methodology described in Sect. 3, the multidisciplinary team started the first step:

- Phase 1: Diagnose needs for project construction. The solution developed in the first version of QB presents some limitations, namely:
  - Vitality: The latest version has not been evaluated since 2012;
  - Location: The location is static, in school training with little visibility.
  - Content: The QB refers the internal defects and does not consider customer defects.
- Phase 2: Selection of ideas. The predominant idea given by the team was to focus on the division of the Quality Box into three: a fixed, an itinerant and a dynamic. The second change occurs at the level of defects, defective parts from the customer will be exposed. The central focus will be on awareness and training, giving to the trainees a new perception of defects detected by the clients.
- Phase 3: QB definition. The first change occurs at the location level. It is a worth adding moving the QB to shop floorcloser to the workers and with more possibility to be remembered. It will be divided into 4 spaces separated by different colours, due the small area.
  - Room 1 Quality Definition: This room will be aimed at the definition of quality, focused on the all quality dimension. It is intended to emphasize the importance of quality and to show that there are real facts that seek this concept. We are all consumers, and we do not like the lack of product quality. If we want this excellence when we buy, we should also be with the ones we produce. It will be promoted by dynamic games that allow the internalization of the customer perspective in the approach to quality.
  - Room 2 Value of Standard Fulfilment: This room wants the employee to be aware that for each operation there is a standard that must be fulfilled and that it must be guided by it. In this room, educational games related to sensitive processes can be implemented. Sensitive processes represent processes in which more problems occur, that is, more defects. It was thought to put a Job Element Sheet (JES) with all the information necessary the operator should perform the operation. A construction activity of a Science4you mountable car has been incorporated. After the game is over, there will be a debate about the conformities of the cars produced.
  - Room 3 "We are all Manufacturers": This room aims to emphasize that each sector depends on the previous, any defects that arise in any productive sector, will affect the following. Show the trainees with the use of a vehicle photograph, the defects that occur in each of the manufacture sectors and that will impact in the next sector. Detected and communication defects produced must be encouraged. In doing so, they prevent the defect from reaching the customer and therefore do not degrade the factory image.
  - Room 4 "We are all costumers": Show of the defects that arrive from customer, and not those observables only inside the company. In this room will be presented defects from the clients, exposed in showcases. It will exposure parts

without defects beside the defective part. Finally, the idea is putting a canvas decorated with a model produced by the company and collect the signature and commitment of each collaborator.

- Phase 4: Training. With the support of QB developed it is intended to develop a set of training actions with objectives really focused on the quality dimension perceived by the client. The actions will have the development of dynamic actions, with resources to simulation strategies and didactic games. To support training actions is being developed a training manual "Quality Box - all manufactures, all customers" where are described the objectives of each stage, the planned time, dynamic strategies to adopt and support materials to each step.

At this moment, the project is ongoing process, implementing the phase 3 and phase 4, and it is expected to be completed by the end of March 2018. The company intends to achieve a positive evolution in the number of vehicles that do well to the first one, with consequent reduction of defects coming from the customers.

5 Conclusion and Contributions

With the work developed by the organization in the first version of the Quality Box, it can be concluded that the efforts developed in 2012 for the employee involvement and empowerment was effective. The objective to reduce the number of defects associated with the aspect degradation was achieved. This first version was developed targeted product-based and manufacturing-based quality approaches, allowing develop the dimensions of quality: features and conformance.

Even so, the organization feels that the employees' involvement in quality management must integrate another level, the user-based approach needs also to be internalized. Being more subjective and dependent on customer perceptions, thus puts up the challenge: how can the principle of quality employees' involvement reaches this level? We can conclude that practices to develop the employee involvement need to include the various quality approaches as well as the several dimensions associated with it. This is the only way to achieve products with quality, perceived by the various perspectives in the quality approaches developed by Garvin [7].

The name of the 2nd version of QB reveals the need to incorporate the multiplicity of quality approaches "Quality Box: All Suppliers, All Customers". Other problems were identified with the first version, namely the need that the practices for employee development should to be promoted systematically and dynamically. This problem was met in the design the second version QB, by the definition of its location, being necessary the identification of a strategic location, the shop floor, where the contact and presence was noticed.

The other essential aspect of the effective performance of employee involvement practices is the dynamic feature, associated with training and awareness strategies [42] In all rooms (steps QB) training strategies have been introduced to promote

discussion, analysis, interaction and trainees intervention, using educational games, real examples with their own vehicle, non-conforming parts, simulations.

For now, 2nd version QB project is under development, as it was explained in the section Case study. Therefore, the future work includes the completion of the last stages, physical and material implementation of QB and the accomplishment of the training actions. It is recommended that the project implementation follows an agile and iterative methodology [43].

A gap that the project presents today is some uncertainty in how the effectiveness of the project will be evaluated. Thus, as a next step, it will be necessary to develop a process that allows this evaluation, because for an improvement in customer quality performance, there are several independent variables. How is it possible to measure the contribution of QB to these results in an individualized way?

The research developed, since it is an intrinsic study, has as main contribution the support of the implementation of the 2nd version QB project, in a real case context. This kind of works highlight the bridge between industry and academy. The project QB, promote de employee involvement, contributing to settle their involvement in quality management, and consecutively contribute to improving their performance.

Being a study developed in a recognised organization, enclosed in a very competitive sector like the automotive market is, it also contributes to the dissemination of a set of real good practices integrated in the QB project, which certainly could inspire other organizations.

A literature review performed could conclude that were already several studies on quality management principles, like definitions, classification of them and its relationship. The originality of this work is justified by the relation that establishes between the implementation of QM principles with the quality management approaches and its dimensions. Highlighting the importance that all activities related to quality management, need to know, understand and integrate multiple approaches to quality.

The pertinence of Employee Involvement could be questioned in the digital era transformation, since the main idea in this context is the replacement of the Man by smart machines. However, given the organization structural changes as a consequence of technological advances, it is necessary to increase the human relationship between workers, developing soft skills, such as collaboration, empowerment, teamwork and decision making.

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A Bibliographic Review of Software Metrics: Applying the Consolidated Meta-Analytic Approach

Ari Melo Mariano, Ana Carla Bittencourt Reis, Lucas dos Santos Althoff and Laís Bandeira Barros

Abstract This research aimed to provide an integrating model for the principle contributions of the scientific literature on software metrics with an impact on that field. Software metrics has emerged as a crucially important aspect of software development planning insofar as indicators representing development costs and the effort involved are essential for the formulation of new systems proposals and the analysis of the systems already in use inside organizations. To that end an exploratory, quantitative, bibliometric study was carried out using the Theory of the Consolidated Meta-analytic Approach. The study retrieved 658 relevant registrations from the Web of Science database for the period 2010–2018. The main contributions and most important approaches are presented together with an integrating model with three main classifications (a) Metrics for Quality in Cloud (40.93%), (b) Software Metrics as Technique (29.30%), and (c) Current Uses of Software metrics (29.77%). In addition the taxonomy of the most cited articles was established and comparisons were made with the results from multi-language databases like Scopus and Google scholar.

Keywords Software metrics · Theory of the consolidated meta-analytic approach · Categorization · Integrating model

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1 Introduction

The increasing applications of Information and Communication Systems means that the most varied organizations devote ever greater efforts to developing software. Output demands and the growing complexity of data call for high levels of processing capacity to meet the requirements of Systems that are increasingly integrated and complex and still has to be elaborated in different programming languages.

In that regard, software metrics emerges as a crucial aspect of software development planning insofar it can work as indicators representing development costs and the effort involved are essential for the formulation of new systems proposals and the analysis of the systems already in use inside organizations. Thus, software measurement is a particularly important procedure in the sense that it provides essential information about the software artefact itself [1].

The theme of Software metrics is a particularly difficult to address due to its internal diversity [2]. In general, metrics is defined as the observable value which results from some measurement assigned to attributes of the real or abstract world. It verifies the size, quantity or degree of some attribute using a validated measuring device. In the computational context there is continual testing and proposal of new quantitative indicators with greater capacity in respect to the respective context.

The importance of this subject stems from the current context of increasing integration of market participants in the course of digital transformation in which software has become the mechanism for consolidating the great variety of information that industries need for their very existence and their development [4.0]. From the social point of view, understanding software metrics literature means having updated indicators of IT systems (i.e. complexity, quality and productivity), collaborating in the progress of software development, enabling improved utilization and ensuring appropriate support for organizations or countries to conduct their planning activities. The present bibliometric review, in particular, will assist the Brazilian Army to identify recent advances in the field of software metrics collaborating with the dimensioning of its developers teams and determining the costs of development systems designed to unify previously unfolded actions improving the effectiveness of their IT systems.

The purpose of this study is to explore where software metrics research is situated as well as the tendencies related to this subject by bibliometric reviewing the main recent papers obtaining answers to the research questions: (a) who are the leading authors? (b) which are the most-used approaches? (c) which are the most important lines of research today?

This paper sets out to provide a model for integrating the main contributions in the scientific literature with an impact on software metrics and to that end it adopts the Theory of the Consolidated Meta-analytic Approach (*Teoria do Enfoque Metaanalítico Consolidado*—TEMAC). To achieve this, the review is organized appropriately around the Methodology (Sect. 2) where we present our research method, Results and Analyses (Sect. 3) which contain the literature review itself with the result of the research, followed by the final remarks (Sect. 4).

2 Methodology

This exploratory study adopts the Theory of the Consolidated Meta-analytic Approach (TEMAC) [3]. It consists of three stages: (1) preparing the research, (2) Presenting and inter-relating data, (3) Detailing the integrating model and evidence-based validation.

The first stage embrace respectively the definition of key-words, the kind of documents, the timeframe of interest, the databases to be consulted and the area of knowledge the review will investigate. In the second stage the bibliometric information is extracted from the literature databases and then the laws of bibliometrics are applied in an analysis of the relations among the extracted data. An analysis of those articles that have historically been the most cited makes use of CitNetExplorer software to portray the evolution of contributions to the theme.

Lastly integrating and validating models will be applied to the evidence obtained from the Citation, Bibliographic Coupling and Co-occurrence mapping study. Those steps are based on Pritchard's laws of bibliometrics [4]. The importance of using bibliometric techniques is underscored by the increasingly rapid generation of scientific-technological information, corresponding to an ever increasing number of publications and broadening the scope of the task of identifying the most important ones and their interconnections [5].

This study used the 1.6.5 version of the *VOSviewer* software to ensure a satisfactory analysis of the bibliometric data. Heat maps concentrate similar information in clusters and a color scale indicates the degree of importance of the respective articles or key-words; red denotes the most important and blue the least important in each one of the bibliographic displays used. The construction of the heat maps to represent interrelations of information made use of the "density" visualization option. That made it possible to combine the cumulative analysis with the network analysis [6].

The survey made use of the string "software metrics" and searched for correspondence in the Web of Science (WoS) database with a time interval filter of 2010–2018. The choice of that particular database was because it is widely acknowledged to be one of the most complete and prestigious of the specialized scientific literature databases [7].

To consolidate more recent data in the integrating model, Iramuteq software was used to achieve a Descendent Hierarchic Classification of sixty abstracts from articles published in 2017 and 2018. In addition, the most cited articles were classified taxonomically after being carefully read.

In advance, we have chosen a single database for the whole analysis for transparency purposes. To ensure a wide outreach for the review the results of WoS were compared with results in multilingual databases, notably Scopus and Google scholar (GS).

3 Results and Analysis

3.1 Preparing the Research

The first stage of TEMAC is preparatory and is orientated by the following questions: (a) What is the research's descriptor, string or key-word? (b) What is the research's time-space field? (c) Which database will be mined? (d) Which areas of knowledge will be delimited?

For this general overview we defined the key-word "software metrics" for the period 2010–2018, using the Web of Science database. The areas of knowledge filtered were: clinical neurology; optics; environmental engineering; mechanical engineering; ocean engineering; energy fuels; environmental sciences; geography; gastroenterology; hepatology; imaging science and photographic technology; physical geography; green sustainable science technology; applied mathematics; logic; nuclear physics; mechanics; applied physics; particle and field physics; biology; neurosciences; nuclear science technology; education scientific disciplines; mathematical computational biology; medicinal chemistry; multidisciplinary chemistry.

The filtered search retrieved 658 registrations. The filter was selected in the light of the Brazilian Army and the Researcher's interest in collecting information associated with organizational context.

For the multilingual comparison it was selected the same key word and time interval for the Scopus research resulting in 1415 documents, and for the GS research that was done through Publish or Perish extracting the first 1000 results. All research was carried out from 8th of February to 15th of March.

3.2 Data Presentation and Inter-relations

The second stage of TEMAC is presenting and inter-relating the data. The data are drawn from the same Web of Science platform and also obtained by actual reading of the articles obtained after the filtering process using the relevance criteria.

The earliest study found is entitled "Exploring the Influence of Identifier Names on Code Quality: an empirical study" by [8] published in the annals of the 14th European Conference on Software Maintenance and Reengineering and it addresses the question of source code quality. This continuation of an earlier work by the same author evaluates source code and identifier quality using software metrics. The results show that poor quality identifiers are associated to low grade source codes. The study was evaluated in a medical context (diagnosis tests) and proved to be satisfactorily consistent.

The average number of citations for the whole set of retrieved articles is 3.06 while the most cited one, "What's up with software metrics? - A preliminary mapping study" by Barbara Kitchenham was cited 70 times. In her work Kitchenham makes a systematic review of the years 2000–2005 and reveals a panorama of tendencies

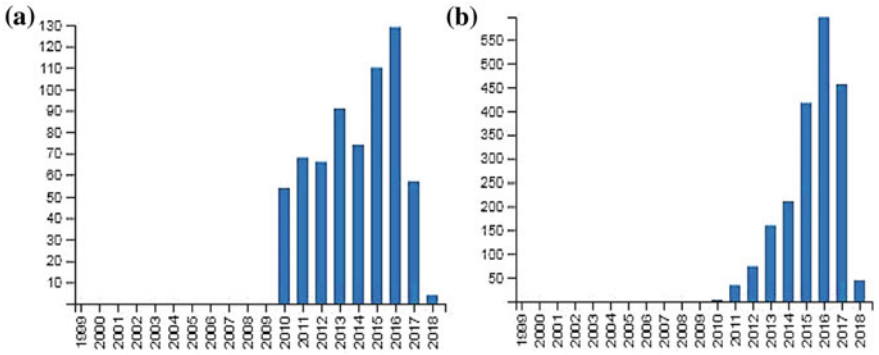

Fig. 1 **a** Evolution of the number of publications. **b** Evolution of the number of citations on the theme of software metrics. *Source* Web of Science

among articles with a strong impact in the field of software metrics. She confirms the wide scope of that area and states how difficult it is to evaluate the current state of research investigating that topic, suggesting that new systematic investigations need to be elaborated capable of categorizing the fields and tendencies associated to the theme.

Most of the 658 studies retrieved by the database search (2010–2018) are proceedings papers (n = 427, 65%) followed by 225 articles (34%) and just 6 reviews (0.9%), one of which was the single most cited work.

In regard to the evolution of citations over time, it can be seen from Fig. 1 that software metrics has been incrementing its notability in the scientific community in spite of the substantial drop in the number of publications in the year 2017 when it went back to the level of 2010.

Among the publications retrieved, the author with the highest number of citations is Khoshgoftaar, T. M., with 155. Works of his that are cited mainly refer to software quality aspects and especially to the correct use of software metrics to forestall defects and avoid risks. Seliya, N. is the second most cited author with 102 citations. That number, however, is largely because he appears as co-author of many of Khoshgoftaar, T. M.'s publications.

In third place comes Williams, L., with 89 citations. His articles present the main approaches to software metrics as well as feedback on the use of metrics and its complexity. Wang, H. J., (87) and Gao, K. H., (85), are in fourth and fifth position respectively also with their numbers boosted by publications in which they appear as co-authors with Khoshgoftaar, T. M., revealing the existence of a robust study nucleus.

Among the articles with the highest numbers of citations (71) is "What's up with software metrics? - A preliminary mapping study", by Kitchenham [2]. It presents work referring to empirical studies of software development and assessment in industries and organizations as, for example, those by authors [9, 10] who discuss the importance of software metrics in decision-making in the context of large

organizations dedicated to software development or in aggregating quality to those metrics. The second most cited work (69 citations) "Software fault prediction metrics: A systematic literature review" by Radjenović [19] is a systematic review of the literature for the period 1991–2011 and it identifies and evaluates software metrics capacity to predict flaws. That author's approach takes into account how the context influences metrics selection and performance. In his results he categorizes metrics in three types: (1) Object-oriented metrics, (2) Source code metrics and (3) Process metrics.

Shin [11] is the author of the third most cited work, ("Evaluating Complexity, Code Churn, and Developer Activity Metrics as Indicators of Software Vulnerabilities", with 62 citations. In his article the author creates an empirical model and conducts a case study of two large-scale projects studying indicators for code vulnerability in relation to discriminant and predictive capacity in which 28 metrics divided into three measurement categories are tested in regard to (1) Complexity (2) Code Churn, and (3) Developer activity [11]. "Empirical validation of object-oriented metrics for predicting fault proneness models", by Singh [21] is the fourth most cited work with 60 citations. The author concentrates on metrics software models for predicting flaws or defects which are also associated to studies of indicators for estimated development effort. In regard to Brazilian publications, the outstanding author is Ferreira [22] in tenth position with 36 citations. In his work that author describes object-orientated software and definitions of the thresholds that control the violations and principles of software design.

Having obtained an identification of the main documents in terms of citation, it is important to verify the presence of those authors that publish most in this area and gain an understanding of their influence on the field of software metrics. The most prolific author in publishing terms is Khoshgoftaar, T., with 22 works and he is also the author of the most quoted article ("an empirical study of feature ranking techniques for software quality prediction"). It is an empirical study involving software quality prediction. Part of the published works of Misra, S. (13) and Gao, K. (9) are those in which they appear as co-authors and they are accordingly, the major exponents of the theme. Other authors like Napolitano, A. (12) and Dohi, T. (9) also appear but their publications have lower numbers of citations.

Another factor that suggests how widely studies on the theme of software metrics are disseminated is the variety of countries that produce material in that area. Among those that produce the most are India, the United States, Brazil and China. India has one of the most cited authors, Singh and Rath, S. K. who is responsible for the greatest quantity of Indian publications. It is also worth underscoring Brazil's contribution on that theme and the authors who published most are Garcia, A. (9) and Figueiredo, E. (5).

The Key-words that occurred most frequently in the titles and abstracts are suggestive of the main lines of research. The main key-words are: software (746), metrics (502), prediction (185), design (122), quality (110), object-oriented (107), models (102), defect (100), code (84), analysis (57), and complexity (55). There is a visible tendency towards the use of models designed for defect prediction or that analyze quality or complexity using software metrics with object-orientated codes.

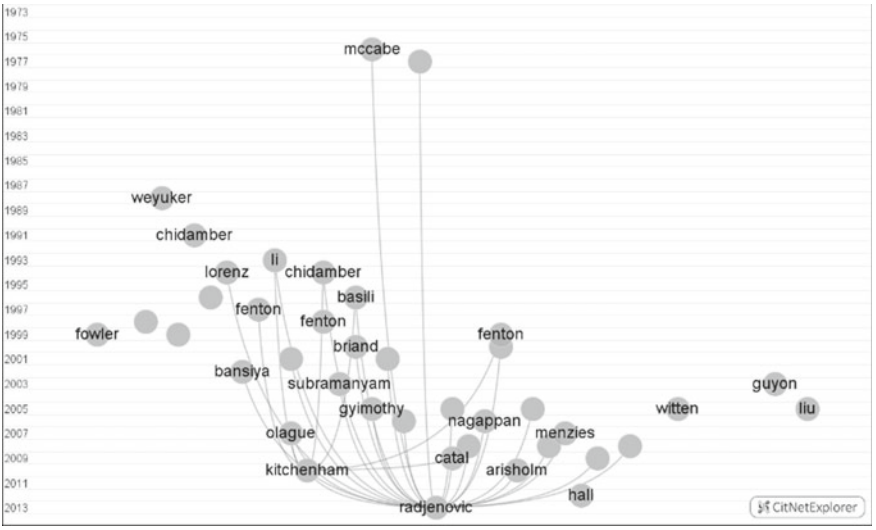

Fig. 2 Map cross-referencing authors' citations as a function of time. *Source* Web of Science. Map generated using CitNetExplorer

A preliminary review of the articles demonstrates conclusively that the lines of research that make most use of metrics software are those designed to predict flaws and defects in object-orientated software. There are also many studies in this area that formulate empirical models that seek to validate software complexity. Finally there is a third line of software metrics studies that focus on the control and management of software development processes.

The last action in this stage is to cross-reference the data on the earlier patterns of citations; that is, referring to other periods prior to 2010–2018 and their evolution over time, together with their authors (Fig. 2).

It can be seen that authors Mccabe, T. J. (1976) and Halstead [20] are the precursors of software metrics research and that their discoveries are still being reflected in more recent studies of authors like Radjenović [19], who stands out as the most robust reference insofar as he carried out a complete review of the literature and identified the most cited authors.

Once the main literature on the theme and the lines of research are identified by analyzing which are the most cited works, key-words and authors and those that published the greatest number of materials and once the evolution of the citations over the course of time has been portrayed, it is time to pass on to the third stage of TEMAC which consists of detailing, applying the integrating model and evidence-based validation.

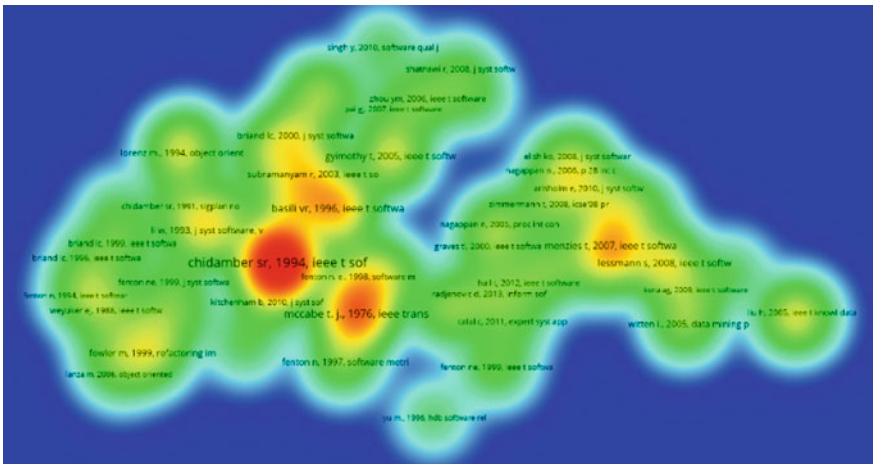

Fig. 3 Co-citation density map *Source* Web of Science. Map generated by VOSViewer

3.3 Detailing, Integrating Model and Evidence-Based Validation

The detailing is achieved using co-citation which is a search for the main approaches and for any coupling, with a view to presenting the principal sources of the research. After that the integrating model will be presented with the evidence-based validation.

Figure 3 shows the density map based on co-citation. Mccabe, T. J. (1976) has an approach nucleus of a historical nature. Based on his work one can see the growth of interest in the complexity of software in 1976. Halstead (1977) appears in that very same nucleus ratifying the earlier work. Those were the origins of software metrics.

There is another red patch in Fig. 3 corresponding to the work of Chidamber [24], who reports on the increasing improvement of processes driving the growth of software metrics, especially for object-orientated projects and that is in agreement with Basili [25], thereby formatting one of the strongest metrics approaches to object-orientated projects. Lastly there is a third pale red blotch in which the work of Menzies, T., appears, revealing a third approach to software metrics involving their application in data mining for the purpose of avoiding errors by means of defect predictors.

With the three most important approaches identified, the next step is to use Bibliographic Coupling (Fig. 4) to map the currently most important sources for research. To correct for the time factor in the number of citations this research considered the normalized numbers of citations [12].

The diversity of approaches in the current literature stands out. There is a miscellany of measuring and evaluation methods and studies of the various different software metrics.

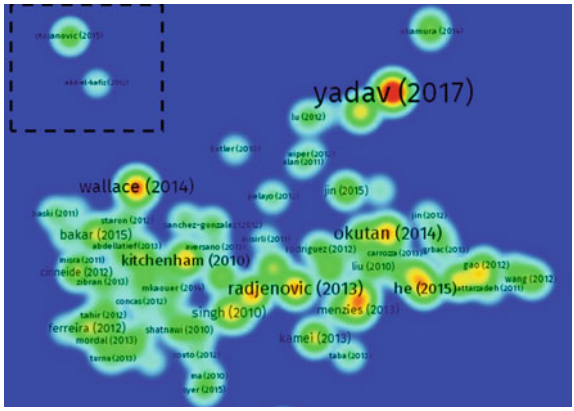

Fig. 4 Bibliographic coupling density map. **a** Elements displaced from the image frame inserted. *Source* Web of Science. Map generated by VOSViewer

In this case there is only one red nucleus visible but there 7 orange ones and 7 yellowish ones. Some of the yellow nuclei are close to other yellow ones suggesting a certain proximity of the respective studies. The single red nucleus refers to Yadav [13] and indicates a model tested and validated in the literature as an indicator that predicts defects of software in the early stages of development (analysis of requirements, design, implementation) offering qualitative information based on fuzzy logic associated to cost saturation, future problems and optimized development strategies [13]. The nucleus represented by Wallace's [14] empirical study proposes and tests a prediction model on the use of software metrics based on the Technology Acceptance Model. Those authors intention is to offer a guide for software engineers when selecting software measurements and to facilitate coordination of the software metrics planning [14]. Another nucleus that stands out is the one represented by Okutan [15] which conducts an empirical study of software metrics related to defect prediction for Bayesian Networks in an effort to optimize the set of metrics used on the basis of an investigation of Promise data repository metrics [15]. Radjenović's [19] work, mentioned above, dialogues with Madeyski [26] and Singh's [21] outstanding empirical studies, both studying flaw prediction; the first using process metrics and the second validating an object-orientated metrics [16]. Shin [11] and Menzies [27] represent a focus on the ways of thinking software engineering data; a factor that should be determinant in metrics selection. Inside another perspective, he [17] argue in favor of process metrics presenting a guide for the selection of a simplified metrics set.

Two analyses were performed with the abstracts of the articles for 2017 and 2018, to create the integrating model. One of the analyses was based on Descending Hierarchic Classification with the aim of determining the main classes that are addressing software metrics; the other was based on an actual reading of the most cited articles, classifying them according to the type pf research and the levels of metrics and characteristics that have intersections, all with the aim of understanding the taxonomy of those most cited articles.

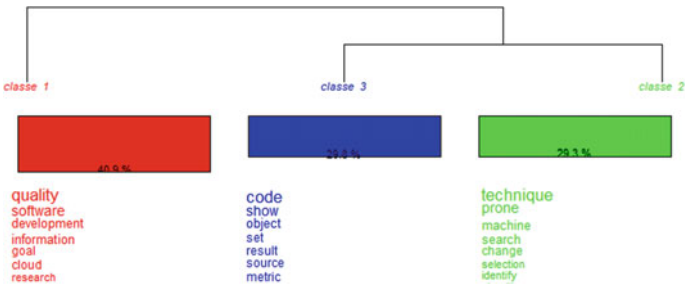

Fig. 5 Descending hierarchic classification dendrogram. Taken from Web of Science. Dendrogram generated in Iramuteq

The first analysis examined 60 abstracts and found 311 text segments of which 70.01% were made use of. The text segments were organized into three classes: Class 1 with 40.93%, Class 2 with 29.30% and Class 3 with 29.77% (Fig. 5).

In Class 1 the most representative works appear, namely: Hussein, A.; Kumar, N.; Okamoto, T.; Tirumalai, S. V.; Dahab, S. A.; Zhao, F.; Ganea, G.; Densumite, S.; Lumpe, M.; Ma, J.; Ali, M. M.; Shi, Y. With the exception of Okamoto, T., all those authors published articles in 2017. Analyzing the words that represent the class such as Quality, Software, Development, Information and Goal, it can be seen that they all share a similar concern for software quality right from its development by means of metrics and especially in cloud computation environments. Accordingly the glass is called **Metrics for Quality in Cloud**. In class 2 the works of Basal, A.; Malhotra, R.; Yan, Y. Q.; Shatnawi, R.; Stuckman, J.; Yohannese, C. W.; Morasca, S.; Azzeh, M.; and Huijens, H., are the most representative. Analyzing the words most associated to class 2 such as Technique, Prone, Machine, Search and Change, it can be seen that the authors' research is directed at software metrics utility such as techniques for constructing research and machine-learning algorithms. There are also some studies based on prediction, statistical tests and comparisons of models to test their efficacy and they too make use of software metrics. According the class is referred to as **Software Metrics as a Technique**. Lastly there is Class 3 where the representative authors are Kumar, L.; Gil, Y.; Anwer, S.; Yadav, H. B.; Kumar, C.; Suganantham, S.; Ebad, S. A.; Cinneide, M. O.; Mansoor, U.; Zhang, F.; Savic, M.; Gu, A. H.; Sultana, K. Z.; and Scalabrino, S. All of them had their articles published in 2017. The most frequently occurring words in that class are Code, Show, Object, Set, Result, Source and Metric. The analysis of those words suggests a strong tendency to studies on the use of object-orientated and source code-orientated software metrics, thereby ratifying their authors' interest in aforementioned themes. That being so the class was called **Current uses of software metrics**.

Thus from the Descending Hierarchy Analysis it can be concluded that the three classes that were found and duly denominated, namely: (a) Metrics for Quality in Cloud, (b) Software Metrics as a Technique, and (c) Current Uses of Software metrics, agglutinate more recent work (2017–2018) addressing software metrics and integrate

Table 1 Identification of the principle authors in the citation method. *Source* Web of Science

Author	Article	No. citations WoS/Scopus/GS index	Category
Kitchenham, B	What's up with software metrics?—a preliminary mapping study	70/103/181	(i)
Radjenović, D	Software fault prediction metrics: a systematic literature review	69/111/186	(i) (1)
Shin, Y	Evaluating complexity, code churn, and developer activity metrics as indicators of software vulnerabilities	62/115/204	(ii, iii) (B, C) (2)
Singh, Y	Empirical validation of object-oriented metrics for predicting fault proneness models	60/–/147	(iii) (A) (1, 7)
Gao, K	Choosing software metrics for defect prediction: an investigation on feature selection techniques	52/92/146	(ii) (1, 3, 2)
Menzies, T	Local versus global lessons for defect prediction and effort estimation	41/–/129	(iii) (C) (1, 4)
Ferreira, K	Identifying thresholds for object-oriented software metrics	38/63/100	(iii) (A) (6)
Liu, Y	Evolutionary optimization of software quality modeling with multiple repositories	33/52/81	(ii) (5, 1, 3)
Brown, N	Managing technical debt in software-reliant systems	–/142/245	(iv) (C) (4)
Alves, T	Deriving metric thresholds from benchmark data	–/83/135	(iii) (B) (6)
Rahman, F	How, and why, process metrics are better	45/76/124	(iii) (B, C) (1, 3)
Chowdhury, I	Using complexity, coupling, and cohesion metrics as early indicators of vulnerabilities	36/66/131	(iii, iv) (A, B) (1, 2, 4, 7)

them to a three-part integrating model. The second analysis consisted of a meticulous reading of the most cited articles in order to obtain the taxonomy of the most important works (Table 1).

In order to map the amplitude of the presence of the works in databases open to languages other than English, a comparison was made with their citations in Scopus and GS [18].

In regard to types, the studies were organized into (i) Systematic reviews (ii) Case studies (iii) Empirical Models (iv) Conceptual study. As regards the type of metrics the were: (A) Object or design-orientated Metrics (B) Source code metrics (C) Process metrics (D) Traditional metrics (E) Dynamic metrics. In regard to the characteristics of the metrics studied they were: (1) Flaw and defect predictor metrics (2) Software vulnerability indicators (3) Selection of Software quality characteristics (4) Effort and Development estimation (5) Software evolution and quality metrics (6) Threshold metrics (7) Complexity metrics.

Those articles that presented systematic reviews were the most cited but the majority of the studies are of the empirical model type. The works addressing source code and process metrics were the most frequent and most cited together with those addressing object or design-orientated Software Metrics. These results corroborate the classes found earlier in the more recent works. Lastly, as regards the most frequently registered characteristics in the most cited studies they are the flaws and defects predictor metrics followed by the Software vulnerability indicators.

The three levels of categorization were found to be independent and what characterizes the measures is considered to be the objective of the author in exploring a given metrics, one which might be considered by other authors as being merely an indicator for another different measure. Therefore, the so-called characteristics of the measurement can be considered in sub-categories of indicators that partially represent those characteristics. The finality of the empirical studies is to certify, statistically, to what extent a given indicator predicts specific categories. In order to maintain consistency, however, our categorization did not attain that level of detail

It can be seen that some of the work that is indexed in the *Web of Science* (WoS) is not in the Scopus and vice versa. Furthermore, there is a greater number of citations registered in the database that has the wider linguistic scope and above all in the GS which is open.

According to the thresholds established in [3], the theme of software metrics has proved to be based on solid evidence because the use them is the object of more than one systematic review of literature on well delineated, randomized experiments [2, 19], in addition various research centers around the world are studying the theme. Accordingly, not only the principle contributions regarding software metrics but also the importance of the review studies have achieved a great number of citations and aroused considerable interest, as witness the works of Kitchenham [2] and Radjenović [19]. A general analysis of the results obtained shows Radjenović [19] at the center of the various maps, ratifying that author as an indispensable source for understanding the theme.

4 Final Remarks

This research aimed to provide a model to integrate the principle contributions of the scientific literature on software metrics with an impact on that field, in obedience to the steps established by a bibliometric methodology of an exploratory nature

denominated the consolidated meta-analytic approach theory. The integrating model revealed three classes named in accordance to the macro-context of the studies set: (a) Metrics for Quality in Cloud (40.93%), (b) Software Metrics as Technique (29.30%), (c) Current Uses of Software metrics (29.77%). The study identified the main authors, most common approaches and principle lines of research established according to the laws of bibliometrics thereby providing a response to research questions.

It is believed that the results will assist the Brazilian Army to identify the most up to date and appropriate software metrics to apply in its IT systems program planning [14]. As an agenda for the future it is hoped to expand the class studies to all research samples and to be able to present a panorama of changes, period by period. As well as including analysis from other relevant databases (e.g. GS, Scopus, IEEExplorer, Springer Link etc.) in order to absorb all relevant works related to the subject.

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Risk and ISO 9001: A Systematic Literature Review

Yasmin Silva Martins and Carlos Eduardo Sanches da Silva

Abstract The search for excellence, related to the processes, products and services quality and to the market requirement, makes organizations to implement their Quality Management Systems (QMS). In this context, with ISO 9001 standard revision, published in 2015, a new requirement is established: risk-based thinking. The main focus of this article is to provide information, by doing a Systematic Literature Review (SLR), about the state of the art of Risk and ISO 9001 standard, identifying the risks' approaches used by the organizations and finding gaps and inconsistencies in the literature. This SLR was conducted as follows: (a) establishing the research main question; (b) locating studies (defining the research sources, timing and criteria); (c) analysis and synthesis (supported by QSR NVivo); and (d) findings and conclusions. The main field of research was chosen to answer the question "what kind of methodologies and methods, companies that have a QMS based on ISO 9001 can use as a support to the risk-based thinking requirement?" The paper's aim is also to contribute with companies who are looking forward to implement the Risk Management in their processes.

Keywords Risk · ISO 9001 · Quality management system

1 Introduction

Organizations have been facing a strong and competitive market besides high customer expectations, what makes them to look for ways to stay competitive. To reach that, companies try to improve the activities that add value to the process and business [1].

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The search for excellence is intimately related to their products, services and processes' quality and to achieve it, many organizations opt for a Quality Management System (QMS) implementation, supported by several models and tools [2]. Besides not being considered a TQM model, the ISO 9001 standard can be a good start for companies that are at the beginning of the quality achievement process [3].

The ISO 9001 standard, elaborated by the Technical Commit of the International Standardization Organization (ISO/TC 176), defines requirements to support organizations on the quality and conformity of their products and services, fulfilling customers' necessities [4]. International Organization for Standardization (ISO), in 2016, announced that there are 1,643,529 valid ISO 9001 certificates worldwide, being only 7% in ISO 9001: 2015. In Brazil, there are 20,908 certified companies, 3% in ISO 9001:2015 [5].

On its latest version, ISO 9001:2015 contains changes apparently easy but that implies big challenges for the organizations [6, 7]. One of the most significant changes was the risks approach, implicit on the preview versions of the standard and now treated as "risk-based thinking", as a requirement for the entire organizational environment. This concept seeks to instigate organizations to be more careful and to think in long-term [3, 8–10].

The risk management is a very comprehensive term and the researches related to it are in contrast, much specifics, which always leads to a gap, even small, to be filled [11]. This can be inferred from a number of studies that have analyzed risk management in the context of companies QMS and ISO 9001 implementation processes.

It is important to observe that being in the Digital Transformation Era, organizations have to adapt their strategies and models for business processes to the digital reality [12], what can also be related to the risk-based thinking approach, in terms of long-term thinking and opportunities to company's growth.

In order to assist further research in this field, the paper aims at finding relevant literature contributions on risks, with particular interest on its relation with ISO 9001 standard, in the aspects of its emerging issues, most frequent talked themes and existing gaps. This paper was structured as follows: the first section covers the introduction; Sect. 2 characterizes this paper's research methodology; and Sect. 3 describes the findings and conclusion.

2 Research Methodology

To conduct the study, the authors based on a systematic literature review (SLR) which is a methodology used by academic researchers to manage knowledge diversity, mapping and evaluating the existing intellectual territory, being capable to develop and increase the subject aspects, contributing to the state of the art [13].

The SLR was conducted as follows: (a) establishing the research main question; (b) locating of studies, where it is established the search sources, timing and criteria; (c) analysis and synthesis (supported by QSR NVivo); and (d) findings and conclusions

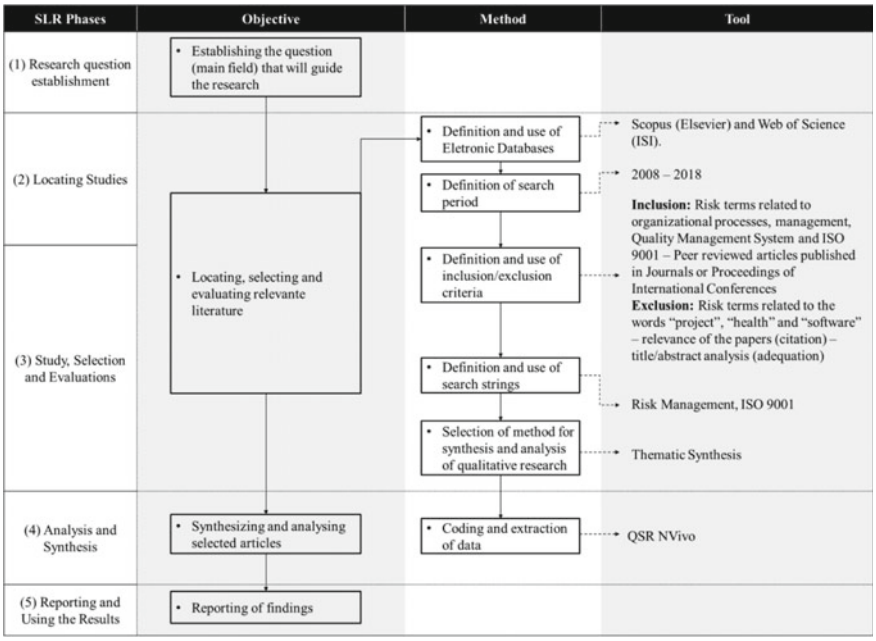


Fig. 1 SLR phases, methods, criteria and tools (*Source* adapted from [14])

[14, 15]. The topics (a) and (b), described previously, are discussed on this section as follows.

2.1 Locating of Studies

The SLR process (Fig. 1) was conducted as follows: the main field of research was choose to answer the question "what kind of methodologies and methods, companies that have a QMS based on ISO 9001 can use as a support to the risk-based thinking requirement?". The location of articles considered the key words in two electronic databases: Scopus and ISI Web of Science (WoS), citation indexes that coverage mainly focuses on journals [16]. Li et al. [17] affirms that WoS "*is the oldest citation database with both bibliographic data and citation data going back to 1900*". Besides being oldest and having the longest coverage, WoS does not index all of the journals that are found in Scopus, what aims to the fact that Scopus "*has a larger proportion of exclusive journals and this is the case in all fields*" [16].

The period of research was established based on the ISO 9001 standard transition process: its past edition was published in 2008 and replaced in 2015. In terms of key words, it was observed macro themes, which are "risk" and "ISO 9001". The standard

Table 1 Systematic literature review process: papers selection (elaborated by the authors)

Criteria	Filters	No. of papers
Keywords	"Risk", "ISO 9001", "Quality Management System"	
Type	Papers and Conference Proceedings	220
Exclusion	"Project", "Health", "Software"	91
Thematic analysis	Organizational Processes/Contexts	46

Fig. 2 50 most frequent words (elaborated by the authors supported by QSR NVivo)

version was not specified due to the transition process. The research included peer reviewed articles published in Journals or Proceedings of International Conferences.

From Table 1 it is possible to see the number of found papers and the selection process criteria, inferring the excluded ones. The process's result was 46 articles.

2.2 Analysis and Synthesis

As inferred from Table 1, the locating of studies resulted in a final number of 46 articles, 18 of them found in both WoS and Scopus databases. To analyze the selected articles, it was used the thematic synthesis approach, coding and extracting data with QSR NVivo, an effective computer software used to code data from full articles [15].

QSR NVivo supported the most frequent words used in the literature analysis (see Fig. 2), making it easier to find the main subjects approached by each article.

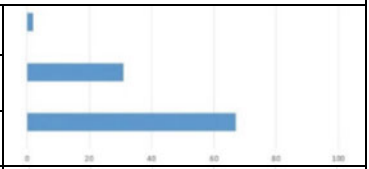
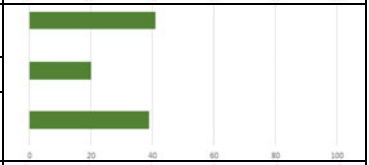
Articles Classification			
Articles/year period	2008 - 2011	2%	
	2012 - 2015	31%	
	2016 - 2018	67%	
Articles published by database	Scopus	41%	
	WoS	20%	
	Scopus and WoS	39%	
Articles published by type	Journal	74%	
	Conference	26%	

Fig. 3 Articles classification (elaborated by the authors)

In parallel with the investigation above, the articles were analyzed by year of publication, indexed databases and types of publications (see Fig. 3); Table 2 presents the selected articles list.

The main analysis of the present article is described in this section. To answer the question proposed at the beginning of the SLR, the 46 papers were analyzed by methodologies, methods, models and/or tools presented in (see Fig. 4).

It was found from the selected papers, 16 (P1; P3; P4; P6; P8; P11; P12; P13; P14; P19; P23; P28; P31; P32; P39; P44) that do not mention any of the topics listed above. Therefore, besides presenting subjects related to risks, quality management system and ISO 9000, they were not used to compose the final chart. All of the others, propose, explain or mention some methodology, method, model or tool to support the risk management activities and to the "risk-based thinking" required by ISO 9001.

It can be inferred from the Fig. 4 that 15 papers describe methodologies, while 22 present some method/model/tool. The most frequent methodologies observed were ISO 31000 and PDCA cycle. Regarding to them it is important to highlight that ISO 31000 is based on PDCA, prescribing a risks approach unfolded in: to identify, to analyze and to evaluate (P—plan), to treat (D—do), to monitor (C—check) and to analyze (A—act). The most related tool was the FMEA (Failure Modes and Effects Analysis), probably due to its wide dissemination and customers' requirements (for example automotive and aeronautic sectors and healthcare products). However, FMEA has its limitations.

The analysis process can become cumbersome and long, with possible costs for application; and the method is not prepared to discover complex failure modes involving various failures or subsystems. To solve that question it should be used the FTA (Fault Tree Analysis) [18].

Table 2 Articles included in the literature review by author(s)/year, title and database

No.	Author(s)/year	Title	Database
[P1]	Anttila & Jussila, 2017	ISO 9001:2015—a questionable reform What should the implementing organizations understand and do?	WoS
[P2]	Atan, Ramly, Musli Mohammad, 2017 [21]	A review of operational risk management decision support tool	Scopus
[P3]	Barata, Rupino and Costa, 2013 [22]	Developing an IS quality culture with ISO 9001: Hopefully, a never ending story	Scopus
[P4]	Boiral, 2011 [23]	Managing with ISO Systems: Lessons from Practice	WoS/Scopus
[P5]	Budaj and Hrnciar, 2015 [24]	The Importance of Risk-Based Thinking for Enterprise Performance Planning	WoS
[P6]	Chen and Chang, 2017 [25]	A practical flow regarding 2nd party audit on quality proficiency in supplier management	Scopus
[P7]	Chiarini, 2017	Risk-based thinking according to ISO 9001:2015 standard and the risk sources European manufacturing SMEs intend to manage	Scopus
[P8]	Da Fonseca, 2015 [26]	ISO 14001:2015: An Improved Tool for Sustainability	WoS/Scopus
[P9]	Emetumah, 2017 [27]	Integrated management systems as a risk management tool: Combining ISO 9001, ISO 14001 & OHSAS 18001 standards in process industries	WoS/Scopus
[P10]	Ezrahovich et al. 2017 [28]	Risk-based thinking of ISO 9001:2015—The new methods, approaches and tools of risk management	Scopus
[P11]	Fonseca and Domingues, 2017	How to succeed in the digital age? Monitor the organizational context, identify risks and opportunities, and manage change effectively	Scopus
[P12]	Fonseca, 2015a	FROM quality gurus and TQM to ISO 9001:2015: A review of several quality paths	WoS/Scopus
[P13]	Fonseca, 2015b	ISO 9001 Quality Management System through the lens of Organizational Culture	Scopus
[P14]	Galetto, Franceschini and Mastrogiacomo, 2017 [29]	ISO 9001 certification and corporate performance of Italian companies	WoS/Scopus
[P15]	Giannetti and Ransinf, 2016 [30]	Risk based uncertainty quantification to improve robustness of manufacturing operations	Scopus

(continued)

Table 2 (continued)

No.	Author(s)/year	Title	Database
[P16]	Gołaś, 2014 [31]	Risk Management as Part of the Quality Management System According to ISO 9001	Scopus
[P17]	Gołaś, Mazur and Gruszka, 2016 [32]	Improving an organization functioning in risk conditions in accordance with ISO 9001: 2015	WoS
[P18]	Gorlenko, 2015	Development of Management Methodology for Engineering Production Quality	WoS/Scopus
[P19]	Harafonova, Zhosan and Yankovo, 2017 [33]	Distinctions and features of ISO 9001:2015 standard implementation in the context of social and strategic development of enterprises	WoS
[P20]	Harasymiuk and Barski, 2016 [34]	Risk management as a determinant of the effectiveness of the quality management system in a building company	WoS
[P21]	Kline and Hutchin, 2017 [35]	Enterprise risk management: A global focus on standardization	Scopus
[P22]	Kotek et al. 2016 [36]	Risks in industrial management systems	Scopus
[P23]	Lenning and Gremyr, 2017 [37]	Making internal audits business-relevant	Scopus
[P24]	Liu Qi et al., 2012 [39]	Modeling of Risk Treatment Measurement Model under Four Clusters Standards (ISO 9001, 14001, 27001, OHSAS 18001)	WoS/Scopus
[P25]	Liu, He and Cui, 2017 [38]	Product assembling quality risk analysis approach based on RQR chain	Scopus
[P26]	Luburić, 2015 [40]	Quality management principles and benefits of their implementation in central banks	Scopus
[P27]	Luburić, 2016 [41]	Knowledge and learning in terms of operational risk management in the financial and banking systems	Scopus
[P28]	Medić, Karlović and Cindrić, 2016 [42]	New standard ISO 9001:2015 and its effect on organizations	WoS
[P29]	Nováková, Pauliková and Cekanová, 2017 [43]	Risk Management as part of a Quality Management System in Woodworking companies	WoS/Scopus
[P30]	Pacaiová, Sinay and Nagyová, 2017 [44]	Development of GRAM—A risk measurement tool using risk based thinking principles	WoS
[P31]	Parra-Lopez et al. 2016 [45]	ISO 9001 implementation and associated manufacturing and marketing practices in the olive oil industry in southern Spain	WoS/Scopus

(continued)

Table 2 (continued)

No.	Author(s)/year	Title	Database
[P32]	Psomas, 2013 [46]	The effectiveness of the ISO 9001 quality management system in service companies	WoS/Scopus
[P33]	Rebelo, Silva and Santos, 2017 [47]	The integration of standardized management systems: managing business risk	WoS/Scopus
[P34]	Rewilak, 2015 [48]	MSA Planning—A proposition of a method	Scopus
[P35]	Rodriguez, 2017 [49]	Partial implementation of the Quality Management System by ISO 9001:2015. Case study	WoS
[P36]	Ruamchat, Thawesaengskulthai and Pongpanich, 2017 [50]	Development of quality management system under ISO 9001:2015 and Joint Inspection Group (JIG) for aviation fueling service	Scopus
[P37]	Rybski, Jochem and Homma, 2017	Empirical study on status of preparation for ISO 9001:2015	WoS/Scopus
[P38]	Sari et al., 2017 [51]	From ISO 9001:2008 to ISO 9001:2015: Significant changes and their impacts to aspiring organizations	WoS/Scopus
[P39]	Sartor et al., 2016 [52]	The SA8000 social certification standard: Literature review and theory-based research agenda	WoS/Scopus
[P40]	Savino and Brun, 2017 [53]	A fuzzy-based multi-stage quality control under the ISO 9001: 2015 requirements	WoS/Scopus
[P41]	Sitnikov and Bocean, 2015 [54]	The role of risk management in ISO 9001:2015	WoS
[P42]	Sitnikov et al., 2017 [55]	Risk management model from the perspective of implementing ISO 9001:2015 standard within financial services companies	WoS/Scopus
[P43]	Sousa, Nunes and Lopes, 2015 [56]	Measuring and Managing Operational Risk in Industrial Processes	WoS/Scopus
[P44]	Vasile, 2017 [57]	A critical approach of thinking risk-based existing in the new issue of ISO 9001: 2015 standard	Scopus
[P45]	Vasile, 2012 [58]	The improvement of the manufacturing processes of electric servomotors by applying the new editions of the international standards on the quality and environment	Scopus
[P46]	Wong, 2017 [59]	Risk-based thinking for chemical testing	WoS/Scopus

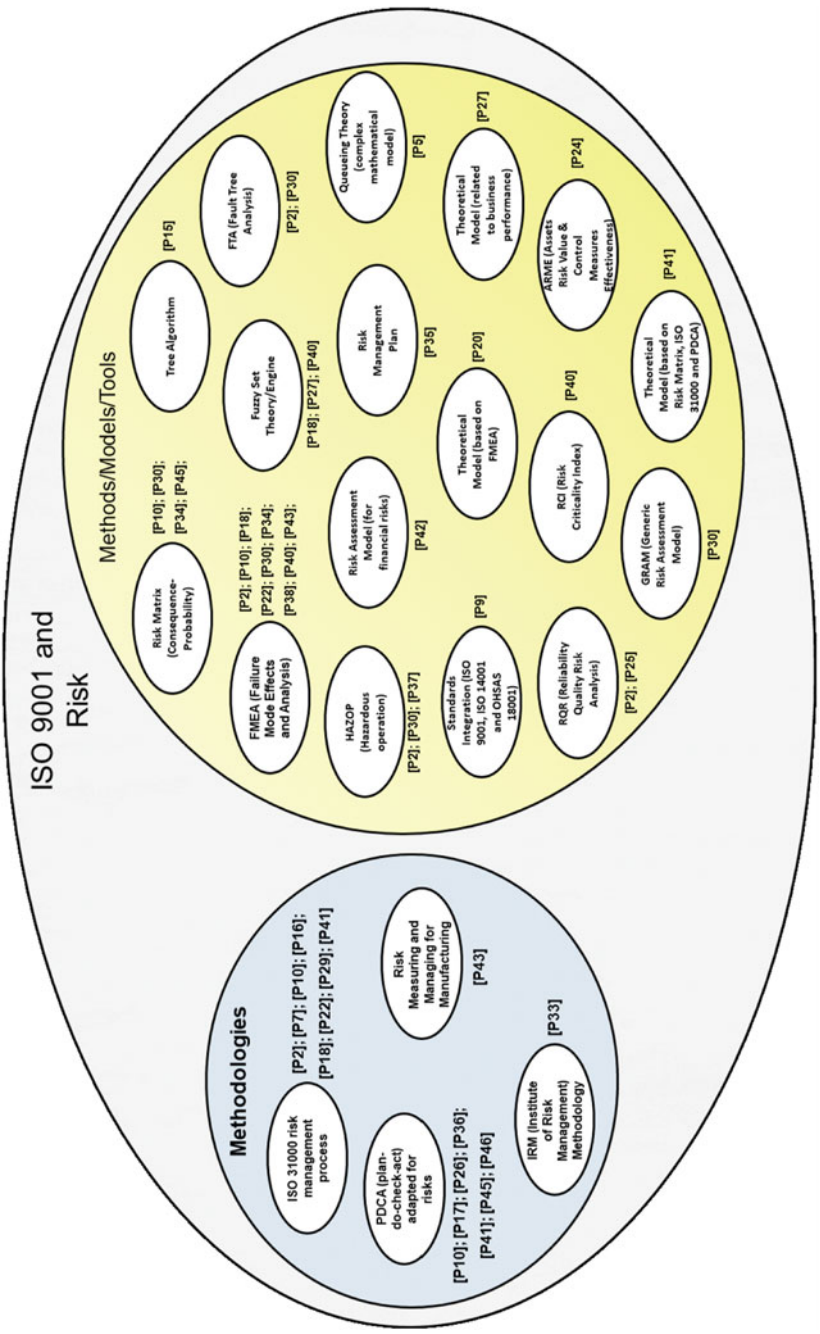


Fig. 4 Articles x methodologies/methods/models/tools

In addition, the mathematical formulation for the Risk Priority Number (RPN) is questionable and discussible since there is not any justification that, the product of Severity, Occurrence Probability and Detectability, results in the RPN [19, 20].

That tree factors are hard to be determined precisely because most of the FMEA's information is expressed by a linguistic form, what makes the interpretation in a subjective way for the reader [19]. The same problem can happen with the Risk Matrix.

3 Findings and Conclusion

Nowadays, researches in risks and ISO 9001 are increasing, once that the companies are in an embryonic and underdeveloped stage to integrate the risk management approach into their QMS's. This SLR addresses a current challenge for companies that want to maintain their QMS's, helping them to understand how the risks approach can be realized, supported by theoretical models designed and described, in the most part, in conformity to ISO 31000 methodology.

As it was described in the preview section, qualitative tools may have issues that, if not observed or treated adequately, can give unexpected results to the analysis. To avoid problems like that, companies should look for combinations of qualitative and quantitative tools that better adequate to their necessities.

However, it has much more to be done regarding to the applicability of the tools in the companies' contexts and about the efficiency of them. The authors suggest as future researches the application of some methodology in the context of certified companies, to evaluate its efficiency for the risk-based thinking approach.

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The Importance of Analysis Cycles in Defining Criteria for Selecting Digital Era Projects

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Abstract The technological advances of the Digital Era can be a success depending on the quality of the data for decision making. There are many opportunities to invest in solutions for quality improvement. Many technologies promise to identify faults and even resolve them automatically. There is a gap in identifying the criteria that support decision making. It has been perceived the need to describe how the flow is for decision making of quality improvement projects and innovation within an automotive company. The purpose of this article is to examine and identify how an industry, which invests in high technology, is addressing the advances of these technological transformations. The applied methodological design is the explanatory research carried out in the form of a case study through the combination of document analysis, direct observations and semi-structured interviews. The contribution of this research highlights the importance of using criteria that best demonstrate the benefits, constraints and risks in the decision-making process for solving quality problems with the adoption of new technological resources. The main results indicate a convergence with the already existing data in the literature, considering, for example, the local culture. There is a need to consider other criteria to better inform decision-making in the adoption of technological artifacts.

Keywords Criteria · Decision-making · Quality · Continuous improvement and digital era projects

1 Introduction

Digital transformations provided an unlimited flow of information. Opportunities for real-time data access anywhere can mean an effective profit to organizations. The means to reach this level certainly goes through the management of manufacturing and quality. Elimination of losses combined with standardized and controlled

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production processes is the initial step. Thus, in the cycles of continuous improvement can be identified from possibilities of incremental progress to innovative improvement projects. Cycles of problem analysis are critical to knowing the current situation and designing the desired steps to obtain more effective results.

After identifying a problem and taking the actions of containment, it can be concluded that the definitive solution is developed through an in-depth study for the development of a project. With reliable information, the solutions can be long lasting, otherwise, they can make the situation worse. With the technological resources available a change of concept can become a viable alternative. In order to make feasible criteria for decision-making not considered until now, they will need to receive attention. The gain will continue to be defined by the numerical value of cost, but certainly better supported by the analyzes of other sources of impact.

In this way, a gap is identified in the decision-making process for the adoption of new technologies by the industries, mainly to apply in the solution of quality problems. Common sense preaches that feedback comes through the launch of new products. However, it has already been proven in the literature that investing in product quality is a differential directly linked to the cost of product, image or brand.

The question that the article wants to address is to describe how the flow is for decision making of quality and innovation improvement projects within an automotive industry.

The study will be carried out by examining the criteria applied to solve problems, the commitment of those involved and the specification of the current criteria and others, which can contribute to the decision making by investments.

The applied methodological design is that of the explanatory research carried out in the form of action research, that is, on an empirical basis. Information collection occurred through the use of multi-methods combining document analysis, direct observations and semi-structured interviews conducted in an automotive industry.

The contribution of this research is to highlight the importance of the use of criteria that best demonstrate the benefits, constraints and risks in the decision making to solve quality problems with the adoption of technological advances.

The article is composed of this introduction followed in Sect. 2 of the theoretical framework and Sect. 3 of the methodological design. Section 4 presents the results that will be discussed in Sect. 5. Finally, in Sect. 6 is the future conclusion and opportunity followed by bibliographical references.

2 Background

The cycles of industrial evolutions have produced the digital transformations that allow the union of previously unimagined systems. Direct communication between data and image impacts organizations' management systems due to the accessibility of information in real time. Soon, a problem can be detected faster and more accurately, which can make better decision making. With access to more data, the positive and negative requirements identified by customers make it necessary to

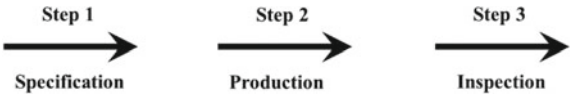


Fig. 1 Old Shewhart cycle [6]

develop more flexible production systems through modular changes [1]. The development of projects has more variables to consider and with it increases the risks in the production line. Along with this evolution are also updated the standards to which the companies are certified.

2.1 Digital Era

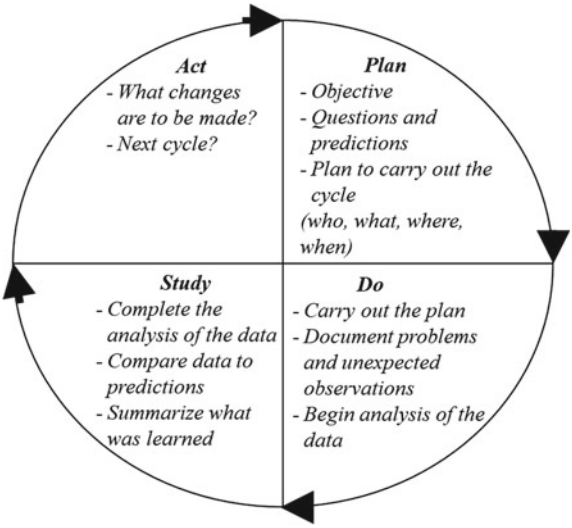
As said by Birchfield (2002, cited in [2]) the evolution of information systems has a crucial role in the adoption of new information technologies in manufacturing. Computational simulations, which include manufacturing control products and equipment and resource planning systems, are assembled in a virtual simulation environment. This helps to improve the analysis of future problems such as interference between parts, ergonomics and manufacturing lead-times. In the same way, there are other innovations available to improve productivity. In addition to these, there are also a diversity of data, machines and consumers that can be treated to better address solutions to internal and external organizations.

2.2 Lean Production and Analysis Cycles

The system of lean production through the reduction of waste has the objective of assigning greater value to the product [3]. Manufacturing fault-free and customer-focused products is the philosophy [3, 4]. With the diffusion of the lean production systems also appeared strategies of quality improvements, considered also within the development of new products. The points considered critical of quality deserve a significant attention. Because of this, the companies invest in integrated and robust production and quality management systems applying through various quality tools, from Shewhart, Kaizen (continuous improvement) and other cycles. They deal with and solve problems, which generate better artifacts and processes, as well as knowledge making use of improvement cycles [5]. These stages of continuous improvement have their origin in studies of the evolution of the scientific method. The model developed by Shewhart in 1939 proposed that the phases should follow in a cycle, although it is represented in line as shown in Fig. 1 [6].

The model has a new proposal in 1994 that includes a study stage in order to emphasize the construction of a new knowledge, as shown in Fig. 2. Given that it would not yet contemplate the prediction, the researchers Langley, Nolan and Nolan

Fig. 2 PDSA cycle [6]



(1994, as cited in [6]) included three questions: (1) What is necessary to try to improve? (2) How to identify that change is an improvement? and (3) What changes must be made that will result in improvement? The combination of the questions with the PDSA cycle form the improvement model proposed by Langley et al. (1996, as cited in [6]), presented in Fig. 3.

2.3 Lean Six Sigma—LSS

The Lean Six Sigma [7–9] is a strategy that contains a statistical method of problem solving, coupled with improved process speed with reduced time. In its philosophy, it relies on analysis cycles. The focus of this strategy is on reducing the potential variability of the process and improving quality [5, 10]. Figure 4 shows the alignment of the PDCA cycle with the DMAIC method—Define, Measure, Analyze, Improve and Control—applied by LSS [7, 11]. This method involves the application of several analytical tools, such as: the seven quality tools (Layering, Check Sheet, Pareto Chart, Cause-Effect Diagram, Histogram, Scatter Diagrams, and Control Chart), the seven planning tools (Diagrams of: Affinities, Relationships, Tree, Matrix, Prioritization, Decisional Process and Arrows) and failure analysis in addition to other tools (Process Capacity Index, Repeatability and Reproducibility, Sampling, Regression Analysis, multivariate and Reliability) [11].

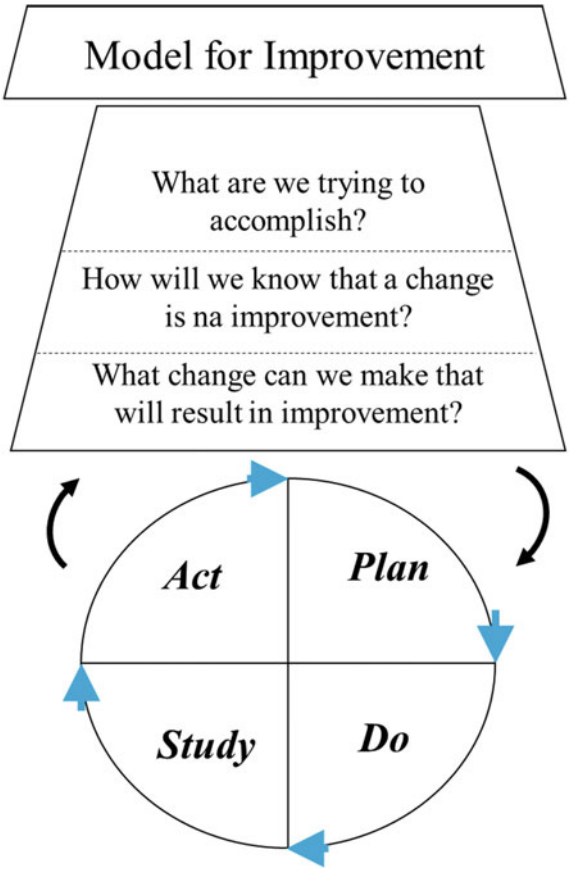


Fig. 3 Question supplement [6]

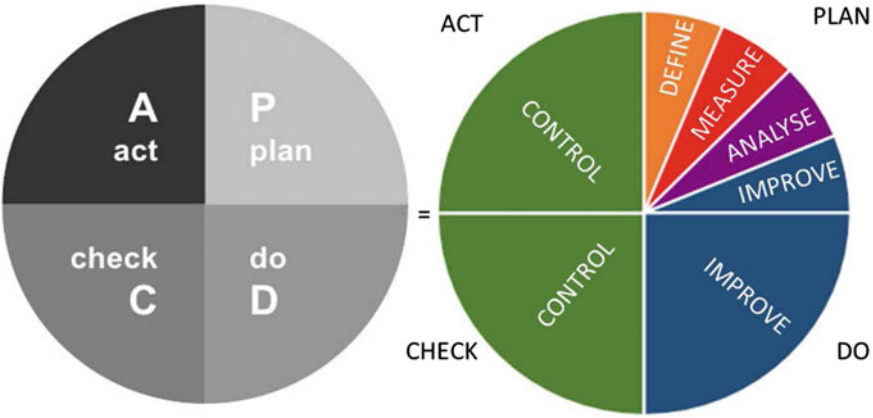


Fig. 4 PDCA and DMAIC alignment [6]

2.4 Project Management

The definition of a widely disseminated project in the sense of producing a unique result has in its process of monitoring and controlling a cycle of analysis whose purpose is to assist the other stages of initiation, planning, execution and closure. Another important, but untreated cycle, is the lessons learned throughout the project. All this information can optimize the project portfolio management process. Portfolio management follows criteria that are fundamentally the analyzes of the threefold constraint, scope, time, cost and sometimes considered quality [12–15]. Considering criteria more appropriate to the use and allied to the organizational strategy may be one of the greatest challenges for decision making [12, 15]. Since projects that have the best cost/benefit ratio will have priorities. However, the concept of gain needs to be updated. Triantaphyllou (2002, as cited in [12]) considers that a multicriteria analysis that evaluates different dimensions and organizational needs together can be more meaningful to achieve more efficient results. There is no ready-made solution that attends every type of project because it depends on the preferences and values of the decision maker [12, 15].

2.5 ISO 9001:2015—Continuous Improvement and Integration

In order to attend the requirements of consumers and continuous improvement of quality, there is the ISO 9000 family of standards. Its function is to help organizations to be more efficient and to promote greater customer satisfaction. It is based on principles of quality management and continuous improvement [16, 17]. The most recent ABNT NBR ISO 9001:2015 review includes risk-based focus, incorporates the PDCA cycle with the emphasis on leadership commitment. This can ensure that processes have sufficient recourse with proper management. This allows for the implementation of preventive controls that reduce problems and identify several opportunities for improvement considering change of rupture, innovation and reorganization. Within the tips for achieving certification, it is suggested that core processes be identified in order to attend the organization's and consumers' goals. This forms part of the basis of the quality management system. It should also be noted that the standard is based on the principles of quality found in ABNT NBR ISO 9000, which are customer focus, leadership, people engagement, process approach, improvement, evidence-based decision making and relationship management.

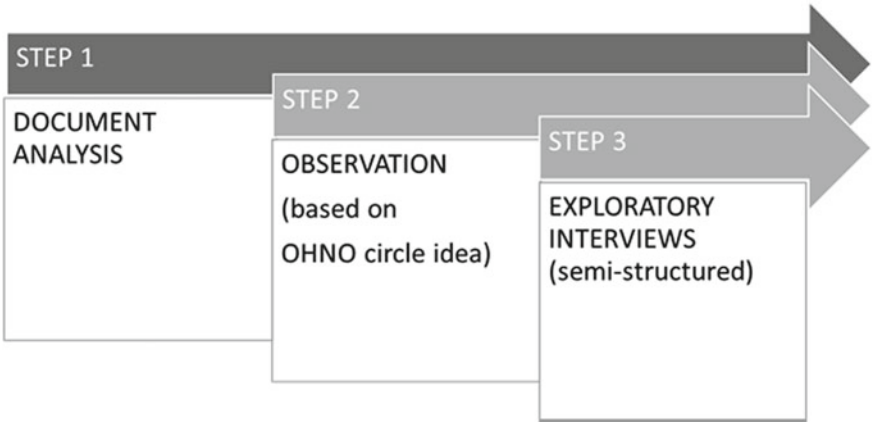


Fig. 5 Research method of the article

3 Methodology

This article is part of studies on the topic of quality improvement in an automotive industry. The hypothesis considered was that there were no criteria developed for the inclusion of new technologies in the solution of quality improvement problems.

The methodological design is an explanatory research carried out in the form of a case study, where the researcher and participants act in a cooperative way, with a qualitative approach. Figure 5 illustrates the procedure adopted for the paper.

The data collection was based on direct observation in documental analysis and semi-structured exploratory interviews, guided by a questionnaire based on the Likert scale [13] of five items (Agree Completely, Agree Partially, Neither Agree nor Disagree, Disagree Partially and Disagree Completely). The direct observations followed the model proposed by Ohno, that is, monitored locally during occurrences [18]. The script was constructed based on the theoretical basis and the documentary analysis, later adjusted with two interviews for calibration. The meetings followed a three-tier division, identification of participants, assessment of knowledge about the flow of quality problem solving, and finally, a macro observation on the vision of technological innovation projects. Held in an automotive industry in the final assembly area, specifically in process engineering.

4 Results

The analysis stage of specific documents and procedures related to innovation was performed on the organization's intranet and was not successful. Applied the same process of searching in the quality system, did not return any direct document linked

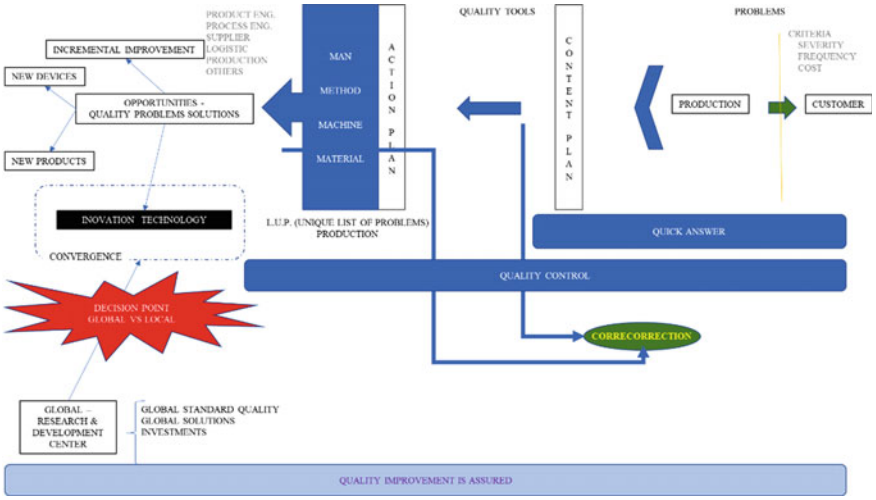


Fig. 6 Process flow

to innovation. The demand needed to be changed, the quality management procedures were evaluated. A way of analyzing quality problems was found, which indicates the application of Lean Manufacturing tools and an adaptation of a process of continuous improvement. From the identification of this path, an informal meeting with a quality improvement project manager was realized. It resulted in the access to a procedure of treatment of new ideas proposed by the collaborators. It derives from a weekly meeting, where the different initiatives are dealt with which are then tabulated and analyzed by a multidisciplinary group to verify the viability conditions. The opportunities are recorded in one of the organization's systems.

In the second stage, through direct observation and semi-structured interview with process engineering analysts, the flow for the analysis of quality problems was identified, as shown in Fig. 6.

From the daily inspections of quality, the problems are pointed out. At each work shift the occurrences are treated following procedures adapted from total quality management [7, 19, 20]. First, in the workplace until the stocks run out. At this point, the flow of analysis begins with the other participants in the process involved in the final assembly, where containment actions are defined and others that can define a rapid response in the direction of solving the situation. With the use of problem solving tools [3, 4], this research is continued to confirm the solution or the need to develop a more robust response to eliminate occurrences. A list of problems is maintained by supervision for follow-up. From this point on, they are addressed to the appropriate treatment, that is, directed to the responsible department that through a project will present an answer to the indicated fault. The list of obstacles is available for many areas, including research and development at the headquarters located in Europe, which also proposes improvement projects. These projects are included

Table 1 Criteria for procedural understanding of project implementation

Criteria	Min.	Max.	Average	Standard dev.
Knowledge of corporate goals	1,00	5,00	2,93	1,52
Commitment—quality improvement	1,00	5,00	4,00	1,55
Problems identification	2,00	5,00	3,21	1,14
Data acquisition	1,00	5,00	3,50	1,33
Data reliability	2,00	4,00	3,36	0,85
Root causes—problems	1,00	5,00	2,79	1,52
Action plan—problems	1,00	5,00	2,57	1,45
Projects prioritization	1,00	5,00	3,50	1,39
Standard criteria—prioritization	1,00	5,00	4,14	1,04

Table 2 Criteria for technological innovation in projects

Criteria	Min.	Max.	Average	Standard dev.
New technologies—procurement	1,00	5,00	3,71	1,52
Alignment—goals & new tech.	1,00	5,00	2,43	1,39
Metric standard—new tech. proj.	1,00	5,00	3,29	1,56
Commitment—stakeholders	1,00	5,00	3,14	1,68
Start of prod.—time no flexible	1,00	5,00	3,36	1,84
Estimated initial cost	1,00	5,00	4,29	1,17
Final evaluation of projects	1,00	5,00	2,70	1,52
Adequate criteria—result	1,00	5,00	2,86	1,77

in the organization's global strategies. In this way it reaches the point where the opportunities are. This is the meeting of the proposals, global and local and where many actions of implantation studies are taking place to help in the adoption and interaction on the technological advances.

The third stage was carried out through a semi-structured interview and with the questionnaire support in a group of employees who work directly on quality improvement projects in the final assembly: managers, project leaders and technical managers, totaling fourteen meetings. The profile of the participants has a mean age of 34, 7 years with a project management experience of 7, 8 years. Table 1 presents the level of general understanding of the process of targeting problems.

The discussion of results will be presented in the next section. After the stage regarding the general vision, from the understanding of the goals to the criteria applied in the prioritization of projects, the stage regarding the projects of technological innovations was executed. Table 2 reports the treatment of technological innovations.

In the same way as the previous table, this (Table 2) will have the discussion of the results presented in the next section. Regarding the questions open to propose

other criteria, in addition to the triple constraint (Cost, Scope and Time), considered to prioritize the projects were remembered the quality, the severity of defects, safety, urgency, technical training, human resources and participation in the marketplace. Similarly, when employees were asked to suggest criteria and metrics for the selection of new technology projects, the company considered gains, performance, quality, technology domination by the supplier, interoperability, leadership, technical training, solution acquisition objective, safety, functionality, time to start production and risks.

5 Discussion of Results

The step of searching for documents and procedures was not satisfactory, since it did not return any effective results. By expanding the search including the quality system it was possible to establish a research way. Here, it is necessary to consider the limitation of the researcher regarding the complete domain and access the information of the organization's intranet. The interest and help of managers in addressing the issue was important. Their reports point to ways that are being followed by the company and which began in 2017, such as the process of reception and treatment of employees' ideas, the formal and multidisciplinary process that counts on the participation of other units from South America to address innovative ideas and the creativity lab, which also has a system for registering and treating innovation opportunities. However, they are actions that did not show unification of method, mode, process, system and, mainly, of interconnection and direct collaboration. In this way it can be understood that the same initiative can be treated simultaneously in two or more places. Contesting for the same resources and demanding the development of common suppliers.

Understanding the flow of treatment of the problems was very enlightening. It derived a review of the roadmap to be investigated. By following the treatment of some problems, it was possible to identify virtues, defects and opportunities. With a look at the possibilities for improvement, a young team was identified, but with an average of 7 years of experience working with projects. Focusing on the points of agreement, it can be observed that there is a high involvement with quality improvement and with the recognition that the basic criteria (triple constraint) are applied for project prioritization. As for the treatment of the problems, there is a great field to evolve, since the agreement is not expressive. This is demonstrated in the averages obtained for problem identification, data collection and reliability, and for the recognition that the basic criteria are insufficient for prioritizing actions. Finally, at this stage, there is a disagreement regarding the knowledge and mastery of the information about the goals of the organization and in the treatment and proper addressing of the problems.

The previous steps form the understanding to analyze the treatment aspects of the acquisition and implantation of the new technologies in the solution of quality problems. There was only agreement on the cost budget for the execution of this

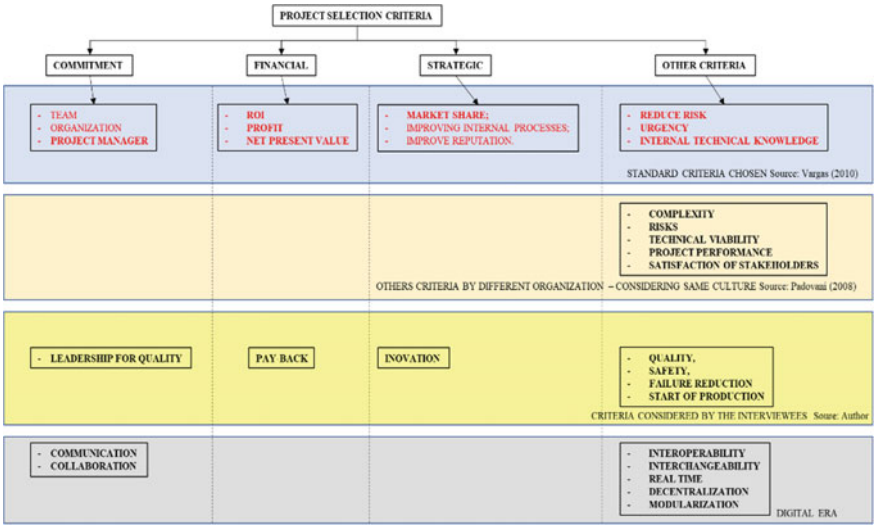


Fig. 7 Convergence framework

type of project. The results of a formal process of introducing new technologies, stakeholder participation and the start-up period are not common ground. Finally, there is a repetition of what has been achieved in terms of goals, because there is a disagreement about their alignment with technological advances, as well as the evaluation process of these projects and the applied criteria.

Based on the theoretical framework, Fig. 7 presents a way of observing project prioritization criteria by aligning research with theory. From the studies of Vargas and Padovani, studies realized in Brazil, were grouped the considerations in common remembered by the participants as criteria that can be considered in the selection process of these projects.

Considering the criteria (Source: Vargas [12]) commitment, financial, strategic and other criteria, accepted as a mode of analysis, another theoretical basis was added (Source: Padovani [14]), but also with the same focus on cultural essence. Participants agreed on the importance of these criteria in all types of projects. The collaborators proposed criteria that were aligned according to the mode of analysis, these being the additional criteria for selection of projects of the digital era. Thus, with the exception of the financial and strategic criteria, there is a way to direct gains aligned to the projects of digital transformation. Regarding the commitment, the involvement of the manager and the leadership for quality is highlighted, which converges with the literature on the revision of the quality standard ABNT NRB ISO 9001:2015. Digital communication and collaboration tools can better share the goals, urgency, assessments, and criteria considered for better team alignment in understanding what is important. Focusing on other criteria identifies the opportunity to apply resources focused on interoperability, real-time analysis, decentralization and modularizations.

6 Conclusion and Future Opportunities

The applications of the resources of the digital era can, with the knowledge of the productive process and the flow of decision-making, provide the desired profitability increments. The domain of information processing from identification, collection and analysis will be the turning point for this improvement. Reviewing the criteria for adoption and implementation of new technologies may be the starting point.

The validity of investigating this lack of criteria is not based on the premise that the fundamentals—Quality, Cost, Scope and Time—are inappropriate. On the contrary, they are essential, but they may be better suited when combined with other criteria making them even more effective.

The objective of the article to identify current criteria, to understand the way of solving problems and to raise the proposition of additional criteria was fulfilled. From this description, efforts can be directed towards more convergence and better sharing of information that results in a significant increase in collaboration.

Like a traditional tool such as PDCA, which is reviewed several times through studies and applications, should follow the criteria for decision making. This is the way to achieve the incremental improvement and, consequently, the best financial result.

In addressing quality, this article considers three relevant points where theory and practice converge. Supported by ISO 9001: 2015, common items can be highlighted such as integration with business management, risk thinking and the inclusion of leadership in the PDCA process. The results of the research are aligned with these exponents as drivers in the quest for better quality results. However, this does not mean that everything should be extremely formalized and the adoption of new criteria must be rigid. What should be sought is the balance, whenever possible, with focus on agility, flexibility and collaboration, always remembering the ultimate goal is profit.

In future studies, it will be proposed the elaboration of the revision of the project management model in order to contemplate new criteria allied to mathematical methods of decision making. It is suggested to study models that introduce risk assessments in a less protocolary way, but more effective ones that develop the conscience focused on quality, the end customer and the business management.

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The Efficiency of Small Farmers in Goiânia/Brazil for Food Security: An Analysis by the DEA Method

Diogo Ferraz, Lie Yamanaka, Maico Roris Severino, Hélio Yochihiro Fuchigami and Daisy Aparecida do Nascimento Rebelatto

Abstract The aim of this article is to analyze the efficiency of the provision of healthier foods for public school students whose offer was made by family farmers. The importance of this work stems from the need to change the eating habits of children and young people, based on the assumptions of Food Security. In addition, proving the efficiency of small farmers is important to encourage Solidarity Economy projects in order to raise the incomes of the poorest workers. We use Data Envelopment Analysis (DEA) as a research method, through the Variable Returns of Scale (VRS) model oriented to the output. The choice of this model is justified because it takes into account the scale of production and the need to increase the number of schools served by small farmers. Our results show that small producers are efficient especially in agricultural products (Vegetables, Tuberous vegetables and Fruits). On the other hand, more elaborate products (Canned food, Flour and semolina, Dairy products) did not reach the efficiency. This result shows that schools can be supplied with fresh and healthy food from the region itself, benefiting the health of children and young people and the economy of small local farmers.

Keywords Small farmers in Brazil · Solidary economy · Data Envelopment Analysis (DEA)

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1 Introduction

In developing countries, the importance of alternative ways to exchange goods has grown. In this aspect, we have sought more inclusive forms for the generation of wealth, leaving aside the traditional models of capitalism [1–3].

A new form of production organization is the Solidarity Economy [2]. This form seeks the generation of work and income for people excluded in the formal labor market, where they find in the collectives (associations or cooperatives) opportunities to improve the quality of life for their family. It should be noted that Solidarity Economy is present both in urban spaces and in rural areas. In the case of rural areas, there is the presence of the Solidarity Economy in Family Agriculture, which seeks in the collectives to reach markets, especially the government procurement programs, which would be inaccessible if they acted individually [2, 3].

In Brazil, several family farmers have become suppliers of products for school meals. However, there are few studies that analyze the efficiency of this process for the Food Security of public school children. Thus, the aim of this article is to analyze the efficiency of the provision of healthier foods for public school students whose offer was made by family farmers.

Brazil has overcome the hunger problems and poverty by utilizing public policies, which distribute income in a fair way. The relation between poverty and food insecurity has been analyzed by models that estimate the consumption of certain type of food. These findings report that the income is one of the most important factor to favoring a much heathier diet. Any kind of food insecurity tends to drop after the third strata household income per capita (R$ 40), even though some kind of less nutritious food rises among the wealthier social classes [1, 4–9].

At this scenario, the hunger and malnutrition are no longer the major challenge. Studies and public policies have been concerned with analyzing the type of food is eaten by low classes and education deficit. It is known that industrialized goods with low cost and low nutritional value are preferred rather than healthier ones, for instance, fruit, legumes and the greens [10–12].

This is a relevant topic, since it deals with two important social aspects for the development of Brazil. Firstly, it analyzes if the products offered by Family Agriculture are efficient with respect to the average price and the quantity offered. On the other hand, it seeks to integrate the offer of these products with the pressures of Food Security, so that safer foods are offered to the children, which contributes to the change of eating habits in the future.

This article is divided into four sections in addition to this introduction. The second section discusses the concepts of Solidarity Economy and Food Security. The third section presents the method used in this work. The fourth section discusses the findings and the fifth section concludes.

2 Solidary Economy, Small Farmers and Food Security

Solidarity economy is a society project that seeks a new form of economic organization as a strategy to cope with unemployment and social exclusion. The solidarity economy breaks with capitalist production relations, introducing popular experiences based on foundations of economic cooperation and self-management [10].

Economic cooperation is fundamental to this type of economy, which has as its principle collective property and the right to individual freedom [2]. Self-management, however, corresponds to the way in which these ventures are administered. Democratic management is necessary to guarantee self-management. Thus, self-management requires a greater effort from workers who, in addition to the usual tasks, must deal with the general problems of the organization, and for this it is necessary that all partners have knowledge of what happens and possible alternatives for making decisions.

This new economic form projects with the foundations of collectivity and solidarity that are important for the scenario of great social inequalities, however, they have challenges to be faced in order to continue and grow this movement. The main challenges are: maintenance of ideological consistency, technical-scientific contribution, structuring of commercialization and organization of public policies [3].

Regarding the structuring of commercialization and the organization of public policies, there is the opportunity to strengthen the Solidarity Economy in Family Agriculture through the government procurement program called the National School Feeding Program (PNAE), also known as the Merenda Campaign School. This program is governed by law No. 11,947 of June 2009, which governs the guidelines of school feeding, one of which is a preference for the acquisition of food produced by family farming. In addition, the law determines that at least 30% of the financial resources passed on to the National Education Development Fund (FNDE) by the National Education Development Fund (FNDE) should be allocated to the rural family farmer or the family farmer.

The family farmers need to decide whether they will participate of the program, through feasibility analysis, as well as produce quality food with nutritional and sanitary standards of food production.

Small farmers need to be prepared for changes in eating habits because the standard of food consumption in Brazil has been changed over the years. These changes come from a number of social and economic factors, which influence the preference of the consumers such as the urbanization, age group and woman entrance in the labor market. All of these compose an important role in the composition of family food basket [4].

It is important to observe the aspects of food habits in Brazil. In the end of last decade, the country was about to reach some of the world Millennium Development Goal target set by the United Nations (UN), particularly in reducing the extreme poverty and malnutrition. More than that, the nutritional transition started to show that the bigger part of Brazilian population is out of the problems related to the hunger, however, new challenges come out. Among them, the fight against the overweight

and obesity is highlighted, making the scene much more complex, and ensuring the need to analyze the consumption of food in the less privileged Brazilian classes [5].

After the global nutrition crisis in 2007/2008, the food security has been made a part of the political agenda of many countries. This issue of great political relevance has been attracted interest in researching, but there is a lack of sense in the present studies about the link between small farmers and food security [12].

The first step towards achieving food security is the access to food, although to the best of our knowledge, hunger is not caused by the inexistence of enough food, but because people do not have the right to access it. Food security exists when the residents in a house own the regular and permanent accessibility to sufficient food.

Food security is a multidimensional concept that widely features the availability of food (physical access to food), food accessibility (economic access to food), the use of food (absorption of the nutrients into the body) and the vulnerability [12].

To enable this transition possible, "Fome Zero", a government program is the answer to reduce the hunger, malnutrition and the extreme poverty. The social programs like as cash transfers (Bolsa Familia), Beneficio da Prestação Continuada, rural pensions and the valorization of the minimum wage were very important factors in reducing poverty and food insecurity of the poor families, particularly since 2001 [1, 6, 7]. Bolsa Familia has contributed to the rise of the nutritional and food security, due to 76% of the cash transfers are spent on food ensuring a better diet for the families in the lower classes.

The importance of the income increase for food security can be better understood as it verifies that the income elasticity on dieting expenses goes up with the household income per capita (RPC), despite the elasticity is always smaller than 1. The money spent on food is 60.2% in the first class of income (RPC up to R$ 100), then it drops to 36.6% in the second class (from R$ 100 to R$ 200) and keeps systematically decreasing to only 5.2% in the RPC class that is above R$4 thousand Reais [8]. According to the authors, rice and beans have negative elasticity which means that a proportional income increase of all Brazilians will not make a rise in the demand for the these products.

Although the household income is the main constraint on the food insecurity measured by Escala Brasileira de Insegurança Alimentar (EBIA) [9], Hoffmann [1, 6, 9] has studied the determiners of the probability of the families in consuming some types of food and in having food insecurity in their homes. The Pesquisa Nacional por Amostra de Domicilios (PNAD) data in 2004 shows that 34.9% of residences still remained with some level of food insecurity [6]. In 2009, despite the number of residences analyzed increased to 12.6%, the number of those ones at the moderate insecurity was reduced to 40.2% and the number of the severe insecurity dropped to 12.4% [9].

When it comes to terms of the type of food consumption, there is a bigger probability in the consuming of pork meat in the South, whereas, in the North and Northern, it is the consuming of basic food (rice, beans, manioc flour, powder milk and margarine). In the Southeast, the consumption is based on french rolls and in the Central-west rice and liquid milk, in contrast to that, the annual per capita

consumption of manioc flour in São Paulo State does not reach one kilo, while in the Northern, it is over fifteen kilos and in the North 33.827 kg [8].

The average rate of consuming manioc flour can be explained by the location, whether the residence is rural or urban. The consumption of this good is four times bigger in the rural areas than in the cities [8].

It is estimated that there is a bigger probability of happening food insecurity in the residential places after controlling the income effect [6]. However, the remote rural areas tend to have poorer residences. The unfavorable evolution of the food security in the rural homes from 2009 to 2013 might have occurred due to the "rural" in 2013 be one of the more restricted areas whose residences are, in general, relatively poor [1].

When the probability of occurring food insecurity is analyzed by the occupation sector by a reference family member, there is bigger probability for the workers of the agriculture sector [6]. The proportion of homes with extreme food insecurity is almost three times bigger among those, in which the reference person is black or brown (10%), than among those whose reference person is white (3,55%) [6]. Notice that black and brown people have the bigger probability of acquiring sugar, rice, second class bovine meat, and manioc flour. Also, there is a negative probability of consuming first class bovine meat, banana, potatoes, tomato, cheese and fluid milk [4].

This result might be associated to the income elasticity of some high quality products or relatively expensive, which are, that way respectively bought in bigger quantity by the relatively rich and white people. The flexibility of income in consuming first class bovine meat is bigger that the second class bovine meat. Thus, Hoffmann [1, 6, 8, 9] findings report that people in poorer income bracket now have more probability of consuming powder milk, a type of food known by its bigger income elasticity. At least, in some aspects, the consumption of powder milk by the poor could be justified by the lack of fridges in the houses. Because of that, the presence of fridges increases the probable acquisition of fluid milk [4].

Education background of the reference person is also a change responsible for the food security occurrence. An additional year of schooling lessens the severe food insecurity (−8%) and the light, moderate or severe aggregate insecurity (−4.3%) [7]. According to the author, the level of education and the income distribution brings transformation in choosing more nutritious food. When the family's chief is uneducated, the probability of consuming sugar, rice, beans, manioc flour and second class bovine meat is higher, furthermore, the increase in education, beyond the income, rises the probability of consuming organic and light/diet products [11].

As far as family members are concerned, the probability of food insecurity in the residences with one or two people is bigger [6]. This matches to the international survey data, in which the great number of the family members helps to dilute the fixed costs for living [12]. However, other work demonstrates how the extreme food insecurity in the residences with more than seven people is possible [6].

PNAD data (2013) appears to show that the average residents per private home was 3.09 as general, and 2.96 in the homes with food security, 3.57 in the homes with light insecurity, 3.46 in the homes with moderate insecurity and 3.43 in the

private homes with extreme food insecurity [1]. It is clear that the average number dropped from 4.14 in 2004 to 3.43 in 2013 in the homes with moderate or extreme food insecurity.

3 Method

The efficiency of a system can be measured from the division between the current value of an indicator of system performance and the maximum value that this indicator reaches [13].

The method used to determine system efficiency is called Data Envelopment Analysis (DEA). The DEA is a nonparametric method, by the empirical construction of a linear frontier by pairs, to measure the productive efficiency of a set of Decision Making Units (DMU) [14, 15].

From the efficiency of each DMU, a ranking of relative efficiency is generated. Efficient frontier expresses maximum number of outputs that can be produced per unit of inputs, representing the production limit determined by the technology. Efficient DMUs represent a best practice frontier, serving from analysis for the least efficient [16].

Several studies analyze the efficiency of production systems in different aspects, such as the banking sector [17], airports [18], the industrial sector [19], cities and countries [20–22] and rural producers [23].

For this work, social efficiency studies can be used as a theoretical basis [24]. It is worth mentioning that many authors have used the DEA to construct indicators of human development and social well-being [24–26].

Our work differs from others because it uses food groups such as DMUs to measure the efficiency of food security for students in public schools being attended by small farmers in the region of Goiânia (Goiás/Brazil).

There are different models that can be used to implement DEA. These models differ according to their assumptions. The type of returns of scale designates the two main DEA models: CRS (Constant Returns to Scale) and VRS (Variable Returns to Scale). The hypothesis of the VRS model considers that the variation of outputs is not necessarily equiproporcional to inputs, being that in the frontier there will be three regions: increasing, in which the outputs grow proportionally more than the inputs; Proportionality; and decreasing, where outputs grow proportionately less than inputs [13, 16].

Table 1 illustrates the mathematical formulation of the major DEA models.

The data used in this research are primary data, collected by the researchers with the support of a project funded by the British Council and the Goias State Research Foundation (FAPEG). We used 90 types of food that were categorized according to the Table of Nutritional Composition of Food Consumption in Brazil from Pesquisa de Orçamentos Familiares (POF), which is the largest family budget survey in Brazil, published by the Intituto Brasileiro de Geografia e Estatística (IBGE).

Table 1 Main DEA radial models

Model	Input oriented	Output oriented
CRS	$\text{MAX} \sum_{i=1}^{m} u_i \cdot y_{i0}$ Sujeito a : $\sum_{j=1}^{n} v_j \cdot x_{j0} = 1$ $\sum_{i=1}^{m} u_i \cdot y_{ik} - \sum_{j=1}^{n} v_j \cdot x_{jk} \leq$ 0, para k = 1,2, . . . , h	$\text{MIN} \sum_{j=1}^{n} v_j \cdot x_{j0}$ Sujeito a : $\sum_{i=1}^{m} u_i \cdot y_{i0} = 1$ $\sum_{i=1}^{m} u_i \cdot y_{ik} - \sum_{j=1}^{n} v_j \cdot x_{jk} \leq$ 0, para k = 1,2, . . . , h
VRS	$\text{MAX} \sum_{i=1}^{m} u_i \cdot y_{i0} + w$ Sujeito a : $\sum_{j=1}^{n} v_j \cdot x_{j0} = 1$ $\sum_{i=1}^{m} u_i \cdot y_{ik} - \sum_{j=1}^{n} v_j \cdot x_{jk} + w \leq$ 0, para k = 1,2, . . . , h *w without signal restrictio n*	$\text{MIN} \sum_{j=1}^{n} v_j \cdot x_{j0} - w$ Sujeito a : $\sum_{i=1}^{n} u_i \cdot y_{j0} = 1$ $\sum_{i=1}^{m} u_i \cdot y_{ik} - \sum_{j=1}^{n} v_j \cdot x_{jk} + w \leq$ 0, *para k* = 1, 2, . . . , *h* *w without signal restrictio n*

Source Mariano and Rebelatto [13, p. 5]

The categories of food analyzed are: Cereals and pulses, Dairy, Sugars and sugar confectionery, Baked goods, Processed meats, Oils and fats, Poultry and eggs, Sugars and products confectionery, miscellaneous.

The variables chosen were: total amount of food offered (input), average price of food offered (input), total price of food supplied (input). We choose the output-oriented DEA-BCC model. We decided to take the orientation to output, considering that one wants to maximize outputs (number of schools attended) without reducing input (price and quantity). The software used for this analysis was MATLAB.

To validate our variables, we used a Pearson correlation matrix with statistical significance. The software used for this analysis was STATA 13.0.

4 Findings

Our Pearson correlation matrix showed that the inputs and the output have statistical significance. For example, the correlation between the schools served and the quantity of products offered was 0.6931 with a significance level of 1%. The price of the products and the schools served presented the coefficient expected by the economic literature (−0.7452), considering that when the price increases the quantity demanded decreases. This correlation also showed a level of significance of 1%.

The output-oriented DEA-BCC model evaluated the efficiency of the process for offering food to public schools from the local family farm. The model showed that the

only effective foods were fruits and vegetables. Cereals and pulses, Dairy products, Flour and sugar products, Flour, starch and pasta, Bakery products, Processed meats, Oils and fats, Poultry and eggs and others were not efficient.

This result shows that among the foods offered for school meals, the most efficient are those considered healthy and, therefore, offer greater food security for the children. This shows that the partnership between family farmers and public schools is important for the development of the local economy, but also for the nutrition of children and young people (Table 2).

Table 2 Efficiency estimation

Products	Type	Efficiency
Cabbage/couve	Vegetables and other	1.00
Jiló	Vegetables and other	1.00
Almeirão	Vegetables and other	1.00
Beet	Tuberous vegetables	1.00
Saffron	Tuberous vegetables	1.00
Sweet potato	Tuberous vegetables	1.00
Green pepper	Vegetables and other	1.00
Mint	Vegetables and other	1.00
Yam	Vegetables and other	1.00
Basil	Vegetables and other	1.00
Salsinha	Vegetables and other	1.00
Tomate	Fruits	1.00
Watermelon	Fruits	1.00
Green smell	Vegetables and other	0.97
Cabbage/repolho	Vegetables and other	0.94
Green corn	Canned food	0.90
Lettuce	Vegetables and other	0.88
Chuchu	Vegetables and other	0.88
Cassava flour	Flour and semolina	0.85
Onion	Vegetables and other	0.84
Green cabbage/repolho	Vegetables and other	0.84
Garlic	Vegetables and other	0.83
Cress	Vegetables and other	0.82
English potato	Tuberous vegetables	0.78
Peeled cassava	Tuberous vegetables	0.77
Carrot	Vegetables and other	0.77
Coriander	Vegetables and other	0.76

(continued)

Table 2 (continued)

Products	Type	Efficiency
Pod	Vegetables and other	0.70
Chard	Vegetables and other	0.69
Cará	Vegetables and other	0.67
Orange	Fruits	0.66
Orange pear	Fruits	0.63
Broccoli	Vegetables and other	0.63
Pineapple	Fruits	0.59
Lemon	Fruits	0.58
Mango	Fruits	0.58
Cauliflower	Vegetables and other	0.53
Bean	Cereals and legumes	0.52
Cheese	Dairy products	0.52
Soy	Cereals and legumes	0.51
Fruit pulp	Sugar and confectionery products	0.50
Soy flour	Flour and semolina	0.49
Pumpkin	Vegetables and other	0.48
Avocado	Fruits	0.47
Canjica corn	Cereals and legumes	0.46
Grated cheese	Dairy Products	0.44
Corn	Cereals and legumes	0.43
Papaya	Fruits	0.43
Assorted sweets	Sugar and confectionery products	0.41
Banana	Fruits	0.40
Pasteurized milk type C	Dairy products	0.39
Arugula	Vegetables and other	0.39
Chive	Vegetables and other	0.38
Cashew pulp	Sugar and confectionery products	0.37
Passion fruit pulp	Sugar and confectionery products	0.37
Strawberry pulp	Sugar and confectionery products	0.36
Tamarind squash	Sugar and confectionery products	0.36
Okra	Vegetables and other	0.35
Cheese bread	Bread	0.32
Swine sausage	Processed meats	0.30
Pineapple pulp	Sugar and confectionery products	0.30
Cucumber	Vegetables and other	0.26

(continued)

Table 2 (continued)

Products	Type	Efficiency
Chicken sausage	Processed meats	0.26
Tangerine	Fruits	0.25
Soy oil	Oil and fat	0.25
Eggs	Poultry and eggs	0.25
Rice	Cereals and legumes	0.24
Tangerine type 2	Fruits	0.24
Cakes	Sugar and confectionery products	0.24
Soy protein	Flour and semolina	0.24
Candy “Rosca”	Bread	0.22
Mexerica ponkan	Fruits	0.21
Melon	Fruits	0.20
Mozzarella cheese	Dairy products	0.19
Cajá pulp	Sugar and confectionery products	0.18
Acerola pulp	Sugar and confectionery products	0.18
Yogurt	Dairy Products	0.18
Corn pasta	Flour and semolina	0.18
Candy “Rapadura”	Sugar and confectionery products	0.17
Bread “Pão Caseiro”	Bread	0.13
Juice	Miscellaneous	0.12
Apple	Fruits	0.12
Dairy beverage	Dairy products	0.09
Sweet milk in pasta	Sugar and confectionery products	0.03
Radish	Tuberous vegetables	0.02
Sour sprinkles	Bread	0.02
Type 2 sweet sprinkles	Bread	0.02
Cheese grated type 2	Dairy products	0.02
Sour passion fruit	Fruits	0.02
Milk butter	Dairy products	0.01

However, industrialized or semi-processed products presented low efficiency, which may demonstrate a disadvantage of this business model. Future studies need to analyze which agents are most effective in offering the different types of food to public schools, which may differentiate the business models to be adopted.

5 Conclusion

This article measured the efficiency of food offerings by small farmers to public schools in order to verify the food security of Brazilian children and young people. The results showed that healthy foods are the most efficient in the partnership between small farmers and public schools (Solidary Economy), which demonstrates the importance of this business model for Food Security.

Processed foods were not efficient, which shows that the purchase of these products needs to be done with other suppliers (industries or traders). Future studies can map which products are suitable for each type of supplier, taking into account logistics and business strategy.

Finally, our results have shown that Solidarity Economy and Food Security are important in two respects. First, because the partnership between small farmers and public schools develops the local economy, benefiting mainly family farming, usually characterized by lower income workers. Second, the provision of locally produced healthy and fresh food benefits children and young people in public schools through a balanced diet and can change eating habits in the future.

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Correction to: Reverse Logistics Costs: Case Study in a Packaging Industry

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In the original version of this book, the author name "Gabriela Hames" has been amended correctly as "Gabriela Hammes". The chapter and book have been updated with the changes.

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