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João Reis  
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# Industrial Engineering and Operations Management II

XXIV IJCIEOM, Lisbon, Portugal,  
July 18–20

 Springer

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João Reis · Sandra Pinelas ·  
Nuno Melão  
Editors

# Industrial Engineering and Operations Management II

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# Preface

Industrial Engineering and Operations Management (IE&OM) are enabling enterprises around the world to adapt and survive in 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 enhancing 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 18–20 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 by renowned scientists specialized on the aforementioned topics. This Springer book is the second of two volumes and contains 25 articles. Inside, you can find papers that explore real-life phenomena under the IE&OM scope, thus, providing various perspectives in the fields of: healthcare, social technologies, mathematical programming applications, public transport services, new product development, industry 4.0, occupational safety, quality control, e-services, risk

management, supply chain management, governance, and digital operations. All these papers put forward novel approaches and relevant findings that shed new light on IE&OM.

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

Amadora, Portugal  
Amadora, Portugal  
Viseu, Portugal  
October 2018

João Reis  
Sandra Pinelas  
Nuno Melão

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# Performance Measurement System to Continuously Improve a Brazilian Industrial Engineering Program: A Process to ABET Accreditation



Gabriela Lobo Veiga, Edson Pinheiro de Lima, Fernando Deschamps and Rafael Rodrigues Guimarães Wollmann

## 1 Introduction

There is an increasing claim for managing engineering courses through competences. By the mid-1990s, the Accreditation Board for Engineering and Technology (ABET) recognized that the international challenge of competitiveness was in part a problem of competencies in engineering education and adopted a revolutionary method proposing the concept of student outcomes (SO) [1]. The importance of this approach is increasingly recognized, even in today's digital transformation era. The purpose is to evaluate what students have learned instead of what students were being taught [5].

This paper focuses on ABET's continuous improvement criterion, which states: "The program must regularly use appropriate, documented processes for assessing and evaluating the extent to which SOs are being attained. The results of these evaluations must be systematically utilized as input for the continuous improvement of the program" [1]. The continuous improvement process should be designed to evaluate PEOs (Program Educational Objectives) and SOs (Student Outcomes). PEOs are "broad statements that describe what graduates are expected to attain within a few years after graduation", while SOs are defined as "what students are expected to know and be able to do by the time of graduation" [1]. Recently, ABET disclosed a new version of SOs to the 2019–20 accreditation cycle. According to ABET, SOs are outcomes (1) through (7) plus any additional outcomes that may be articulated by the program, as seen next. Indeed, as the new SOs version is very recent, this paper brings out a pioneering approach.

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- SO 1: An ability to identify, formulate and solve complex engineering problems by applying principles of engineering, science, and mathematics.
- SO 2: An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
- SO 3: An ability to communicate effectively with a range of audiences.
- SO 4: An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
- SO 5: An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
- SO 6: An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
- SO 7: An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

The determination of where, how, and when to assess SOs must be defined by each engineering program individually [5] and there are few papers already exploring the process of ABET accreditation assessment [3, 5]. Awoniyi [2] presents a template that can be used to organize the efforts to satisfy ABET EC 2000 requirements, focusing mainly on criteria 2 and 3 [2]. Felder and Brent [6] also focus on assessment criteria, but the authors bring out an additional contribution since they make clear the difference among some important concepts such as objectives, outcomes, and indicators [6]. McGourty et al. [8] present a more comprehensive approach through the proposition of a five-step process to assess program and make it a model of continuous improvement. There are also other authors that describe their own accreditation process experience. Lohmann [7] describes the Georgia Tech practice and Schachterle [14] approaches the implementation case at Worcester Polytechnic Institute.

Despite the existence of these papers exploring the ABET accreditation assessment, the challenges for establishing such a process are still unclear. A point of attention is to consider both ABET scenario and particularly institution context. Beyond that, there is no publication that proposes a suitable model to Brazilian Institutions in Engineering Education.

In doing so, this paper proposes a Continuous improvement framework to the Engineering Education area, including Performance Measurement Systems (PMS). We propose an eleven-step systematic process to develop an integrated assessment of engineering programs. The procedural framework includes considering external and internal requirements and is based on an in the deep bibliographic review which is not the focus of this paper.

The Industrial Engineering (IE) Program at PUCPR, in line with its efforts to improve and maintain the quality of engineering education, initiated external evaluations towards accreditation by the Accreditation Board for Engineering and Technology (ABET). The proposed framework is tested in the IE Program at PUCPR, located in Brazil. By means of a qualitative approach, it uses action research, since

the authors are involved with the development and testing of the proposed framework. Action research is the methodology used in projects in which practitioners seek to effect transformations in their own practices.

## 2 Proposed Continuous Improvement Framework

This paper uses Platts and Gregory [10] model as a strategy to propose a framework to continuously improve an engineering program. These authors propose a tool to conduct audits to the manufacturing strategy formulation process. They suggest some steps, through worksheets (WS), for manufacturing audit in the process of strategy formulation. Such steps are used as a reference to develop a proposed framework that seeks to attend the continuous improvement of ABET requirement. Table 1 shows Platts and Gregory's propositions in the two first columns and the equivalent in the proposed framework in the remaining columns.

### 2.1 Framework Steps

Steps presented in Table 1 are also coherent with the DMAIC Cycle and allow the development of an integrated assessment of engineering programs (see Fig. 1). The implementation at PUCPR is described in each step and lessons learned are shared. PUCPR's IE Program, in Curitiba, Brazil, has around 600 students and started its activities in 1998. The program has started to apply this continuous improvement framework in the first semester of 2017.

**Step 1—Identify market view of competences.** PEOs must reflect the needs of the program's various stakeholders [1]. That is why getting plenty of external views is included in this framework step. This step covers the gathering of specific views concerning the professional market and requirements for an Industrial Engineer. It should be carried out every three years. This is of primary importance since it is only possible to develop students according to necessities if market expectations are well known.

At PUCPR, structured interviews and surveys were conducted in this phase with IE professionals, seeking to reflect the needs of the program's various stakeholders. They were asked to list the important technical knowledge, abilities and behavioral factors desired in an Industrial Engineer. In 2016, 17 interviews were carried out with professionals from industry, including alumni that graduated between 2006 and 2015. In 2018, a survey was promoted to cover a larger number of respondents. 869 alumnis were invited to answer the survey, and a final number of 83 responses was obtained, which is equivalent to about 10% participation.

**Step 2—Define/Review competitive professional profiles (PEOs).** This step is about the establishment of PEOs which are considered a way to declare external

**Table 1** Proposed framework steps

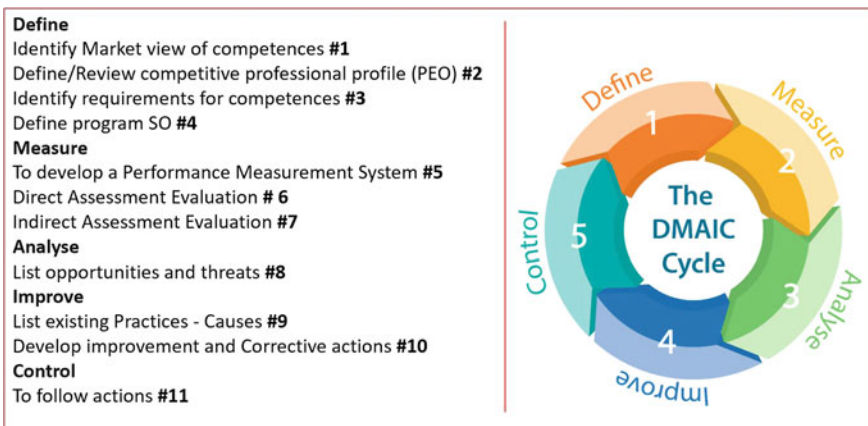
Audit process		Engineering education program process	
WS	Name	What?	How?
WS01	Competitive profiles	#1	Identify market view of competences Analyze data from industry
		#2	Define/review PEOs Define PEOs
WS02	Basic data	Not Applicable	
WS03	Competitive criteria	#3	Identify requirements for competences Align SOs
		#4	Define Program SOs Establish coherent SOs, related with PEOs
WS04	Achieved performance	#5	Develop a PMS Get a coherent PMS
		#6	Direct Assessment Evaluation Identify in what extent SOs are being developed to deliver PEOs
WS05	Opportunities and threats	#7	Indirect assessment Evaluation Look at opportunities and threats
		#8	List opportunities and threats Summarize results as opportunities or threats
WS06	Existing practices	List existing practices—causes	Identify what is contributing to poor performance Identify causes of poor performance
WS07	Action worksheet	#10	Develop improvement and corrective actions Establish actions to improve results
		#11	Follow actions To guarantee actions implementation

expectations. They need to derive from the institution’s vision. Based on the results of the previous step, PEOs were written at PUCPR and validated with PUCPR’s IE faculty. The establishment of an Industry Advisory Board (IAB) from market is considered in this phase to discuss program structuring, always looking forward to being aligned with external claims. This IAB is composed by faculty and market professionals of different companies. PUCPR’s IE Program promotes an IAB meeting twice a year as part of the process of understanding program’s various stakeholders needs.

The first PEOs declaration proposal was discussed and validated by the IAB in October 2017. Once they were validated, the timeframe for alumni to achieve the PEOs is between 3 and 5 years. The PUCPR PEOs first version is as follows:

- PEO 1: Enhanced organizational performance through assertive decision-making in projects and operations management.
- PEO 2: Created value for stakeholders by promoting innovative solutions (product, process and technology) or by solving complex problems.
- PEO 3: Performed as a transformer of the existing reality, in an ethical and sustainable way, striving for continuous education.
- PEO 4: Lead and motivated multidisciplinary team member through communicating appropriately for the context in an assertive manner.

**Step 3—Identify requirements for competences.** Program SOs and PEOs must be coherent with a set of internal and external requirements. This is context-driven and depends on each university. Elements such as strategic vision and internal and external political requirements should be considered. In case of PUCPR’s IE Program, there are internal requirements from the pedagogical university department to be



# 1 - 4 | Each 3 years  
 # 5 -11 | Each Semester

**Fig. 1** Continuous improvement processes of the Industrial Engineering program at PUCPR

considered, and external requirements from MEC (Brazilian Ministry of Education) and the Brazilian Board of Engineers (CONFEA/CREA).

**Step 4—Define Program SOs.** ABET establishes a reference model to SOs definition, as it prescribes a well-known list of expected SOs. The set of PEOs drives the assessment process, therefore it is important to have completeness between PEOs and SOs. Based on program characteristics, PEOs and ABET (1)–(7) SOs recommendations, SOs must be defined in this step. ‘Competitive criteria’ [10] are considered the SOs in the proposed model. SOs from PUCPR’s IE Program have the same description as suggested by ABET. The relationships between PEOs and SOs are as follows: PEO 1 helps in SOs 1, 2, 4, 6 and 7; PEO 2 helps in SOs 1, 2, 4, 6 and 7; PEO 3 supports all SOs; PEO 4 contribute to SOs 3, 5 and 7.

**Step 5—To Develop a Performance Measurement System (PMS).** According to ABET criteria 2018–2019, the extent to which student outcomes are being attained needs to be evaluated and documented. It can be accomplished through direct and indirect measurement processes.

Indirect assessment is the evaluation obtained without directly observing the students work. This kind of assessment is important to evaluate specific cases, especially regarding professional skills, which are difficult to evaluate by traditional direct assessment methods [13]. Direct assessment can be obtained in class exams, written lab reports, National Standard Tests and performance evaluations in oral presentations. As indirect assessment examples, the author proposes student perception surveys, graduate school placement rates, employer or alumni surveys and senior exit interviews [5].

Direct assessment is when the evaluation is directly performed from student work. It can be compiled with well-defined indicators. ABET defines that the indicator is what faculty are going to look for in student performance to have confidence that, by the end of the program, students can demonstrate the learning outcome.

At PUCPR, the evaluation of SOs attainment is accomplished through direct and indirect measurement processes, as detailed in Table 2.

The first is performed by Program Criteria (PC) evaluations, and the second by a set of surveys. The senior student survey seeks to ponder the perception of the level of SOs development and satisfaction within the program and should be conducted with last semester students by the time of graduation. PUCPR’s IE Program conducted its first PC evaluation in the first semester of 2017 and is in the fourth measurement cycle. The evaluation through the PCs encompasses the design of the PMS, in which steps

**Table 2** SOs measurement

Capture data method	Way of measuring	How to evaluate
Direct or indirect assessment method	PC definition for each SO	Evaluate PC at selected courses
Indirect assessment method	Overall student outcome evaluation	Senior student survey



are proposed to develop a PMS coherent with the context of measuring performance in Engineering Education.

The definition of high-level PCs associated to each SO is included in this step. In this way, it is important to guarantee that the set of PCs embraces the intention of each SO. Each SO should be associated with two or more PCs describing the characteristics, skills, knowledge, attitudes, and/or values that students must exhibit to demonstrate the achievement of an SO. To have completeness in PCs definition, Pettigrew et al.'s [12] framework was used as a foundation to define the indicators. To fulfill it, each SO has PCs regarding context, content, and process. The context can be both external and internal. The first regards to the economic, political, and competitive environment in which an organization operates. The internal context refers to the structure, corporate culture, and politics. Content is about the area of transformation under examination, as technology, manpower, products, geographical positioning, or organizational culture. It regards to objectives and assumptions, targets, and evaluations. Finally, process regards actions, reactions, and interactions from the various interested parties as they seek to move the firm from its present to its future state [11].

At PUCPR, after meetings involving all faculty, PCs were defined. An example for PCs defined for PUCPR's IE Program are presented in Table 3. The PCs are assessed on courses and an evaluation is conducted by each responsible faculty.

PCs are mainly assessed in courses and the evaluation is conducted by each responsible faculty. It is recommended that PCs of the same SO be evaluated in different courses. To have an overview about courses that can measure each PC, it was suggested the development of a correlation matrix, attributing in which level each course is able to develop each PC. Three levels of contribution can be determined, for example.

**Table 3** PUCPR's IE Program Performance Criteria (PC) for SO 1

SO	PUCPR IE PC	Completeness evaluation
(1) An ability to identify, formulate and solve complex Engineering problems by applying principles of engineering, science and mathematics	Apply IE knowledge, techniques and modern tools, in an integrated way	Content
	Apply mathematical analysis (calculation, statistics and algebra) revealing accuracy	Content
	Represent (illustrate) a real-world situation in an appropriate mathematical model (formulate a problem)	Process
	Completely define an engineering problem	Process
	Formulate a complete solution for an engineering problem	Process
	Demonstrate an Industrial Engineering problem solution using software and applying techniques of data and process modeling	Context

Strategy:		Strategy Code:							
#	Performance Criteria (PC)	Proposed evaluation activity <small>Ex: Exam, question inside na exam, individual work, team work, oral presentation, case study...</small>	Application Situation <small>(Detailed description of the proposed activity)</small>	Evaluation instrument <small>(Ex: Rubric, check list of criterias, proof template...)</small>	Evaluation instrument Code	Year	Semester	Weight of the indicator in the course grade (%)	Comments

Fig. 2 Specific PC standards sheet

PUCPR’s IE Program faculty are invited to participate in the process of mapping SOs and PCs correlation through a survey. The used correlation levels of each course in the PC were introduce, reinforce and emphasize. Each faculty attributed the level of correlation for courses that they felt comfortable to analyze. Only specific program courses were considered in the mapping, as this is easier to manage within faculty under the leadership of the program. Through the result of this mapping, it was possible to select the courses able to measure each of the PC. Furthermore, this mapping provided a holistic view about SO development, making it possible to know at which stage a SO is developed and, then, contributing to defining the requirements for each semester.

The Performance Measure Record Sheet was then developed to formalize the PC standards. Such a sheet is based on Neely et al. [9] that proposed the performance measure record sheet, summarizing works approaching what a good performance measure constitutes. Each PUCPR’s IE responsible faculty must detail and document the measurement strategy for the respective PC through the ‘Specific PC Standards Sheet’. A template can be seen in Fig. 2.

**Steps 6 and 7: Direct and Indirect Assessment Evaluation.** A simplified sample of measurement results is presented in Fig. 3, which represents the direct assessment report. As mentioned before, there is also the Senior Student Survey an indirect assessment process to avoid bias on results. It encompasses another perspective of evaluation: the student view. A senior student survey is planned to collect student’s opinions about the contribution of PUCPR’s IE Program in developing each SO. Such a survey also looks at understanding student’s satisfactions and employability data.

**Steps 8 and 9—List Opportunities and Threats/List Existing Practices—Causes.** This is an analytical step that seeks to summarize results from direct and indirect measurement as opportunities or threats. This is important to avoid threats and explore opportunities within action plans. It is vital to recognize results lower than expected and investigate reasons to such results. A well-developed root cause analysis is of primary importance to develop a consistent action plan and should be developed in this step. A continuous improvement group can be established in this phase. Based on direct and indirect measurement results, PUCPR’ IE Program defined priorities

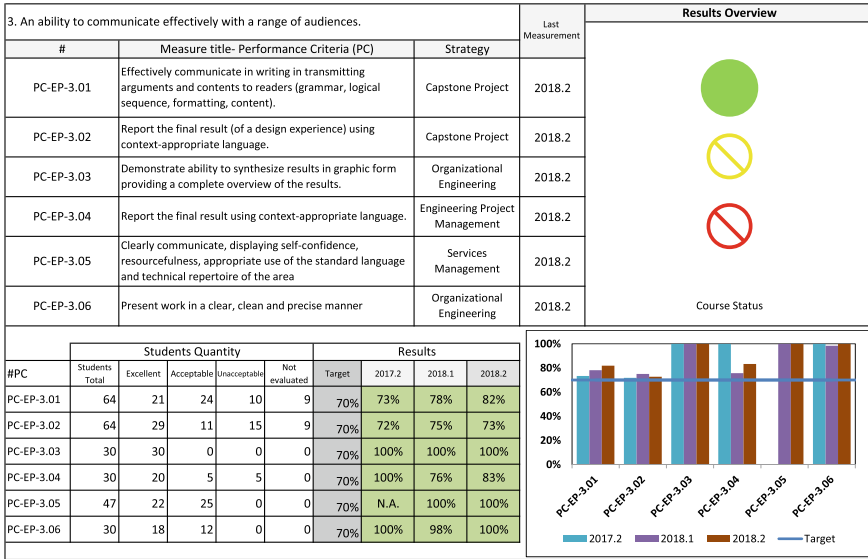


Fig. 3 Sample of SO evaluation through PC

to take actions. An annual meeting with faculty is organized to discuss results and defining priorities for action. A root cause analysis is conducted to prioritize weak points selected by faculty.

**Steps 10 and 11—Develop Improvement and Corrective Actions/Follow Actions.**

Actions should be established considering the analysis in Step 9. This is the key step to stimulate continuous improvement. The action plan introduces alternatives to address poor results. Additionally, this phase includes the daily management of planned actions and results, to guarantee continuous improvement. It is important to check realization and results of undertaken actions.

An action plan is established seeking to improve PUCPR’s IE Program results. Additionally, always when a weak point is identified, an improvement plan is also required. PUCPR’s IE Program has developed an improvement procedure that encompasses the steps to guarantee the process realization in long term. The established actions must be implemented, and it is the responsibility of the Program’s leadership to ensure that the actions are carried out.

The eleven presented steps, in this sequence, are part of a continuous improvement process. The stages need to be performed frequently. To be a feasible process, different frequencies to realize each step are suggested, as some processes are more demanding. Keys for an effective assessment tool requires low faculty effort to develop, administer and maintain the process [3]. Steps 1–4 can be developed every 3 years, but Steps 5–11 need to be developed every semester, to collect data from a considerable number of students and to implement improvement actions more dynamically.

### 3 Conclusion

The paper attains the objective of proposing a process to continuously improve performance in the context of Engineering Education. The developed framework needs to be implemented with faculty support. In doing so, it is important to make the process easy to be used in the faculty's routine. PUCPR's IE Program has a continuous improvement procedure that documents every criterion in a more detailed way.

There are some opportunities for improvement in the presented framework. It is recommended to expand the market view, collecting a wider overview about market requirements for an IE Program. It is possible to enhance the quantity of interviews and apply other methods of data collection to accurately map alumni profile. The application of a survey is suggested to get more opinions from different stakeholders. The CDIO questionnaire can be used as the basis for this survey [4]. It is recommended to conduct this survey with alumni, market professionals, and faculty.

As a future opportunity of work, necessity to evaluate the consistency of the proposed model is pointed out. It is believed that, to be effective, the process of measuring and improving SOs must be coherent with external requirements, regulatory institutions such as MEC (Brazilian Ministry of Education) and the Brazilian Board of Engineers (CONFEA/CREA), and have internal needs reflected by the strategic vision of the educational institution.

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# Internet of Things (IoT): Technological Indicators from Patent Analysis



Meire Ramalho de Oliveira, Angela Emi Yanai, Diogo Soares Moreira, Cláudia Daniele de Souza and Carlos Eduardo Gomes de Castro

## 1 Introduction

Connecting various devices over the Internet for the exchange of information in the industry is already possible through the Internet of Things (IoT). The term was first assigned to work developed by Auto-ID Labs on Massachusetts Institute of Technology—MIT on research about Radio Frequency Identification—RFID [1]. IoT is related to research of Gershenfeld [2], which a scenario is modeled as a set of objects able to process information.

IoT applications have different uses and can be adapted to a very large amount of areas such as smart industry, smart buildings, smart health and other applications to

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smart cities. Also, in smart industry, there are systems of intelligent production discussed over industry 4.0, changing the means of acquire, processing, and distribution of basic material and finished products. In smart buildings, we have the construction of buildings based on measurers, safety systems, and apps to provide the monitoring of safety issues, electricity, water, and even gas. Also, in smart mobility, it is possible to monitor the vehicular route, ticketing emission and measure the user patterns to provide solutions for traffic in big cities. In smart health, it is possible to watch patients and chronic diseases follow-up. Finally, we can do real monitoring of smart cities projects such as parking space, illumination and the occupancy of streets and public areas [3].

The Internet of Things is such a vast reality that it has become an umbrella term for many underlying use cases, technologies, and other aspects. In the context of industry changes such as the introduction of automation systems, cyber-physical systems, and the Internet, the industry 4.0 emerged. Industry 4.0 is a new industry revolution that succeeds in three previous revolutions. In order to allow the realization of industry 4.0, it is necessary to use technological infrastructure composed of virtual and physical systems powered by information and connections from simulations, augmented reality, big data, IoT, and robots. Therefore, it is necessary a friendly environment for building and incorporating these new technologies.

The growth of devices connected to Internet increased over the last years. According to European Commission Information Society and Media, there will be 50–100 billion of connected devices to the Internet [4]. All this, together with the ideology of smart homes, smart devices and intelligent transportation are the main core of an infrastructure that may connect our world more than we ever thought possible. In this context, the Internet of Things (IoT) emerged as an expected solution for building a world where things have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network [5].

Thus, IoT implies a very promising concept to build powerful industrial systems and user needs-based applications. Furthermore, in an economic perspective, the value generated by IoT technologies is estimated in a value of 33 trillion dollars [6]. In order to allow the IoT behave properly, IoT bundles different technologies together such as: sensors, semantic, data modeling, cloud computing, communication protocols, storing, and hardware manufacturing.

There is a growing consensus that IoT is also taking a leading role in digital transformation in a wide variety of business applications in locations around the world [7]. The interconnection among objects and things enables many possible applications in many domains. Essentially, these applications can be divided into three categories based on their focus [4]: industry, environment, and society. Table 1 highlights some very promising applications under the IoT main categories.

IoT applications have different finished and can be adapted to a very large amount of areas such as smart industry, smart buildings, smart health and other applications to smart cities. Also, in smart industry, there are systems of intelligent production discussed over industry 4.0, changing the means of acquire, processing, and distribution of basic material and finished products. In smart buildings, we have the construction

**Table 1** Promising applications under three IoT categories

Category	Applications
Industry	Transportation and logistics
	Aviation
	Autonomous driving
Environment	Agriculture and breeding
	Environmental monitoring
Society	Healthcare
	Smart home
	Entertainment

of buildings based on measurers, safety systems, and apps to provide the monitoring of safety issues, electricity, water, and even gas. Also, in smart mobility, it is possible to monitor the vehicular route, ticketing emission and measure the user patterns to provide solutions for traffic in big cities. In smart health, it is possible to watch patients and chronic diseases follow-up. Finally, we can do real monitoring of smart cities projects such as parking space, illumination and the occupancy of streets and public areas [3].

Future expectations about the use and apps for IoT are emerging. However, there is a set of challenges to be overcome which include technologies and operational issues, aside from strategic issues from emerging business models. Thus, it is necessary to identify threats and opportunities. So, existing business models have to adapt to the new positioning of these products [3].

It is possible to know how much a subject has been developed and also forecasts about future expectations. For that, you can monitor products on the market, scientific articles or patent documents. Patents represent a valuable asset and a competitive resource at the disposal of companies. Patents allow the sole exploitation of the product, excluding third parties. In addition, patents can also be used as technological information. In this way, patents can be used as input for new research and development processes [8]. The technological monitoring process through of patents related to IoT allows to know the technological scene on this subject.

With the volume of data produced by machines and people on a daily basis becoming unmanageable, companies need to have a plan of how they will use IoT in their business and how they will protect its data. The objective of this article is to present the overview of patent documents related to the internet of things, in view of their importance for Industry 4.0, identifying the evolution and the main technological subdomains and the depositor countries.



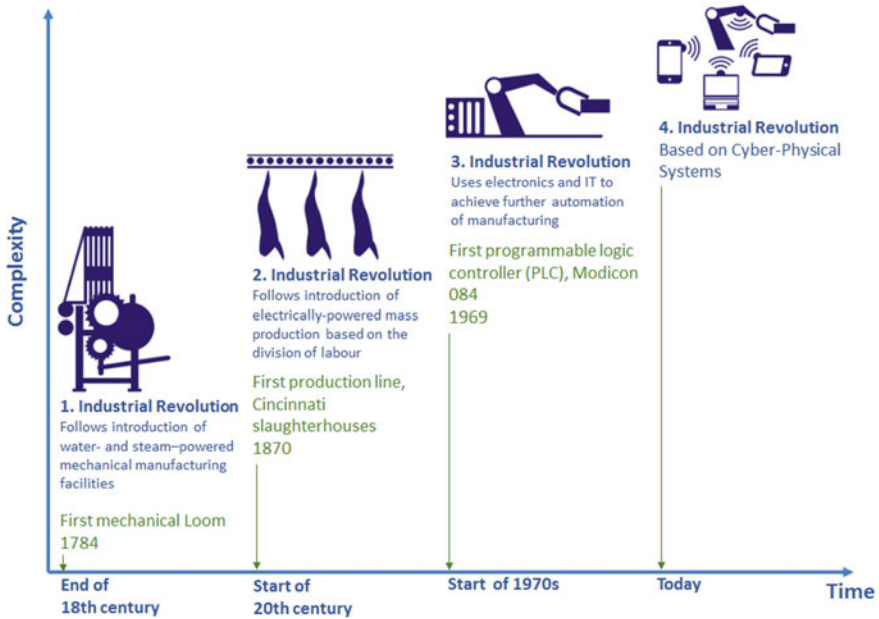


Fig. 1 The four stages of industrial revolutions [9]

## 2 IoT in Industry 4.0: The Future of Connected Industry

Factories have machines, process, and devices that supplement operations. These industrial units can be connected to Internet, allowing interconnection between data and systems, so industrial plants can be digital over industry 4.0.

As presented, the term industry 4.0 emerged to characterize a new industrial revolution that succeeded in the previous three revolutions. The first industrial revolution occurred in the late eighteenth century and was characterized by the mechanization of production, favored by the emergence of the steam engine. The second industrial revolution occurred in the early twentieth century with the emergence of mass production, the division of labor, and the development of the Taylorist and Fordist Systems of production, including the use of electric power. The third industrial revolution began in the 1970s and was driven by the use of electronics, information technology, and greater automation of production processes [9]. Figure 1 summarizes the key development factors achieved in industrial revolutions over time.

Industry 4.0 is based on four main elements: Cyber-Physical Systems, Internet of Things (IoT), Internet of Services (IoS), and Smart Factory. Cyber-Physical Systems (CPS) are constituted by actuators and intelligent sensors which allows information systems to do the physical control of production processes. IoT allows data sharing among devices that control production processes in real time using wireless networks. Internet of Services allows each service can be performed using machine-to-machine

communication or supplier to factory to generate information data. Finally, on Smart Factory, the cyber-physical communication using IoT helps machines and people in tasks execution [10].

So IoT is one of the cornerstones of the 4.0 industry by allowing the connection between machines, vehicles, and other physical objects through embedded electronic devices. IoT enables the exchange and collection of information, and also decentralizes analysis and decision making, allowing responses to occur in real time.

### **3 Sources and Methodology**

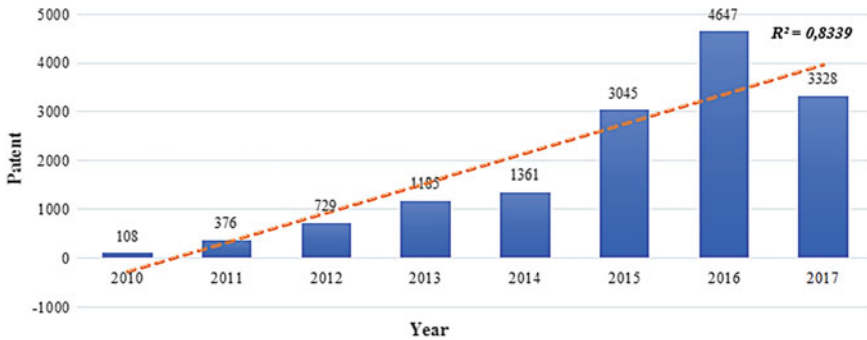
A patent document contains, in a standardized form, a wealth of information about the state-of-the-art about cutting-edge technologies that is often not available in another document. Therefore, they are an important information source to disseminate science and technology information. But, as a first step, it is essential to grasp clearly the basic concepts of the patent system so as to appreciate better the practical usefulness of patent as a rich technological information source. Therefore, the works elaborated by Ardito et al. [11], Milanez [12] and Wang and Hsieh [13] are highly recommended because contribute to understand the universe of research.

#### ***3.1 Derwent Innovations Index***

In this study, technological indicators were developed using patent documents data indexed in the Derwent Innovations Index (DII). Integrated to the Web of Science platform, it is a patent database that covers value-added patent records from Derwent World Patents Index with patent citation information from Patents Citation Index. It is updated weekly and contains over 16 million basic inventions, with coverage from 1963 to present. Patent information is drawn from 41 patent-issuing authorities around the world and is categorized into three categories, or sections; Chemical, Engineering, and Electrical and Electronic. This database allows for complex Boolean searches in multiple bibliographic fields, such as the title, abstract, inventors, assignees, and International Patent Classification (IPC).

#### ***3.2 Methodological Procedures***

Patent information is very important to the policymaker, but it is necessary to collect and analyze a large number of patent documents through tools, such as a data mining, in order to make a decision. Therefore, this study has been conducted following the next steps:



**Fig. 2** Annual number and annual growth rate for patent documents about “internet of things” from Derwent innovations index in the period between 2010 and 2017

- Definition of search expression;
- Search of bibliographic records in database;
- Bibliometric analysis;
- Graphic representation; and
- Analysis and presentation of results.

The following set of bibliometric indicators was developed:

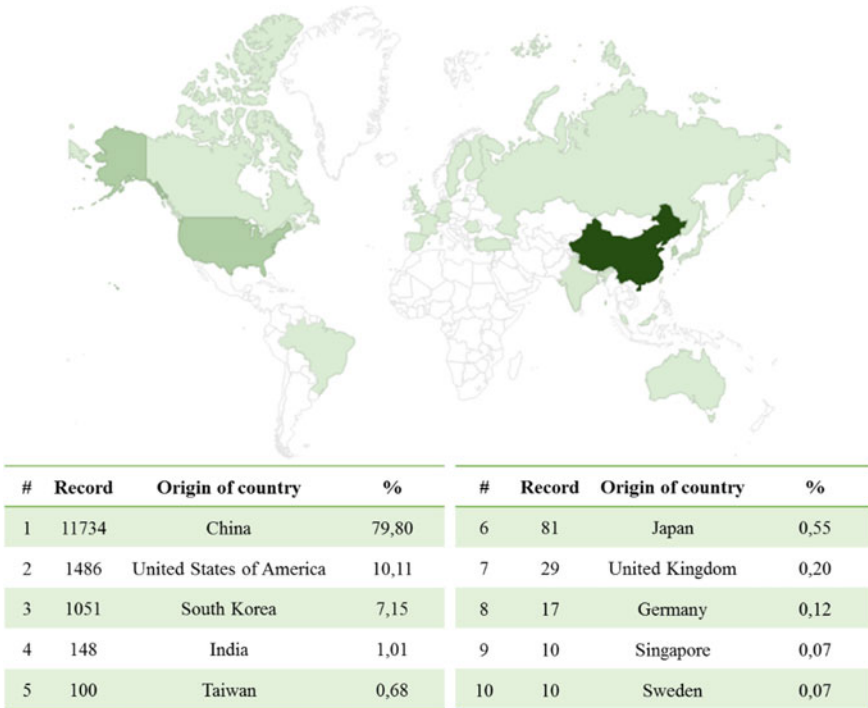
- Number of patents per year and annual growth rate from 2010 to 2017;
- Patents documents per country of origin;
- Distribution of patent documents according to technological subdomains.

## 4 Results

A total of 14.763 patent documents related to IoT in the period from 2005 to 2017 were identified. The term was introduced in 1999 by Kevin Ashton in the context of RFID-related supply chain management [14]. Therefore, in 2005, we have the first patent document indexed in the DII related to the subject and it approaches a method for the production of work products. From 2005 to 2009, it presents only 6 patent documents, of which four are from 2009. It was noted that only from 2009 to 2010, there was a growth rate of 2600% of patent documents.

The evolution of the number of patent documents between the years 2010 and 2017 is presented in Fig. 1. The year 2016 stands out with 4647 patent documents, however, the year 2017 in future research may present a greater amount of documents, since not all patents referring to this year may have been indexed in the DII, having in view, that the data of this research were collected in early 2018 (see Fig. 2).

The databases normally depend on the availability of information from the intellectual property offices of each country and account should be taken of the confiden-



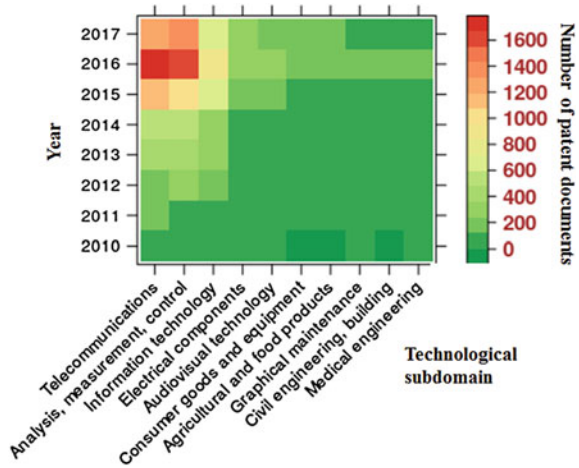
**Fig. 3** Patent documents per country of origin

tiality period of these documents, which may vary from country to country, and the processing time of such information for availability [15].

Thus, from the importance of the internet of things in the context of industry 4.0 and its promising implication for building industrial systems and application based on the user needs, it is possible to note the commitment of several actors to create favorable environments for new technologies to be created and incorporated in the coming years. The technology is so powerful and the percentages of companies committed are so high that IoT-powered digital transformation almost seems inevitable. The economic outlook for IoT technologies is estimated at \$33 trillion [6]. The main countries of origin of patent documents related to IoT in Fig. 3 are presented.

China stands out with 79.80% of patent documents linked to IoT, and this scenario may be related to the fact that the Chinese government adopts the development of IoT as a national strategy, supporting four aspects of IoT: RFID, M2M (machine to machine), merger of industrialization and informationization [16]. The promotion and growth of the Internet of Things in China is marked by competition between cities, in which each city or province is creating its own IoT-linked strategy, setting up research centers, and implementing projects. As well, in the expectation that IoT solves many social problems and brings economic growth from the implantation of companies in the different regions [17].

**Fig. 4** Patent documents according to technological subdomains



The United States of America, in turn, represents 10.11% of patent documents. The number of patent documents is still small, compared to China [16].

Industry 4.0 is a strategic initiative of Germany, therefore the country has an important role in this context, which sought to create intelligent factories, using manufacturing technologies from cyber-physical systems (CPSs), Internet of Things (IoT) and cloud computing [18]. With regards to the IOT, Germany has 0.12% of examined patent documents.

Approximately 50% of the patent documents analyzed are linked to the technological domain of Electronic-electricity and 33% of Instrumentation. Figure 4, on the other hand, presents the main technological subdomains in the period from 2010 to 2017.

The main technological subdomain is Telecommunication, with approximately 28% of patent documents. The subdomain of analysis, measurement, and control corresponds to 27% and Information Technology subdomain, 16%.

As of 2015, there is a significant growth in Telecommunication and Analysis, measurement, and control subdomains. However, with respect to the growth rate in the technological subdomains presented in Fig. 4, growth in Consumer goods and equipment, followed by Analysis, measurement, control.

IoT technology has been used in different areas, whether in smart cities, manufacturing, or health care. Thus, the objectives and applications of IoT may be different, however, different countries work in collaboration to use IoT in projects, in order to improve the development of this technology [18].

## 5 Conclusion

The digital age has brought with it a new way of thinking about manufacturing and operations. Labor rate changes in emerging economies, coupled with challenges associated with logistics and energy costs, are influencing global production and associated distribution decisions [19]. Since the creation of the term Internet of Things in 1999, the term has been gaining more and more importance worldwide and has been applied in different areas such as health, transportation, smart cities, and manufacturing. IoT, on the other hand, is also one of the bases for Industry 4.0.

This paper presented the overview of patent documents related to the Internet of Things, in view, its importance for Revolution 4.0. Thus, it was identified that the first patent document dates from 2005, however, the number of patents became more significant as of 2010 and in 2016 it reached 4647 documents. China stood out as the main country of origin of patents, which may be related to the strong incentive of the Chinese government to adopt IoT as a national strategy. However, research and development in the area of IoT also occurs in collaboration among countries. This would be interesting to analyze in future research.

The technological domain that has mostly developed is that of Electronic-electricity. Parallel to this, in subdomains, telecommunication was supported by further growth among all subdomains, particularly after 2015. Since then devices manufacturing and communication protocols among devices are one of the pillars in IoT, it is reasonable to realize why these are the main subject area of patents development. Furthermore, the highest growth rate in the period from 2010 to 2017 was the subdomain of Consumer good and equipment. Therefore, we can predict that consumer goods and equipment are one of the most promising subdomains to be studied in the coming years.

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# Flexibility Practices in Disaster Response—A Process Approach Based Evaluation



Rafael Duarte, Leticia Gorte and Fernando Deschamps

## 1 Introduction

Organizational systems based on flexible processes are receiving increased importance in the society. This kind of system does not have a preestablished sequence of activities to be performed. This sequence is defined accordingly to the current situation of the system, variables related to the internal and external context of the system and the experience of the people involved. An example of a flexible process is the disaster response (that in Brazil is performed by the Civil Protection and Defense Agencies, which have branches on the states and the cities), and some complex project management situations, such as new product development projects, construction works for infrastructure projects or industrial process improvement projects.

Evaluating such systems to determine if they are well structured and have the conditions to reach their objectives is one of the leading activities to know the real effectiveness and efficiency of these systems. In a previous stage of the current work [1], the authors proposed a set of guidelines that help in the evaluation of flexibility, according to the characteristics of the process and the type of organization analyzed. However, this can be quite hard to accomplish, and the problems come from the lack of standardization of the organizational systems' practices involved and the fact that the practices used can be quite diverse, depending on the characteristics of the systems.

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This paper is based on earlier work on the flexibility characteristics of disaster response processes and their relationship with organizational engineering guidelines. The objective is to seek solutions to two problems: (1) to determine how disaster response processes, with flexibility needs, can be evaluated regarding the compliance with the engineering guidelines of organizations and, (2) the disaster response process meets these guidelines using which practices, mainly related to this flexibility.

## 2 Literature Review

The literature review will present information about the flexible processes concept and the Brazilian Civil Defense, approaching mainly its structure and responsibilities.

### 2.1 *Flexible Process [2]*

Flexible processes are characterized as those processes that are capable of dealing with predicted and unforeseen changes in the context or environment in which they operate [2]. These processes support adaptive processes, declarative models, late modeling, and data-driven processes [3]. Flexibility reflects on the ability to deal with such changes by varying or adapting the parts of the process that are affected by such changes [2]. Flexible processes can have four distinct approaches [2], each with its application area, as explained in the following Table 1.

### 2.2 *Protection and Civil Defenses*

Protection and Civil Defense, in Brazil, is the name of the entity or body created at national, state, and municipal level, with specific attributions and with the objective of human solidarity, in order to help the affected people and to minimize the situations of adversities in which they are after an abnormal event [4].

It is worth mentioning that this body is completely integrated with a Nationwide Civil Defense Structure, called the National System of Protection and Civil Defense (SINPDEC), which brings together Civil Defenses of all Brazilian states, coordinated by Civil Office of the Cabinet of the President of the Republic [5]. In turn, the State Civil Defense Structure that gathers all the Civil Defense of all the cities of the state, and the Municipal Civil Defense Structure that congregates all the Civil Defense Nuclei of the Municipality [5]. Because of this integrated structure, the members of this body cannot be analyzed separated from the context and understanding which actions are the responsibility of each entity eases the understanding of the organization. The goal of protection and Civil Defense is to reduce disaster risks and consists of prevention, mitigation, preparation, response, and recovery actions [6].

**Table 1** Kinds of flexibility definitions

Flexible process	Characteristics
Flexibility by design	It elaborates different paths for the process in the development stage, being able to select the most suitable on the run-time
Flexibility by deviation	This approach does not allow a change in the process definition or the related activities since a process instance can deviate from the predefined path without changing the original model. To accomplish this flexibility, it is possible to undo a task, redo a task, skip a task, create a new instance for the task, or invoke a new task
Flexibility by under specification	It occurs when, due to lack of information, it is necessary to perform an incomplete specification of the process. The execution options are divided into Late Building and Late Modeling (a new process fragment is constructed to verify a given character)
Flexibility by change	Modify the process definition at run-time, even if one or all of the process instances are in the new process template. It can be related to temporary processes, which affect the execution of one or more selected instances, without affecting any future instances, or by evolutionary processes, in which a change is caused by the modification of the process definition, affecting all new instances

For this research, it is important to distinguish the competencies related to COM-PDEC (Municipal Protection and Civil Defense Coordination) and CEPDEC (State Protection and Civil Defense Coordination) according to a capacitation manual developed by Protection and Civil Defense Agency [7], as outlined in Table 2.

CEPDEC’s primary function is to support COMPDEC in its formulation, as well as in the training of technicians, volunteers, and others involved, and to assist with the workforce in the disaster response efficiently.

The federal and state governments act in partnership with cities, which have the autonomy to define their Contingency Plan, a fundamental tool in disaster response actions [7, 8]. The stages of the process (Table 3) that must be carried out in the actions of prevention, mitigation, preparation, response, and recovery of a disaster (Table 4), and what corresponds to each of these actions, were interpreted and classified as a flexible process.

For comparative purposes, the same classification dynamics were implemented by merging flexible processes with actions taken by an organization, based on Federal Emergency Management Agency (FEMA), the agency responsible for the disaster and emergency management in the United States. FEMA has a responsibility to coordinate federal, state, and local government relief efforts [10–13]. It is designed to act systemically and orderly in disaster relief actions, fulfilling its responsibility to prepare, protect, respond to recover, and mitigate all risks, thus protecting all citizens

**Table 2** Different functions from COMPDEC and CEPDEC

Protection and Civil Defense			
Stage	Feature	COMPDEC	CEPDEC
Prevention	Ensure adequate response to disasters and minimize consequent damage and losses	Promote public and educational campaigns	Auxiliary in the organization of COMPDEC
		Suggest works and prevention measures with the aim of reducing disasters	
		Implement volunteer training programs	
		Establish aid exchange with other cities	
		Update data referring the population, risk areas, Executive Plans and Contingency Plans	
Mitigation	Measures designed to reduce or limit the configuration of the risk situation	Establish aid exchange with other cities	Support and advise COMPDEC in planning: elaboration of the Work Plan, Master Plan, and Contingency Plans
		Enable human resources for Civil Defense actions	Guide the COMPDEC technicians in the mapping of risk areas
		Update of risk, vulnerability and population data, human resources, materials and equipment for response action	Conduct training for the COMPDEC's members and volunteers about the areas of performance
Preparation	Ensure the minimization of disaster risks and the optimization of response actions	Establish aid exchange with other cities	Support and advise COMPDEC in planning: elaboration of the Work Plan, Master Plan, and Contingency Plans
			Guide the preparation of simulations for COMPDEC members and the population
			Conduct training for the COMPDEC's members and volunteers about the areas of performance

(continued)

**Table 2** (continued)

Protection and Civil Defense			
Stage	Feature	COMPDEC	CEPDEC
Response	Reestablish the conditions of normality	Inform state agencies of the occurrence of a disaster	Assist in the contacts to obtain information, in the acquisition of material and equipment
		Perform distribution and control of supplies needed to supply the population	
Recovery	Avoid the installation of new risk situations	Establish aid exchange with other cities	Train COMPDEC technicians to carry out disaster damage assessment

**Table 3** Process flexibility approaches [9]

Flexibility approach	Evaluation items
Design	Elaborate different ways for the process, being able to select the most appropriate during the execution of the process
	There are many ways to accomplish flexibility, such as relating process tasks in parallel, by choice, interaction, interleaving, multiple instances, and cancellations
Deviation	Undoing a task before it occurs
	Remaining a task: the task is disabled but is re-executed before it
	Skipping a task: performing the subsequent task
	Creating a new instance for the task
	Invoking a task that in the main process was not authorized or has not been performed yet
Under specification	Perform an incomplete specification of the process for a gap of information
	An incomplete process specification contains one or more sub specified characters
Change	Modify the process definition during execution
	Momentary: changes affecting the execution of 1 or more instances
	Evolutionary: change caused by the modification of the definition of the process

**Table 4** Civil Defense actions

Stage	Feature
1. Prevention	Ensure adequate response to disasters and minimize consequent damage and losses
2. Mitigation	Measures designed to reduce or limit the configuration of the risk situation
3. Preparation	Ensure the minimization of disaster risks and the optimization of response actions
4. Response	Reestablish the conditions of normality
5. Recovery	Avoid the installation of new risk situations

To FEMA, the basis for the response is the Incident Command System (ICS), which presents the best practices taken in emergency situations, and has become the standard for emergency management in the country. The ICS is structured to ease the activities in five major functional areas: command, operations, planning, logistics, and finance and administration [9–12]. As for SINPDEC, FEMA’s actions were also compared to the characteristics of flexible processes through their main processes (from their characteristics).

Following the methodology of classification of Civil Defense actions as flexible processes, the primary responsibilities of municipal (COMPDEC) and state (CEPDEC) Civil Defense branches were considered as activities of one process. These activities were mixed with the characteristics of flexible processes, which gave rise to two new evaluation tables.

Figures 1 and 2 are some excerpts from the evaluation table, as an example of COMPDEC and a CEPDEC action classified as a flexible process.

Figure 1 shows that in the disaster response stage, one of COMPDEC’s responsibilities is “To execute the distribution and control of the supplies necessary to supply the population,” the adequate response to the disaster ensures better assistance and help to victims, minimizing the consequences of the disaster. Therefore, this process of distribution and control of supplies is classified as a flexible process by Design, since it is not necessary to have a predefined sequential process for the execution of the disaster response since there are different ways to execute this process.

FLEXIBLE PROCESS (Characteristics)		Design	
		Elaborate different ways for the process, being able to select the most appropriate during the execution of the process.	There are many ways to accomplish flexibility, such as relating process tasks in parallel, by choice, interaction, interleaving, multiple instances, and cancellations.
CIVIL DEFENSE - COMPDEC			
Stage	Feature		
4. Response	Reestablish the conditions of normality.	To execute the distribution and control of the supplies necessary to supply the population	

**Fig. 1** Excerpt from COMPDEC’s flexibility’s process evaluation table

FLEXIBLE PROCESS (Characteristics)		Design	
		Elaborate different ways for the process, being able to select the most appropriate during the execution of the process.	There are many ways to accomplish flexibility, such as relating process tasks in parallel, by choice, interaction, interleaving, multiple instances, and cancellations.
CIVIL DEFENSE - CEPDEC			
Stage	Feature		
2. Mitigation	Measures designed to reduce or limit the configuration of the risk situation.	Support and advise COMPDEC in planning: elaboration of the Work Plan, Master Plan, and Contingency Plans	Guide the COMPDEC technicians in the mapping of risk areas

Fig. 2 Excerpt from CEPDEC’s flexibility’s process evaluation table

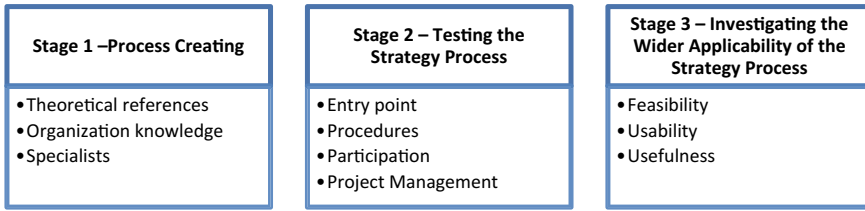
Figure 2 addresses CEPDEC processes. The function of the state body is clear: assist the municipal agencies, with training, technical guidance, advice in the planning of Contingency Plan, Director, and Work [5]. These characteristics were allocated in the mitigation stage since they act to reduce the risk situation. The responsibility of “Supporting and assisting COMPDEC in planning elaboration” is defined as a flexible process by design, because the drafting of plans can change at any time within Civil Defense, either by the change of board or by obsolescence of the plan. The process of advice can have several paths, and the most appropriate one is used during the execution of the process. Concerning the responsibility of “Guiding COMPDEC technicians in the mapping of risk areas,” its classification as a flexible design process is in the form in which this orientation can be performed. It can be related to other tasks of the process, according to the description of the quadrant in which it is.

In this way, each responsibility of both coordinators (COMPDEC or CEPDEC) has been rigorously analyzed and allocated according to the flexible process characteristic that best represents it, according to Appendix 1 and 2.

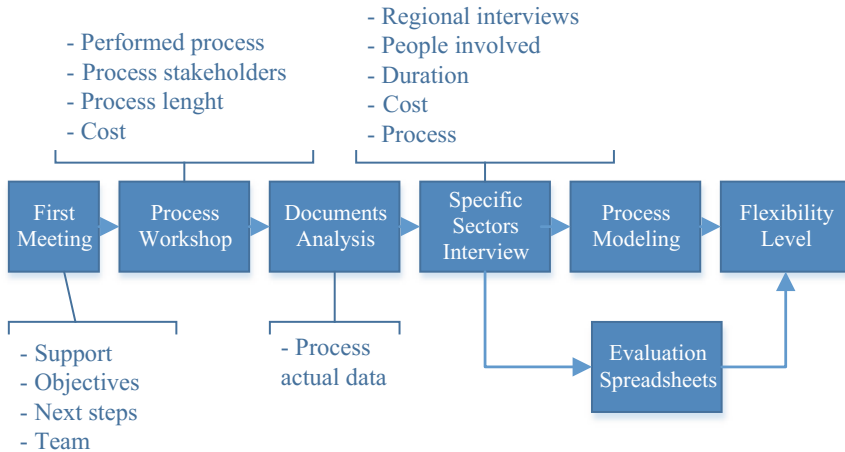
### 3 Method

For the characterization of the disaster response process as a flexible process, the chosen method was the Cambridge Process Approach, also known as Process Approach [14]. This method aims to assist in the investigation of the definition of a feasible and usable process that can be used to generate useful content through the connection of existing structures in the organization and of appropriate empirical tests to verify the proposed process. Initially applied to the industrial strategy manufacturing process [14], it has been applied to other situations [15].

The methodology has three stages (Fig. 5). In the first stage, process creation, the process strategy is set, using literature review, evaluating academic materials (books and articles) and manufacturing and consulting companies. For the success of the



**Fig. 3** General outline of the phases of the Cambridge Process Approach and its main concerns.  
*Source* The authors, based on [14, 16]



**Fig. 4** Process to the flexibility assessment of a disaster response process

research, the process formulation must have four elements: procedure, participation, project management, and entry point. In phase 2, the process based on the four main elements is applied, and finally, in step 3, the process is evaluated to identify if it is effective regarding feasibility, usability, and utility (Fig. 3).

Based on the Process Approach, a process was developed to assess the flexibility of a disaster response process, as shown in Fig. 4.

It starts with an initial interview with the operations team, in which questions about the process are addressed, like the objectives of the process, the next steps, and who is involved in the process. Then, there is a process workshop, where the first insights are discussed and through a second interview more details of the process are obtained: who is the team involved, the duration, and the cost. That is a broader overview, with the strategic team.

Following a regional interview, which addresses the same issues of the general interview, however, the focus is on the regional approach. All interviews are transcribed to get more details about how the actual operation performed.

After collecting information, the process is divided into two parallel paths. On the first path, is performed the process modeling, that addresses the real process

**Table 5** Experts questions and responses frequencies

	Totally disagree	Partially disagree	Partially agree	Totally agreed
The procedure is well defined			2	1
The participation of key stakeholders is guaranteed			1	2
The resources needed for the initiative are available			1	2
The entry point is well defined		1	1	1
The process is feasible		1	1	1
The process is usable			1	2
The process has the potential to generate useful results				3

performed in the disaster response, based on the evidence collected in the interviews. The second path, worksheets evaluation, intends to discover in which points the process can be characterized as a flexible process.

The last step evaluates the process and determines its flexibility level.

The process was submitted to expert evaluation, as ordered by phase 3 of the Process Approach. These experts answered a questionnaire that addressed seven main points of the process, and at each of these points, they decided whether they totally disagree, partially disagree, partially agree, and totally agreed. The results are displayed in Table 5.

The three experts had different opinions about the process, except in the question if the process has the potential to generate useful results, to which they all fully agreed. Regarding the definition and feasibility of the process, each specialist had a different view, but none of them fully disagreed.

## 4 Results

The process of evaluating the flexibility of disaster response processes was applied to the SIMPDEC—Curitiba, evaluating the information and reports from the team that responded to a flood that occurred on June 17, 2014. Following the process, a first meeting was held with the main involved in the actions of this event. A process workshop was elaborated, followed by the document analysis, and interviews with the agents that worked on the disaster response process.

After this rigorous data collection, it was possible to elaborate the process model carried out by Civil Defense, partially shown in a BPMN model (Fig. 5).

This BPMN process model was elaborated based on the evidence raised by the interviews, and it portrays the whole process of disaster response carried out by the Civil Defense of Curitiba, starting with the alerts made by meteorological organs as



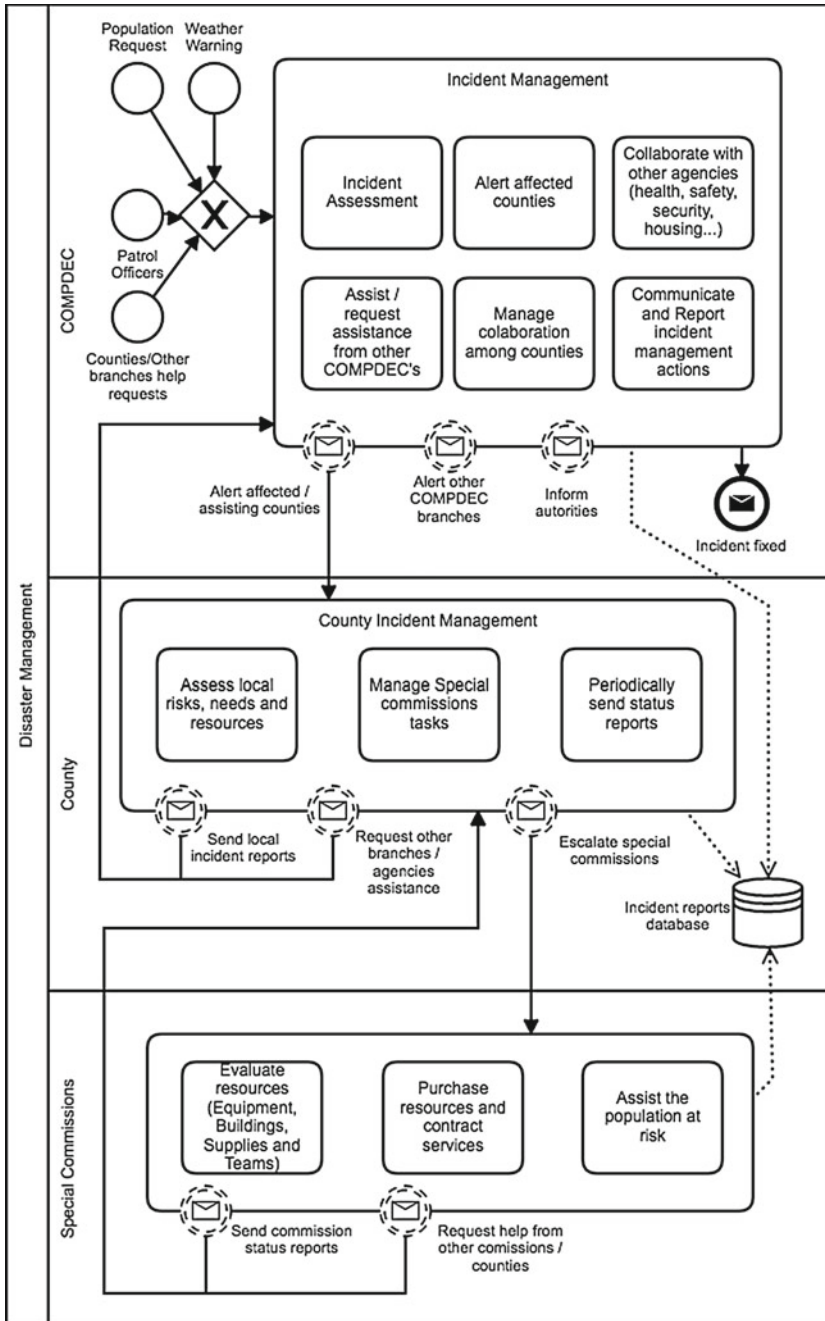


Fig. 5 BPMN model of the disaster response process carried out by Civil Defense

well as by the affected population. Then the incident management begins disaster response actions, ending only after finishing the actions to recover the places and population.

Meanwhile, the process was submitted under the evaluation worksheets. It was possible to determine the degree of flexibility of the disaster response actions of the event in question. To determine the degree of flexibility, the two evaluation tables were used. The actions from SIMPDEC—Curitiba were identified at each point in the evaluation table, and then how flexible the action could be classified: totally, partially, or not at all.

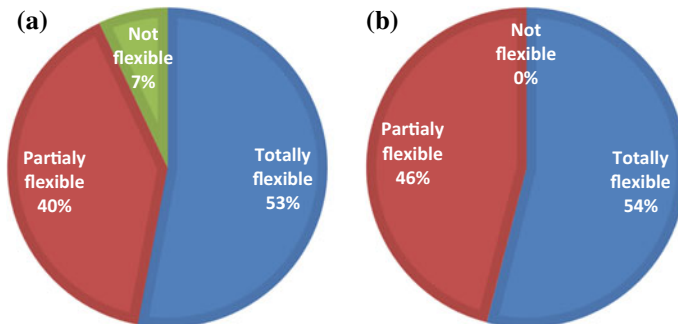
Then, it was compared the classification according to the model predicted by the National Civil Defense the classification according to the parameters established by FEMA of the United States.

Based on the described assessment, two charts were elaborated to display how flexible the process is. Chart 1 refers to the National Civil Defense based assessment worksheet, and chart 2 to the FEMA-based assessment worksheet.

This way, it's evaluated that the actions carried out by SIMPDEC—Curitiba, referring to the flood of June 17, 2014, are very flexible, since the mean value of the charts' results, where 53.5% of the shares are classified as totally flexible, 43% of the shares were partially flexible, and only 3.5% of the shares were not flexible.

## 5 Conclusions

The process, based on the Process Approach, covers the stages of the disaster response flexibility assessment process. It starts with the initial meeting, followed by the process workshop, then the documentation analysis, and interview the specific sectors. After that, the process is modeled, and the worksheets evaluated, to determine the level of flexibility of the process (Fig. 6).



**Fig. 6** a Flexibility of the disaster response process carried out by SIMPDEC in the flood analyzed according to the National Civil Defense; b Flexibility of the disaster response process carried out by SIMPDEC in the flood analyzed according to FEMA. *Source* The authors

After the specialist' evaluation, the designed process still has gaps to be studied and filled, to match it to the Process Approach's requirements. It's advised to improve the definitions of the process and make it more feasible.

Several complications were encountered in the design of the process, regarding the activities that can be considered flexible. Per example, since it is a process of response to disasters, it can be started in different ways (flood, tornado, aerial accident), with different magnitudes, which requires a different procedure for each case.

It is possible to state that the developed process is feasible when applying it in a real situation because it was possible to categorize the degree of flexibility of the analyzed process by following its procedures.

Another perspective that was verified on the current process is regarding the communication and monitoring technologies currently used. A lack of standardization and protocols to the communication between the disaster response team, who uses their own mobile devices to place calls and send messages to the other members, was considered by the authors as a threat to the process stability. In the case of a larger scale disaster, that could damage the antennas of the civilian cell phone operators, and the communication structure would be disabled. On the other hand, it increases the flexibility of the operation, since the team may use different apps, and contact people and organizations not previously aligned to their operation. Anyway, this scenario would be less likely if the team had radios to communicate, the same way the firefighters, police and rescue teams do. Also, although the operation counts on the weather forecast to adjust the readiness level of the group, sending reports and setting the teams ready to work in the case of high risk of storms and inundation, sensors in the rivers and pounds could alert the Civil Defense about the imminence of floods. That would allow the disaster recovery team and the population to respond earlier to these events.

The work still requires further studies, since the subdivisions and ramifications of Civil Defense have their own procedures, rules, and methodologies to fulfill their objectives.

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# A Literature Review of Mathematical Programming Applications in the Fresh Agri-Food Supply Chain



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and Meire Ramalho de Oliveira 

## 1 Introduction

The agricultural business, or agribusiness, includes a range of farm-related industries, especially food manufacturing and food services. It covers activities as farming, production, marketing, and management of rural commodities, such as livestock and crops. A plenty of food and beverage manufacturing plants are engaged in transforming raw agricultural materials into products for intermediate or final consumption.

The term **agri-food supply chain** (ASC) has been coined to describe the activities from production to distribution that bring agricultural or horticultural products from farm to the table. ASC is formed by the organizations responsible for production (farmers), distribution, processing, and marketing of agricultural products to the final consumers [2, 6].

In addition to the problems common to most supply chains, ASCs must also deal with factors such as food quality, safety, and weather-related viability. Also, they may manage issues related to limited shelf life, which restricts the amount of time that most products can spend in storage and therefore the capacity of holding inventory as a buffer for variability. Furthermore, compounding the issues of variability and

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perishability, we have very long lead times from the moment that planting is made, until harvest [19, 22, 27].

As will be seen in the following sections, models and solution methods for ASC problems are relatively abundant. Due to NP-hardness of supply chain problems [7] and the large sized data in the real world, meta-heuristics such as genetic algorithm and particle swarm optimization, have been widely used. However, as well as in other optimization problems, the solution technique of **mixed integer programming** (MIP) models, or mixed integer linear programming, can be employed in supply chain problems. As none of the reviews works reported here (in the Sect. 3) focused specifically mathematical programming formulations, our aim is to investigate the published research addressing MIP models for agri-food supply chain problems and the respective constraints considered.

## 2 Fresh Agri-Food Supply Chain Problem

Due to issues related to public health, in practice agricultural products attracts a great deal of attention, subject to stringent regulations and closer monitoring. This implies that traditional supply chain practices may be under revision and change [2]. In order to address the global challenges and to keep up with the changes occurring in agricultural supply chains, greater efficiency must be achieved by all parties involved. It is because of this strong need to increase the efficiency of the supply chain that planning models will become of increasing importance to farmers, intermediaries, and final distributors of agricultural commodities. Planning tools and information technology for each of these key players must become increasingly refined and applied, in tor to drive non-value-adding costs out of the value chain [22].

Among the specific issues of ASC problem, perishability, in particular, is very critical for horticultural products, whose shelf life is significantly lower than that of traditional crops, like grains, fruits, and other vegetables. Moreover, it is important to consider the greater economic context of the farm business and the position of farmers who are subject to the forces of the market. Also, they have little control over prices, the exact timing and the yields of their crops, all of this while working with relatively small profit margins. Complexity is further compounded when the supply chain has a large amount of stakeholders at various echelon (such as farmers, shippers, and distributors) that must coordinate their actions to avoid losses caused by a mismatch of supply and demand [17, 19, 22].

Nevertheless, Siddh et al. [29] state that the fresh agri-food segment is a profitable venture of all farming activities as it provides ample employment opportunities and scopes to raise the income of the agricultural community. In the last decade, there were dramatic changes in the supply chain of agri-fresh products, which compose a significant position of the world economy as well as they are the supplies for various food processing industries. Inside fresh agri-food supply chains, raw foodstuffs are transformed through packing, distribution, and related services. In this process, it

is very important that not only the product quality is ensured but the supply chain quality should be maintained as well.

The agri-food supply chain network typically is a multi-echelon supply chain network with multiple products, including four stages: primary production (of raw products by farmers), production of semi-product by plants, production of finished products and distribution (transporting finished products to the distribution center or consumers). Broadly speaking, the problem can be to determine the optimal number, location, and capacity of the production plants and product type produced by each plant. It also can select transportation mode (by railway, by sea or by truck) and the corresponding amount of items shipping from supplier to plants, between two plants and from plants to distribution centers. The decisions are made given the market demand, such that the total costs (comprising the production and transportation costs) are minimized [37].

Even for local organic food supply chains, designing and managing are complex, and face socially bound uncertainties such as poor collaboration, communication, and information sharing. Moreover, there are aspects such as ethics, sustainability and human values that influence decision making and supply chain activities. Local organic food supply chains are mainly composed of small-scale enterprises that face limitations in implementing complex mathematical models and sophisticated software used in quantitative supply chain design and management. Viable and well-established approaches to reduce the inherent uncertainty are lacking and need to be developed [32].

As pointed out by Mason et al. [22], the technology and tools for increasing the efficiency of ASC have been researched in the past; however, their implementation has been very limited to their mathematical formulation, which contrasts with the intuition of traditional decision-makers, their limitations on capturing the whole system dynamics, and the added complexity inherent of integrated models. Therefore, this work aims to focus on research in fresh agri-food supply chains which employ mixed integer programming models as a solution approach to investigate its improving potential especially in the efficiency of the products delivery.

### **3 A Tertiary Study of ASC Planning**

There are many literature reviews of solution approaches for agri-food supply chain planning. Thereby, this section presents a short tertiary study of this subject matter, i.e., a review of literature reviews. As pointed out by Abedinnia et al. [1], the main objective of tertiary studies is to investigate core themes that have been studied in a particular research area by reviewing and analyzing secondary works (i.e., literature reviews), providing a compact and comprehensive overview of the state of knowledge and unveil general deficiencies of published literature reviews on the subject under consideration. Thus tertiary studies are valuable sources for finding potential areas for future research. Thereafter, we have conducted a secondary study on the (primary) literature specifically about MIP models for ASC problems (in Sect. 4).

Siddh et al. (2017) provided a structured a review of fresh ASC quality over a period of 23 years (1994 to mid-2016) and a platform for practitioners and researchers that identifies the existing state of work, gaps in current research, and future directions in that field. A critical review of ASC management was presented by Ganeshkumar et al. [13], with the gaps to be explored about practices which may be used by researchers to enrich theory construction and practitioners may concentrate on establishing the extent and frontiers of ASC management.

A comprehensive and structured review on recent studies in the field of agribusiness planning models, aiming to optimize fresh ASC, with a focus on loss minimization in the fruits and vegetables was presented by Pamm et al. [23]. From the literature, it is concluded that the importance of food loss minimization is increasing. However, in most of the reviewed papers, food loss minimization is considered as a secondary scope with the main scope of cost decrease or profit increase.

The development of approaches used to identify and assess the risks that occurred in the ASC have mapped by Septiani et al. [28]. The papers found were classified into three stages: risk identification, assessment, and mitigation. Kusumastuti [18] have reviewed the literature on crop-related agri-chains focusing on the integration, or lack thereof, harvesting and processing planning and related inventory control issues. The research highlighted the importance of minimizing food waste and maximizing food quality since crops are particularly prone to deterioration after harvesting and before processing.

The ASC coordination was aimed by Handayati et al. [15], presenting the spectrum of coordination mechanism taken to deal with different levels of interdependencies and quality requirements. Mason et al. [22] published a brief historical overview of planning and optimization models in ASC, with an analysis of the new tendencies of the market. Tsolakis et al. [33, 34] proposed a taxonomy of the literature and practices that apply to all major issues that stakeholders need to address for the design and management of ASC. They presented the generic system components along with the unique characteristics of ASC that differentiate them from conventional supply chain networks.

Operations research and management science applications in the specialty crop industry (fruits, vegetables, grapes, nuts, berries, and dried fruits) were reviewed by Zhang and Wilhelm [36], with the goal of providing a perspective of models available to assist growers and distribution managers as decision support aids and a vision of research needs to stimulate academic research. A variety of models have been devised to support decisions that maximize profit, improve operation efficiency, balance risks, and integrate systems components much more effectively than human decision maker can without them.

Ahumada and Villalobos [2] presented the state-of-the-art for that moment of successfully implemented models for production and distribution of agricultural crops. They classified the models according to relevant features, such as the optimization approaches used, the type of crops modeled and the scope of the plans, among many others. Through the analysis of the current state of the research, they diagnosed some of the requirements for modeling the supply chain of agri-foods.



Lowe and Preckel [19] addressed the main modeling approaches used in crop planning in the context of agribusiness, highlighting some potential areas for research in the area. Lucas and Chhaged [20] considered the location analysis applied to agriculture, covering applications related to the location of warehouses and processing plants. They exposed the complexity and challenges of strategic production–distribution models applied to the agricultural industry and emphasized the emerging use of these models by large corporations. Glen [14] performed an extensive search of the literature previous of the year of 1985, focusing on the mathematical models for farm planning.

## 4 Publications with MIP Models for ASC Problems

According to the literature reviews presented previously (in Sect. 3), the use of mathematical models and operations research tools for agricultural planning is not a new concept. Instead, optimization models for applications in crop planning can be found since the early 1950 years, even in a tenuous way. This solution technique became more widespread during the decade of 1980, with growing interest in the 1990s. In particular, the perishability of fresh products and risk management are two themes which have quickly gained importance and visibility among the academic community [2, 14, 22]. This last fact highlights the relevance of the present study.

As stated by Zhang and Wilhelm [36], mathematical models have remained relatively small and within the reach of commercial solvers. However, as the industry grows and problems become larger (with more stakeholders, locations, and further collaboration), basic research will become increasingly important to ensure solvability. This review emphasizes the published papers which consider mixed integer programming models as a solution approach for fresh agri-food supply chain problems.

Searches were made at databases Science Direct, ISI and Scopus, from January to March 2018, with the following keywords, isolated and combined: *agri-food*, *fresh food delivery*, *mip models*, *mixed integer programming*, and *mathematical models*. The sample was formed with a manual selection of articles agreeing with the theme of this research. Only papers from indexed journals, peer-evaluated and written in English were considered (excluding publications for scientific events, chapters of books and academic publications such as thesis, dissertations, and monographs).

For each paper reviewed, Table 1 presents in reverse chronological order its reference (author/s and year of publication), the journal (to identify the main research sources of this problem), description of the problem and the case study considered, the objective function of the MIP model, and the kind of numerical input data.

For better visualization of the sample distribution, Fig. 1 presents the number of papers by publication year, from the most pioneering (1991) to the most recent (2017). As can be seen, there are many periods with no published papers: 1992–1996, 1999–2003, 2007, 2009, and 2013–2016. The years with more publications are 2011, 2010, and 2005.

**Table 1** Publications reviewed with MIP models for fresh ASC problem

Reference	Journal	Description	Case study	Objective function	Data
Soto-Silva et al. [30]	Computers and Electronics in Agriculture	Optimization models that deal with three related decisions in horticulture: purchasing, transporting and storing fresh produce	Apple dehydration plant in Chile	Minimizing costs of purchasing and maintenance; minimizing costs of transportation and storage	Real data
Stay et al. [31]	Computers and Electronics in Agriculture	An optimization-based seasonal sugarcane harvest scheduling decision support system	Syndicate of four sugarcane growers and their manager at South Africa	Maximizing the total harvesting operational profit	Real data
Ahumada and Villalobos [3]	Annals of Operations Research	An integrated tactical planning model for production and distribution of fresh produce. Logistic decisions associated with the distribution of the crop	Hypothetical producer of green bell peppers and vine ripe tomatoes	Maximizing the expected revenue, given by expected market prices, amount of each crop to be planted, when to harvest and sell them, the labor resources to contract and transportation mode to user to deliver	Hypothetical data

(continued)

**Table 1** (continued)

Reference	Journal	Description	Case study	Objective function	Data
Ahumada and Villalobos [4]	International Journal of Production Economics	An operational model that generates short term planning decisions for fresh-produce industry. Profitability is affected by management of labor costs, preservation of the value of perishable crops and use of transportation modes	Hypothetical producer of tomatoes and bell peppers	Maximizing the income, given a choice of customers, the prices and the costs incurred deliver	Hypothetical data
Rong et al. [26]	International Journal of Production Economics	Integrate food quality in decision making on production and distribution in a food supply chain	Supply chain for bell peppers	Minimizing the total costs, given by production, cooling, transportation, storage, and waste disposal costs	Generated instances
Rong et al. [26]	International Journal of Production Economics	Integrate food quality in decision making on production and distribution in a food supply chain	Supply chain for bell peppers	Minimizing the total costs, given by production, cooling, transportation, storage, and waste disposal costs	Generated instances

(continued)

Table 1 (continued)

Reference	Journal	Description	Case study	Objective function	Data
Blanco et al. [8]	Networks and Spatial Economics	An agricultural cooperative which uses harvesters for harvesting the crop and trucks for carrying it from the smallholdings to the landowners' silos	Cooperative of northwest Spain which manages the harvesting of grass and com	Minimizing the total working time of machinery (time of harvesters' activity plus the delays by waiting for trucks to unload)	Generated instances
Carpente et al. [11]	Top	An agricultural cooperative that has a big number of partners, each of them having one or more smallholdings. The cooperative has to crop all the smallholdings by using harvesters	Cooperative of northwest Spain which manage the harvesting of grass and com	Minimizing the total traveling time used by the harvester	Generated instances
Ferrer et al. [12]	International Journal of Production Economics	Scheduling wine grape harvesting operations taking into account both operational costs and grape quality	Vineyard in the central zone of Chile	Minimizing costs and maximizing quality	Generated instances
Higgins [16]	European Journal of Operational Research	Scheduling transport of sugarcane to the mill focusing on reducing vehicle queue times	Sugar mill region in Australia	Minimizing a combination of queue time and idle time	Real data

(continued)

**Table 1** (continued)

Reference	Journal	Description	Case study	Objective function	Data
Apraiah and Hendrix [5]	Journal of Food Engineering	A supply chain network with a goal to manufacture a pea-based novel protein food	Data of the Netherlands, France, Ukraine, and Canada	Minimizing the sum of the production and transportation costs	Real data
Blanco et al. [9]	Journal of Food Engineering	Operations management of a packaging plant in the fruit and concentrated juice industry	Fresh fruit industry (apples and pears) and concentrated juice from Argentina	Maximizing total profit (sales income minus raw material, labor and cooling costs)	Real data
Rantala [25]	Silva Fennica	A capacitated MIP model for solving an integrated production distribution system design problem in the seedling supply chain management	Multi-unit Finnish nursery company	Maximizing the sum of production, storage, and transport costs	Real data
Broekmeulen [10]	International Transactions in Operational Research	Tactical decision problem of improves the effectiveness of the operations of a distribution center of vegetables and fruits	A wholesaler of vegetables and fruits in the Netherlands	Maximizing a cost function (the fraction of the quality that is lost every day)	Generated instances (based on real data)

(continued)

Table 1 (continued)

Reference	Journal	Description	Case study	Objective function	Data
Maia et al. [21]	International Journal of Production Economics	Selection of technology routes for fruit and vegetable crops between harvest and market	Small cooperative of banana producers in the southwest of Brazil	Maximizing the expected profit	Real data
Zuo et al. [38]	The Journal of the Operation Research Society	A large-scale agricultural production and distribution problem, involving allocation of products to available production plants and transportation to the customers	Large seed com production company	Maximizing the sum of production and transportation costs	Generated instances

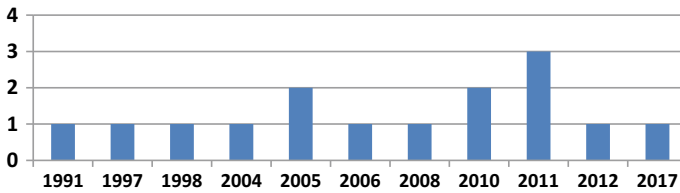


Fig. 1 Number of published papers by year

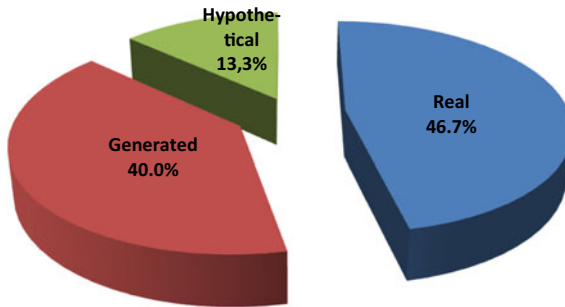


Fig. 2 Percentage of each type of data instances

In relation to the database considered, Fig. 2 shows the three types of instances found in the literature. The most frequent type in the sample is the real data, present in 46.7% of the papers. However, this amount does not represent even half of the papers, which is noteworthy, since the sample composed of cases studies. Of the other types of instances, 40.0% of papers have considered generated data and 13.3% have used hypotheticals.

Apart from the references cited in Table 1 (which considers just paper of journals), we can also refer to some publications of events: Zhao and Lv [36] studied an Apple industry cluster for optimizing the facility location, production capacity selection and choice of transportation mode for an ASC network design; Yandra et al. [35] addressed an integrated decision support system with multi-objective optimization for Transportation of coconut or palm oil and biodiesel; and Quadra et al. [24] considered a three-level (resource, production, and distribution) multi-period multilocation and multi-crop sustainable supply chain model.

## 5 Conclusion

The present work has updated the state-of-the-art of mathematical programming applications in the fresh agri-food supply chain. Despite the considerable amount of research that has used the MIP formulation for fresh ASC, this is clearly not the only modeling technique, nor is it the only exact (or optimal) solution approach.

As observed in the reviewed papers, mathematical formulations are used in cases where the input data are considered deterministic, as is also the case of dynamic programming and goal programming. Otherwise, stochastic modeling approaches or simulation can be used.

A sample of fifteen journal papers, published from 1991 to 2017, was analyzed. No article addressing fresh ASC and applying MIP models was found from 2013 to 2016. The publication sources are relatively spread: the *International Journal of Production Economics* was the one that the most had publications (4 papers); in the *Journal of Food Engineering* and the *Computers and Electronics in Agriculture* was found 2 papers each; and all others had just one article.

As can be seen, less than half of works applied their models to solve real-life problems using actual data (just 7 papers, i.e., 46.7% of the sample). This fact is interesting, since most of them presented a case study, even so with artificially generated instances. Therefore, identifying this gap in the literature, we suggest for future works the utilization of real data in the MIP models for fresh ASC problems.

It can be noticed in the literature review that there are many other papers not considering the perishability characteristic, simplifying the analysis and thereafter the results. However, the perishability is a real-life feature and important data for the models to provide solutions more accurate and effective. This reveals considerable research potential in the area of ASC problems with perishability.

Although it is not a new solution technique, this literature review highlights how little this approach has been explored in the ASC area. Also as can be noticed, mathematical formulations can be applied at several points in the supply chain under study: in production (planting and harvesting), localization, distribution and dimensioning, including the integrated way. For this reason, the use of mathematical formulations, combined with the advances in information technology and the high processing power of modern computers, is strongly recommended and highly encouraging in the fresh ASC problems.

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# A Bibliographic Review on Social Technologies



**Meire Ramalho de Oliveira, Lie Yamanaka, Maico Roris Severino  
and Helio Yochihiro Fuchigami**

## 1 Introduction

The term “social technology” corresponds to the creation and use of knowledge and techniques that promote the economic and social inclusion of disadvantaged or marginalized populations. The use of this knowledge and adapted techniques occurs due to the lack of modern scientific knowledge, due to the loss of economic conditions and also the reproduction of traditional knowledge. Inclusion occurs through the solidarity economy, as a result of the organization of new cooperative ventures and the expansion of existing ventures. Therefore, the aim is to design technologies for social inclusion [1–3].

Solidary economy is mainly emphasized in times of economic crisis, that is, when the capitalist economy is more withdrawn, which entails a workforce in a process of imposed idleness, and that seeks alternatives for survival by through the inclusion of self-managed organizations [1].

It is possible to perceive that in modern societies there is a problem related to the distribution of wealth, originated from the scarcity of resources that could be distributed [2].

Solidarity economy aims social inclusion and redemption of excluded people, in order to overcome these inappropriate conditions through the union, production,

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and diffusion of knowledge and values. This knowledge is then constructed through synergistic interaction. This way of organizing allows the participation of all those involved, in the form of collective decisions. These decisions include even their demands for technologies [1, 2].

Similar to traditional enterprises, solidary economy enterprises also require technologies for the production of ecologically correct goods and services. The search for the development of technologies is also in need of increasing the productivity and development of goods accepted and necessary to the market [1]. Therefore, the justification for the development of social technologies can be based on two pillars. First, conventional technology developed by the private enterprise may not be fully adequate to social innovation. The reason for this is that these technologies are designed to maximize the profit of companies that develop them and limit effectiveness for social innovation. These technologies are usually more intensive in synthetic inputs, environmentally unsustainable, use inconsistent production scales with the production of solidarity economy, among other aspects. Second, public institutions involved in the creation of scientific and technological knowledge—universities and research centers—are often unable to develop technologies for social innovation [3].

Recognizing the importance of social technologies for the solidarity economy and for the development of a more egalitarian society, this article aims to identify the scientific production on this theme. In addition, we intend to analyze the main documents published in the Scielo Citation Index and ENEGEP, as a way of obtaining a better understanding of what has been produced in the last ten years on this field of knowledge.

## **2 Role of Social Technology in the Solidarity Economy**

The Social Technology (ST) currently discussed corresponds to products, techniques, methodologies that have been tested, validated, and with a proven social impact. These technologies were created from social demands, with the objective of solving a problem through interaction with the community. These technologies are always taking into account local realities and are also associated with forms of collective organization, through associativism, creating a self-managing productive environment, voluntary and participatory cooperation. The social technologies represent solutions that culminate with the social transformation and improvement of the condition of life. The ST seeks to balance popular knowledge, the various ways of social organization and technical–scientific knowledge. Usually, social technologies are seeking for a solution of problems related to education, energy, housing, income, health, water resources, environment, among other demands [4–6].

For social technology, a knowledge developed in one place is not possible to apply it in another place. This corresponds to saying that it is necessary that the new process developed takes place exactly where the technology will be used, precisely by the individuals who will use it. The emphasis is on the production process of technology as a central aspect [7]. Social technology entails the construction of collective

solutions by those who will benefit from these solutions. Technology is developed through interaction with the population and appropriated by this population, with the aim of improving living conditions [4].

Solidary economy and social capital are complementary concepts to social technologies, which also act in the pursuit of the strategy of overcoming poverty and integrating excluded sectors. Social capital corresponds to the set of norms, institutions, and organizations that stimulate trust, reciprocal aid, and cooperation, facilitating coordinated actions. It is at the core of the theory of social capital that the solidarity economy emerges, understood as a set of productive enterprises, collective initiative, internal democracy, and that remunerate labor [6]. Social technologies emerge as an alternative to conventional technologies, produced by private companies and created purely for commercial exploitation. On the other hand, the objective of these technologies is not completely the search disordered by profit, it is necessary to consider that these technologies have elements that guarantee its sustainability, therefore it is important to consider its economic dimension [8]. Digital transformation is the integration of digital technology into all areas of business, resulting in changes in the way you operate and, consequently, giving value to products. Thus, social technologies can be used as technologies for greater value. Consequently, social technology has some intrinsic characteristics as adapted to lower production standards; the characteristics of the operator; economic viability for self-management ventures and small enterprises; sustainability in order to ensure their survival; among other aspects [3].

Thus, one way to ensure the development of social technologies is applying the strategy of changing the conventional style of technological development. It is necessary to move towards concepts that support alternative models of society, based on the reuse of scientific knowledge already developed [8, 9].

### 3 Methodology

This work is a quantitative, exploratory, and descriptive research that uses bibliometrics to investigate the advance of knowledge about social technology, through bibliometric indicators of scientific production.

We chose to collect and retrieve data from the Web of Science, Scielo Citation Index, and Proceedings of the Encontro Nacional de Engenharia de Produção—E-NEGEP (Brazil). The Web of Science was chosen as a platform, which offers a database set for the study and broad retrospective coverage. The Scielo Citation Index, in the same way, is integrated with the Web of Science, allowing the international availability of Scielo documents and the use of the same functionalities. The choice of the ENEGEP proceedings is based on the possibility of analyzing academic research in Brazil, since Industrial Engineering is interested in the development of social and technological innovations.

For this purpose, the searched term was: “social technolog\*?”. The period adopted for the analysis was from 2008 to 2017.

- **Web of Science (WoS)**

First, for the collection and retrieval of data, we chose to use three multidisciplinary and international databases available on the Web of Science (WoS) platform: Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), and Arts and Humanities Citation Index (A&HCI).

With the advanced search option of WoS, in the field—Topic, which searches for terms in the Title, Abstract, and Keywords of the bibliographic records and comprising the selected analysis period, 441 documents were located, from 2008 to 2017.

However, when analyzing the results, it was possible to perceive that most of the returned documents dealt with studies on tools for media and social networks, or other computational technologies, without direct relation with the solidarity economy.

Therefore, it was decided to continue the research using the Scielo and the ENEGEP proceedings.

- **Scielo Citation Index**

Data were collected and retrieved in the Scielo Citation Index, using the search term in the title, abstract and keywords of the bibliographic records, in the selected analysis period. As a result, 76 documents were located.

- **ENEGEP Proceedings**

Data were collected in the period (2008–2017), using the search term in title, abstract, and keywords in ENEGEP Proceedings. As a result, 13 documents were located. After the collection of the bibliographic records, the data were analyzed.

The Scopus database was not chosen for analysis. Scielo and the ENEGEP Proceedings were chosen because they are a topic approached regionally.

## **4 Results**

The results are divided as follows: indicators of scientific production through Scielo Citation Index, bibliographic analysis of documents published by Scielo, and bibliographical analysis of exclusively Brazilian articles, published by ENEGEP.

### ***4.1 Scientific Production—Scielo Citation Index***

We identified 76 documents published in the Scielo Citation Index. Through Fig. 1, it is possible to observe how the evolution of these publications occurs over time, with an increase in the number of publications from 2011 to 2013, with 13 documents being published in 2013.

The average number of articles published per year is 7.6. This value is considered low for most research areas. In the same way, when analyzing the average growth rate, a rate of 14.7% was observed in the cited period, a rate also considered low.

A potential cause of these lower rates of scientific production may be associated with Scielo’s regionality. This platform has journals indexed from countries in Latin America, South Africa, and Portugal. This fact does not prevent publications of documents produced by researchers from other countries, but may limit the dissemination of these journals, in other countries. This fact is very evident in the number of publications in Portuguese and Spanish, as can best be seen in Fig. 2.

As for the number of documents published by countries (Table 1), there are only documents published by Latin American researchers, as mentioned, culminating in more regional studies. About 69.7% of these studies were published by Brazilian researchers, indicating a greater interest in the subject

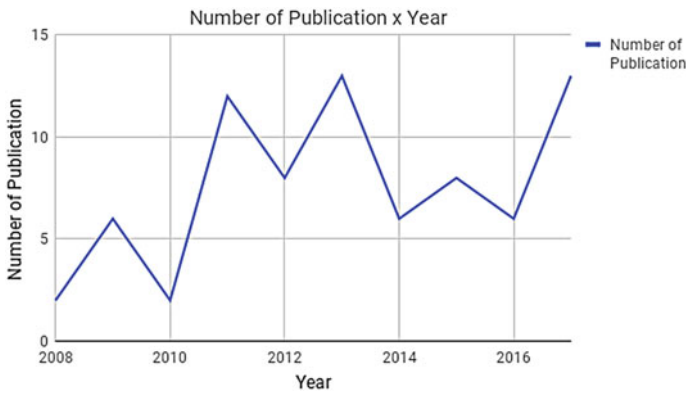


Fig. 1 Evolution of the number of documents published on ST (2008–2017)

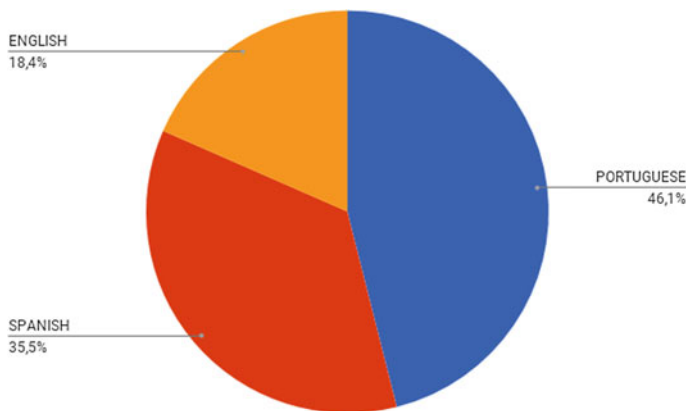
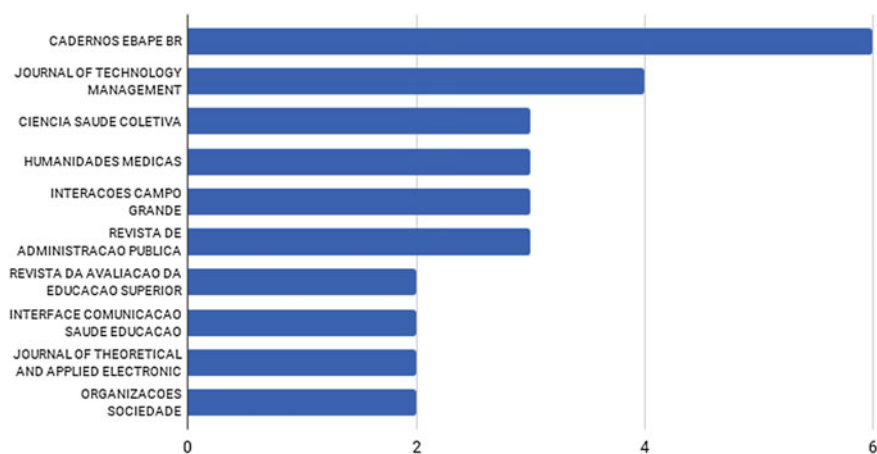


Fig. 2 Languages used in ST (2008–2017)

**Table 1** Number of documents published

Ranking	Country	Number of published documents
1°	Brazil	53
2°	Colombia	5
3°	Argentina	4
4°	Cuba	4
5°	Chile	3
6°	Costa Rica	2
7°	Spain	2
8°	Mexico	2

**Fig. 3** Journals used in publications on ST (2008–2017)

Regarding the languages, documents were predominantly published in Portuguese (46.1%), a reflection of the regional journals mentioned above, followed by publications in Spanish (35.5%), with English being the third idiom chosen (Fig. 2). This result is unusual, since scientific publications predominantly occur in English.

Scientific journals are evaluated and ranked by the scientific community according to criteria of legitimacy or scientific importance of the works they publish [10]. Increasingly these have been a constant object of evaluation by the financiers of the scientific activity, since it is believed that this indicator can be useful to have a view of the essential journals of each area, being these the sources of dissemination of knowledge more used by researchers and consolidated as a channel of scientific communication [11].

Figure 3 shows the title of the main journals and the number of articles published.

It is common to publish this theme in books directed collection and also in journals, but are not indexed in any platform.



The theme of social technology has a direct relationship with the concepts of solidarity economy, and this field of knowledge is multidisciplinary, associated with sociology, anthropology, economics, administration, psychology, political science, among others.

### 4.2 Bibliographic Analysis—SciELO and ENEGEP

Six empirical articles were selected for bibliographic analysis from SciELO. The criterion for selection was the quantity of citations, relation with the theme Social Technology and the practical application of the theme, that is, the use of empirical studies. Theoretical tests were not considered in this analysis (Table 2). These selected studies present the development of social technology. All occurred in Brazil. Only one study was conducted in the form of action research, while the other five studies were case studies.

Moreover, 13 articles were identified in the search of the ENEGEP Proceedings between 2008 and 2017. Five out of 13 articles were selected for analysis because they involved empirical studies. Concerning the five selected studies, three were

**Table 2** Bibliographic review on social technology—SciELO

Reference	Purpose	Research methodology	Location	Number citations
Rodrigues and Barbieri [12]	To identify the innovative potential of ST (cashew nut), considering efficiency, multiplication, and scale	Case study	Fortaleza—CE (Brazil)	9
Andrade et al. [13]	To analyze the “One Million Rural Cisterns” program, implemented in the Brazilian semi-arid region	Case study	Juazeiro—BA (Brazil)	3
Polli et al. [14]	To know the social representations of water in rural communities of Santa Catarina, through the subprojects of the ST program for Water Management, sponsored by Petrobras Ambiental	Case study	Santa Catarina—(Brazil)	3

(continued)

**Table 2** (continued)

Reference	Purpose	Research methodology	Location	Number citations
Moretto et al. [15]	To develop a pedagogical proposal to foster social incubators, in the light of social management, in the extension activity of UFSC	Case study	Canoinhas—SC (Brazil)	2
Mourão and Engler [16]	To know the fundamentals of solidary economy, based on the social design for sustainable economic development	Case study	Bonfinópolis de Minas—MG and Chapada Gaúcha—MG (Brazil)	1
Silva et al. [17]	To analyze the process of incubation of a social technology focused on the sustainability of solidary economic enterprises	Action research	Abaetetuba—PA (Brazil)	1

**Table 3** Bibliographic review on social technology—ENECEP

Reference	Purpose	Research methodology	Location
Silva et al. [18]	To map the ST of the units of SENAI BA using the methodology of the Institute of Social Technology (ITS)	Case study	Bahia (Brazil)
Pereira et al. [19]	To study the design of a human-propelled water pumping unit for a rural settlement in Northeast Brazil	Action research	Paraíba—PB (Brazil)
Silveira et al. [20]	To develop a proposal for an integrated production strategy for fish farming with fertigated drip irrigation	Action research	Vale do Jaguari—RS (Brazil)

(continued)

**Table 3** (continued)

Reference	Purpose	Research methodology	Location
Foscaches et al. [21]	To analyze the Social Technology PAIS for the production of vegetables through agroecology, as a way of developing the region and generating income for farmers	Case study	Campo Grande—MS (Brazil)
Candido et al. [22]	To study the role of technology in the development of coastal communities in the Amazon	Action research	Baixo Rio Madeira (Brazil)

developed in the form of action research and also presented a practical development of some technology (Table 3).

The importance of these empirical studies is the possibility of the construction and use of these technologies in other localities, the possibility of appropriation of this knowledge by other groups.

## 5 Conclusion

This article aimed to investigate the advance of knowledge through indicators of scientific production on social technologies and a bibliographic analysis of the main studies published in the Scielo and in the Proceedings of ENEGEP.

For the development of the research were located 76 articles related to the theme. The number of published documents is still low compared to other topics in the literature.

Among the countries that most research, it is verified that Brazil occupies a prominent position, with 46.1% of the publications made in Portuguese. Most of the articles were published in the Caderno Ebape BR.

The literature review carried out in both Scielo and ENEGEP, had as objective to demonstrate some practical studies technologies for the processing of nuts; construction of cisterns; water pumping modes; processing of fish, among others.

Social technologies may in many cases be a survival issue for marginalized populations. Precisely for this reason, it is believed to be of extreme importance that other research be carried out in this area, to make it possible to advance more and more in the knowledge of how to reach a society with more economic and social equality.

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# The Importance of Education in Enhancing the Innovation Capacity in Serbia



Bojan Lalic, Danijela Ciric, Danijela Gracanin and Zoran Anisic

## 1 Introduction

Innovation is seen as a critical driver of economic performance and essential instrument for business performance improvement of companies especially for emerging economies and economies in transition. Enhancing innovation potential and innovativeness in a way that will keep up with the fast pace of technological changes and changing demands is highly desirable in order to increase competitiveness on both macro level, when talking about the economic growth as the biggest national issue, and micro level, when talking about competitiveness and business performances of companies. In every society, especially in developing countries, innovation and entrepreneurship is a sign of progress and development as it has an impact on social, cultural, and economic development. It is obvious that innovation capacity is a driver of economic growth and sustainable job creation opportunities; therefore, there is a strong need in Western Balkan Countries (WBC), as developing countries, for a systematic promotion and development of innovation culture and innovativeness. WBC are representative examples of economies in transition as they have witnessed significant changes and economic transformations since the beginning of the twenty-first century to enhance innovation potential is not only about financial resources, it is also about appropriate skills and knowledge. Education (formal and nonformal)

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can be one of the main pillars to help enhance innovation capacity since knowledge is a fundamental factor in the innovation and assimilation of new technologies. The role of Serbian higher educational institutions, in this process, is very important. Serbian HEIs in their current situation are not completely able to support growing investments in innovation infrastructure and provide the industry with graduates and PhDs who holistically understand innovation and have related problem-solving skills. But, before developing study programs in the field of innovation and innovation management, it is needed to do an assessment of local needs for professionals in this field and what kind of professionals is needed.

## 2 Basic Concept of Innovation and Innovativeness

The literature dealing with innovation and innovativeness is extremely extensive. Innovation is linked with various topics and fields and put in different context. Innovation is a multilevel phenomenon. In today's modern society the concept of innovation and innovativeness has become very important and we could say mandatory. Innovation today is a key driver of economic growth. A clear understanding of what an innovation represents is crucial to assess the innovativeness. In the literature, [1–5] there are countless different definitions of innovation and they are evolving over time as business and technology advances and innovation opportunities continue to emerge. Innovation is defined broadly and can encompass the use of products, services, processes, methods, organization, and relationship or interconnections. The key requirement to be categorized as an innovation is that it requires the use of something completely new or vastly improved to the organization [6]. It is not just represented by introducing or implementing new ideas or methods. The definition of innovation can be defined as a process that involves multiple activities to uncover new ways to do things. Based on the work by Schumpeter [1], innovation has been defined as the first introduction of a new product, process, method, or system. But innovation is more than the generation of creative ideas. Early on, Schumpeter understood the role of context for innovation [1]. Survival and competitiveness of firms are fostered by innovation but determined by the environment. Innovation is the specific tool of entrepreneurs, the means by which they exploit change as an opportunity for a different business or a different service. It is capable of being presented as a discipline, capable of being learned, capable of being practiced [3]. Majority of existing research at the time, conceptualized innovativeness as the degree to which an individual adopts an innovation relatively earlier than others [7]. Rogers defines innovativeness as “the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a social system” [8]. Innovativeness on macro level refers to country's ability to respond to challenges of innovation through factors that enhance innovation readiness including innovation related policies and practices that promote long-term growth and create framework conditions for innovations [9]. Through this process, nation creates and transforms new knowledge and technologies into useful products, services and processes for

national and global markets—leading to both value creation for stakeholders and higher standards of living [10]. Innovativeness stands for one of the most significant categories in the process of investigating key economic phenomena, including competitiveness of economy [11]. When talking about innovativeness on the micro level it could be defined as the willingness and capability of an organization to undertake all necessary steps to implement and to produce different types of innovation continuously [12]. Therefore, more than ever, in the current global economic situation, policymakers and business leaders recognize the need to create an enabling environment to support the adoption of innovation and spread their benefits across all sectors of society. The importance of innovation readiness, especially at the national level, has achieved prominence on the public policy agenda, with the realization that the right policies, inputs and enabling environment can help countries fulfill their national potential and enable a better quality of life for their citizens according to Global Innovation Report [13]. Innovativeness of economy is quantified by using a number of composite indices. The Global Innovation Index (GII), the Innovation Union Scoreboard, The Global Competitiveness Report, Intelligence Unit developed by Economist.

### **3 Innovation Capacities in the Countries of Western Balkan Region**

The countries of the Western Balkan region are at a disadvantage compared with the European Union member states with respect to innovativeness. For the WBC, the transition from socialism to capitalism and democracy was less smooth than in other parts of emerging Europe. Even though, after the war, these countries rebuilt and reform their economies reform process was not uniform across the region. In the previous research presented in the paper “Macro and micro innovativeness of the WBC” authors conducted comparative cross-country analysis of innovativeness in WBC. A short overview of results is given in the following section. Countries like Switzerland, Sweden, Netherlands, USA, and United Kingdom are innovation leaders. They have a strong knowledge-based economies in which business and the public sector in an equal way invest in the development of innovation. They are characterized by excellent infrastructure, political stability, strong research, and development sector with good international connections, a large number of global companies, a wide and constantly upgraded base of talented workforce and investments in the IT sector [14]. When we look at the WBC, we can conclude that their positions are changing over the years in overall world scale ranking. When we look at the WBC rankings in European region we can conclude that WBC are modest in terms of innovative performances and are lagging behind leading countries. They do not differ so much between themselves; they follow one another in rankings and are at the end of the European list. Croatia is the only WBC country that stands out in ranking, but still, it is far behind European leaders. The highest potential of the WBC lies



in human resources and still respectable scientific outputs. Development of these potentials should be the focus of all activities aimed at strengthening innovativeness and competitiveness [15].

### ***3.1 Innovativeness in Serbia***

The need for innovation in Serbia is emphasized in several reports: Global Competitiveness Report, Innovation Union Scoreboard (IUS), and Global Innovation Index. These reports highlight the fact that innovation is among the undeveloped dimensions of Serbian competitiveness. According to IUS, Serbia is a country with innovation performance well below the EU27 average. Serbia has made progress in strategic planning by Innovation Law, introduced in 2005 which enabled the formation of organizations for support of innovation activities and Technologic Transfer Office (TTS), defined IP rights, and introduced Serbian Innovation Fund. This is supported by the adoption of several national strategies which all aim to transform Serbia to an entrepreneurial economy, fostering innovation, improving human resources and cultivating a general business environment for innovation.

Visible results of these steps are investments in research capacity, including science centers and state-of-the-art labs, and in science and technology parks. The role of Serbian universities in this process is very important. Numerous projects have aimed to strengthen the knowledge triangle in Serbia. These projects brought very important results, e.g. competition for the Best Technology Innovation, numerous new technology-based companies, concrete plans for science and technology parks, pilot TTOs at selected Higher Education Institutions (HEI) and a platform for knowledge triangle in Serbia.

However, despite more than 90 strategic documents produced on innovation, SMEs, research and technology and investment in physical infrastructure, Serbia is lacking in reality innovation and realization of these strategies. In big part, this is because all projects and initiatives missed to ensure sustainable source of specialized human resources able to understand and holistically deal with innovations. Therefore, in further development of Serbian innovative potentials, it is crucial to counteract the lack of skilled and specialized workforce in the field of innovation management.

Thus, Serbian HEIs in their current situation is not completely able to support growing investments in innovation infrastructure and provide the industry with graduates and PhDs who holistically understand innovation and have related problem-solving skills. But, before developing study programs in the field of innovation and innovation management, it is needed to do an assessment of local needs for professionals in this field and what kind of professionals are needed.

## **4 How Companies in Serbia Perceive the Importance of Education in the Field of Innovation Management**

The general objective of this research was to assess how companies in Serbia perceive and understand the importance of education in the field of innovation management.

### **4.1 Methodology**

In order to reach this objective, a number of steps were performed:

1. Research questions, method, and sample were defined
2. Specific questionnaire was constructed
3. Data was collected from the sample
4. The collected data were observed
5. A number of conclusions were drawn.

After the initial pilot sample and some adjustments, the questionnaire was published in forms of an online survey and a printed survey, where the link and the printed version were distributed to companies. The rate of response was approximately 30%.

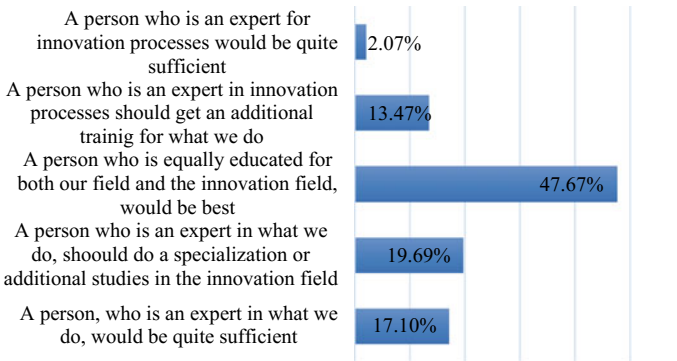
When screening for quality of response has been done, a final sample of 193 companies from Serbia was used for further analysis. Descriptive statistics show that more than half of the sample consists of small companies who have no more than ten employees. Furthermore, two-thirds of the sample companies have an annual income lower than €2,000,000. Therefore, the sample was mainly comprised of micro and small companies, which is a good representation of business context in the observed region. Different economy sectors have been represented, as well as company experience and its market orientation. Questionnaires were mostly filled by company owners, CEOs, or branch managers.

### **4.2 Results**

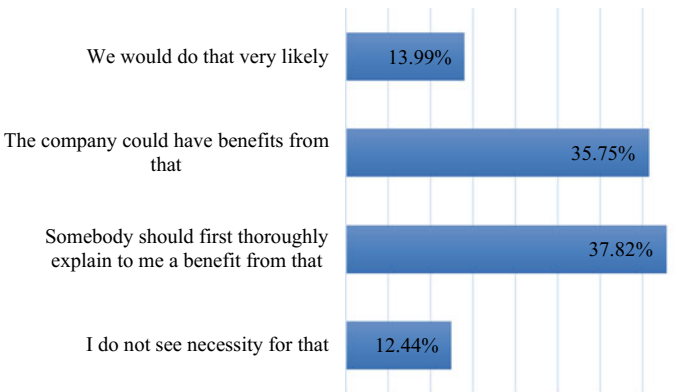
Companies are found to differ significantly regarding their opinion on what kind of professionals they considered to be the most suitable to foster innovation activities in their company, with regard to their educational background and expertise (Fig. 1).

Most of the companies, almost half of the sample, believe that that person should be proficient both in the company's field of work, and in innovation field.

Companies are somewhere reserved when it comes to employing an innovation professional. Most of them would either need a significant explanation about the benefits of that professional, or they would expect some benefits from that professional, but not very likely (Fig. 2). This result calls for significant efforts that need to be put into propagating education in innovation field, it's meaning and its significance.



**Fig. 1** What kind of professionals do you consider to be the most suitable to foster innovation activities in your company?



**Fig. 2** Would your company employ an innovation professional?

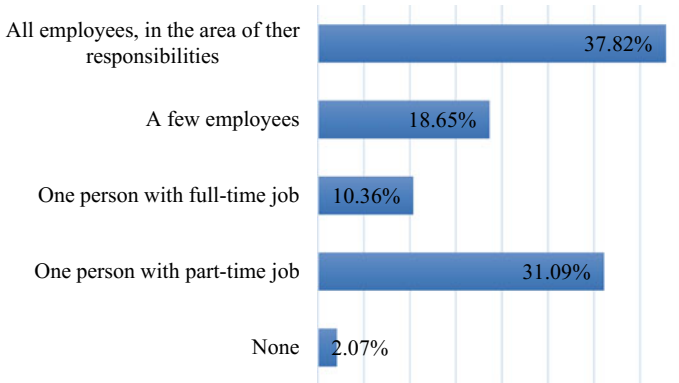
Innovation professionals obviously still need to be recognized in the labor market, which would stimulate companies to search for that profile, which would additionally stimulate this kind of education.

When it comes to acting towards improving in innovation profession, companies from the sample are mostly interested in sending their employees to professional courses in this field, while master and doctoral studies fail shorter (Table 1).

Respondents have quite different perspectives when it comes to who should foster innovation in their companies. Majority of the companies from the sample believe that all employees should deal with innovative processes (one must not forget the possibility of socially desirable responses when it comes to results like this). After this, some companies believe that only one person should be in charge of innovative processes, and only part-time. Not even one-third of the companies believe that innovative processes should be handled by at least one full-time employed person (Fig. 3).

**Table 1** To what extent would you be interested in sending one or more of your employees to the following forms of education?

	N	Min	Max	Mean
m5-3 certificated professional courses in the field of innovation management	190	1	5	3.23
m5-1 master studies in the field of innovation management	184	1	5	2.39
m5-2 doctoral studies in the field of innovation management	186	1	5	2.18
Valid N (list wise)	183			



**Fig. 3** Who should foster innovation in your companies?

**Table 2** To what extent are the following skills and knowledge important for successful innovation projects in your company?

	N	Min	Max	Mean
m7-2 knowledge about the business activity of the company	190	1	5	4.27
m7-3 knowledge about the economic principles of business	190	1	5	3.88
m7-7 long business experience	191	1	5	3.74
m7-8 youth and new perspectives on business challenges	190	1	5	3.68
m7-6 knowledge about the project management	191	1	5	3.60
m7-5 knowledge about the human aspects of business	192	1	5	3.59
m7-4 knowledge about the basic engineering principles	189	1	5	3.58
m7-1 knowledge about the innovation process management	190	1	5	3.33
Valid N (list wise)	182			

A separate question was asked about what skills and knowledge are generally important for successful innovation in a company. These skills and knowledge are something that should be provided by the innovation master studies, at least to some extent (Table 2).

## 5 Conclusion

On the one side, all reports and recommendations stress the importance of human resources who are capable to foster innovation activities in companies. But, on the other side research showed that companies are some benefits from experts in this field, but this needs to be clearly communicated with them. It was also found that companies differ significantly in assessing the importance of this profession. Companies believe that innovation experts should be open, dynamic and proactive persons, without conservative views on business. Based on this research and review of best practice in teaching and research from the existing European study programmes in the field innovation [16], educated professionals should have the following competences:

- to understand the whole innovation cycle process and put innovation into “big picture” of the company’s strategy;
- to analyze and assess different technologies and their impact on business (strategy development, process management);
- to build business cases and procedures to support the development of new ideas into new products/services/business models/processes;
- to use and apply different methods and techniques for creative problem solving;
- to plan, develop and manage (innovative and “regular”) projects in a national and a global environment;
- to know and be able to implement IPR procedures;
- to clearly present and communicate ideas;
- lead cross-functional teams and deal with cross-cultural issues in business.

This approach to education should develop entrepreneurial skills, and provide students and professionals with a unique insight into how established companies and new ventures can become more innovative.

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# Descriptive Evaluation in the Public Transport Service—A Study About of the Satisfaction of Customers



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Mayara Alves de Souza, Vitória Barros Brandão  
and Amanda Mendonça de Oliveira

## 1 Introduction

Nowadays the importance of customer satisfaction is not just to the private sector, but to the public sector too. According to Chen et al. [2] the “customer orientation” has become a popular slogan and now takes pride of place in the strategic statements of many public-sector and private-sector organizations. The authors added that in the UK, for example, public-sector organizations are increasingly demonstrating that “customer orientation” is no longer the exclusive preserve of the private sector. Gore emphasized that the situation is similar in the USA—National Performance Review Project entitled “Putting Customers First”.

In the Brazilian context, the public management has been discussed increasingly. In other words, this theme becomes an important subject to Brazilian research. Conform Yamaguchi et al. [14], today Brazil needs better public management and it could follow in success models as private management, even this one aiming the profit. Ref-

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erent to the public transport services in the Brazilian context the overview is the same. Goulart [4] suggests that the quality of service provided by public transportation has been an important theme in debates, mainly due to the importance to people as a whole, both on the economic and the improvement of the population's quality life aspects. In general, we have several models, methods, and scales to evaluate. These evaluations are linked with three main stakeholders: customers, the enterprises, and the public system.

So the government should pay attention in the quality of the public transport service provided because the transit flow in the medium and big Brazilian cities has shown serious problems as slow mobility and accidents with victims [3]. In this sense, Hassan et al. [6] argue that the quality in the public transport is an essential responsibility of the engineers and public managers.

From these considerations, the purpose of the present empirical study is, therefore, describe and analyze the customers' expectations and perceptions levels referent to the public transport service as well identify the most important attributes of these services from customer's opinions. It is important to say that the customers' satisfaction is obtained from the difference between their expectations and perceptions levels.

## 2 Methods

Regarding the collect data process, it is important to highlight that were collected, in which the sample is sufficiently representative in relation to the population. The primary data were obtained from the survey undertaken in a probabilistic sample of 238 customers at some bus terminals/bus station in Aparecida de Goiânia city, middle of Brazil: Araguaia Station, Veiga Jardim Station, Vila Brasília Station, and Cruzeiro Station. These data were collected between January and February 2018. In this process, we have used a scale (shown as follows), which part one was presented in Soares et al. [12].

In this sense, Joewono et al. [7] highlight that service quality evaluation needs to be defined and carried out carefully since this term refers to a complex relationship between tangible and intangible characteristics of service (supply) and users (demand). According to the authors, this includes travelers' subjective perceptions, expectations, past experience, and well-being. They add that different travelers have different needs and priorities, and these influence their satisfaction and appreciation relating to various quality factors of provided services.



<p><b><u>Research on research on the perception of the users about the quality of the services provided in the area of public transport (fourth version)</u></b></p> <p>User,</p> <p>This questionnaire comes from research that is being performed to evaluate the satisfaction/dissatisfaction on the quality of transport services of the municipality of Aparecida de Goiânia from the "expectation/perceptions" of the users of such services. This research is linked to the Industrial Engineering course Special Academic Unit of Sciences and Technology of Aparecida de Goiânia Campus of the Federal University of Goiás.</p>	<p><b>4- Frequency of use of public transportation</b></p> <p><input type="checkbox"/> Daily</p> <p><input type="checkbox"/> Often</p> <p><input type="checkbox"/> Sometimes</p> <p><input type="checkbox"/> Rarely</p> <p><b>5- Reasons for use</b></p> <p><input type="checkbox"/> Work</p> <p><input type="checkbox"/> Studies</p> <p><input type="checkbox"/> Health</p> <p><input type="checkbox"/> Others</p>
<p><b><u>Part 1 – General data</u></b></p> <p><b>1- Has any disabilities?</b></p> <p><input type="checkbox"/> Yes <input type="checkbox"/> No</p> <p><b>2- Genre</b></p> <p><input type="checkbox"/> Female</p> <p><input type="checkbox"/> Male</p> <p><b>3- Age</b></p> <p><input type="checkbox"/> Up to 18 years</p> <p><input type="checkbox"/> 19 to 35 years</p> <p><input type="checkbox"/> 36 to 50 years</p> <p><input type="checkbox"/> 51 to 60 years</p> <p><input type="checkbox"/> Over 60 years</p>	<p><b>6- What is your degree of education?</b></p> <p><input type="checkbox"/> First degree incomplete (basic education)</p> <p><input type="checkbox"/> Incomplete high school (high school)</p> <p><input type="checkbox"/> Complete high school (ensino médio)</p> <p><input type="checkbox"/> Incomplete higher education</p> <p><input type="checkbox"/> Complete higher education</p> <p><b>7- Place of interview:</b></p> <p><input type="checkbox"/> Veiga Jardim</p> <p><input type="checkbox"/> Araguaia</p> <p><input type="checkbox"/> Vila Brasília</p> <p><input type="checkbox"/> Garavelo</p> <p><input type="checkbox"/> Cruzeiro</p>

**Parte 2 – Expectations**

User,

This part of the questionnaire is part of a survey to be carried out on "expectations" of users of public transport in the city of Aparecida de Goiânia/GO. That way, in this step, it is a rating of "1 to 5" in which:

1 No Importance	2 Little Importance	3 Moderate Importance	4 Important	5 Very Important
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<b>ACCESSIBILITY</b>	
1- The distance between the points must meet the interests of all passengers.	
2- The points of sale and marketing of tickets must be safe and reliable.	
<b>PRICE</b>	
3- The price of tickets should not be abusive, but enough to provide a quality service.	
<b>FREQUENCY</b>	
4- The time between buses of the same line should be adequate according to the flow of passengers.	
<b>REABILITY</b>	
5- The bus must be punctual.	
<b>TRIP'S TIME</b>	
6- The time of the bus ride should be brief.	
<b>BUSLOAD</b>	
7- The buses should not be crowded.	
<b>SECURITY</b>	
8- Public transport should provide security as accidents and assaults.	
9- The stop locations must be safe.	
<b>VEHICLES' CARACTERISTICS</b>	
10- The buses should offer a good conservation status, comfort and cleanliness.	
<b>CARACTERISTICS OF BUS STOP</b>	
11- Terminals and stopping points must have good signage, coverage and seat.	
12- The stop locations must offer access to information about lines and timetables to users.	
<b>CONNECTIVITY</b>	
13- There must be a facility in exchange for buses and good integration between the lines.	
<b>COURTESY/CUSTOMER SERVICE</b>	
14- Drivers, tax collectors and other bus workers must show good behavior and good education.	
<b>ROAD QUALITY</b>	
15- The routes where the buses travel must be good condition.	

**Parte 3 – Perceptions**

Usar,

This part of the questionnaire is part of a survey to be carried out on "perceptions" of users of public transport in the city of Aparecida de Goiânia/GO. That way, in this step, it is a rating of "1 to 5" in which:

1  
Very  
Dissatisfied

2  
Dissatisfied

3  
Indifferent

4  
Satisfied

5  
Very Satisfied

Construct	Attribute	Score
	1- The distance between the points must meet the interests of all passengers.	
	2- The points of sale and marketing of tickets must be safe and reliable.	
	3- The price of tickets should not be abusive, but enough to provide a quality service.	
	4- The time between buses of the same line should be adequate according to the flow of passengers.	
	5- The bus must be punctual.	
	6- The time of the bus ride should be brief.	
	7- The buses should not be crowded.	
	8- Public transport should provide security as accidents and assaults.	
	9- The stop locations must be safe.	
	10- The buses should offer a good conservation status, comfort and cleanliness.	
	11- Terminals and stopping points must have good signage, coverage and seat.	
	12- The stop locations must offer access to information about lines and timetables to users.	
	13- There must be a facility in exchange for buses and good integration between the lines.	
	14- Drivers, tax collectors and other bus workers must show good behavior and good education.	
	15- The routes where the buses travel must be good condition.	

What is your level satisfaction with the public transport service?

1 – Very Dissatisfied \_\_\_\_\_ 5 – Very Satisfied.

We ask that choose three most important attributes conform your perception:

1ª: \_\_\_\_\_

2ª: \_\_\_\_\_

3ª: \_\_\_\_\_

The quantitative data were treated statistically, especially referent to the customers' expectations and perceptions levels. It was obtained parameters inherent to descriptive statistic, particularly measures of central tendency and dispersion, such as average, standard deviation and coefficient of variation. After that, it was obtained the gaps referents each attribute from the difference between customers' expectations and perceptions levels. These results are shown in Table 1.

**Table 1** Mean, standard deviation, coefficient of variation, and gaps

Attribute	Mean score		Gap	Standard deviation		Coefficient of variation (%)	
	Expectation	Perception		Expectation	Perception	Expectation	Perception
1	4.26	2.73	1.53	0.85	1.15	19.86	42.16
2	4.50	2.74	1.76	0.87	1.30	19.32	47.53
3	4.67	1.67	3.00	0.74	1.06	15.79	63.17
4	4.68	1.70	2.99	0.61	0.99	13.11	58.31
5	4.71	2.04	2.68	0.55	1.08	11.74	53.21
6	4.05	2.37	1.68	1.04	1.24	25.61	52.62
7	4.61	1.46	3.16	0.78	0.90	16.92	61.91
8	4.84	1.46	3.37	0.42	0.85	8.77	58.12
9	4.86	1.57	3.29	0.39	0.90	8.06	57.19
10	4.68	1.92	2.76	0.53	0.93	11.42	48.49
11	4.65	2.10	2.55	0.57	1.09	12.18	51.91
12	4.66	1.88	2.79	0.57	1.07	12.23	57.19
13	4.57	2.29	2.27	0.62	1.22	13.52	53.23
14	4.56	2.81	1.76	0.71	1.23	15.50	43.73
15	4.70	2.15	2.55	0.54	1.03	11.54	47.80

We also calculated the Cronbach’s Alpha coefficient in order to estimate the scale reliability. Finally, we processed data referent to the importance level of the attributes/constructs obtained from the customers’ opinions. In this sense, we determine the relative importance to each construct, as shown in Table 2. So we undertake comparative analyses between importance’s levels of the construct and the performances referent to each one from the perceptions levels.

To calculate the relative importance, we defined “weighting” referent to each importance level. For example:

- First more important: weighting 5
- Second more important: weighting 3
- Third more important: weighting 1

From these weightings, we got the relative weighting referent to each construct, using the choices of the customers. For example, if the “security” construct was chosen eight times as the most important (first more important—weighting 5), nine times as second more important (weighting 3) and six times as third more important (weighting 1), the relative weighting for “security” 1 will be

$$(76 \times 5) + (46 \times 3) + (67 \times 1) = 585$$

This process was applied for each construct, i.e., for “frequency”, “price”, and so on. After that, we got the total of the relative weightings, for example, 1972. Finally,

**Table 2** Relative weighting and relative importance

Construct	Relative weighting	Relative importance (%)	Performance
Security	585	29.67	1.51
Frequency	388	19.68	1.70
Price	332	16.84	1.67
Busload	256	12.98	3.16
Reliability	118	5.98	2.04
Accessibility	83	4.21	2.74
Trip's time	64	3.25	2.37
Vehicles' characteristics	61	3.09	1.92
Characteristics of bus stop	32	1.62	1.94
Courtesy/customer service	23	1.17	2.81
Road quality	18	0.91	2.15
Connectivity	12	0.61	2.29
Total	1972	100.00	–

we calculated the relative importance regarding each construct. For example, for security the relative importance will be

$$585 \div 1972 = 0.2967 \text{ (29.67\%)}$$

### 3 Results and Discussions

#### 3.1 Descriptive Analyses and Scale Reliability

The objective of this paper is also to measure and assess the satisfaction of public transportation in Aparecida de Goiânia city. In this sense, according to Tse and Wilton [13] the customer satisfaction is considered a function of the perceived performance relative to consumer's prior expectations. Conform to Grönroos [5] the European tradition posits service quality as resulting from a comparison between the customer's expectations of the service and the customer's perception of the service actually received. Additionally, Parasuraman et al. [9] defined and conceptualized service quality as a form of attitude, which results from a comparison of customers' expectations with perceptions of performance.

So Table 1 shows the values referent to the expectative, perceptions, mean, standard deviation, and coefficient of variation regarding each attribute of the scale in discussion and the gap referent expectative and perception levels.

First, it is possible to affirm that to all attributes the expectations levels are largest than the perceptions levels. Table 1 shows this reality, i.e., in general, the customers are unsatisfied with the public transport services. We can also observe that the largest gap is 3.37 and relates to question 8—“Public transport should provide security as accidents and assaults,” referent to construct “security”. The second and the third largest gap are related to the questions 9—“The stop locations must be safe,” and 7—“The buses should not be crowded,” regarding the constructs “security” and “busload”, respectively. It means that in these attributes there are the main customers’ dissatisfactions.

For the other hand, the three smallest gaps are regarding to attributes: “1—The distance between the points must meet the interests of all passengers,” “6—The time of the bus ride should be brief,” and “14—Drivers, tax collectors and other bus workers must show good behaviour and good education” relative to constructs “accessibility”, “trip’s time”, and “courtesy/customer service”, respectively. In other words, for these attributes, there are the smallest customers’ dissatisfactions.

Observing particularly the expectations values, we can perceive that the three largest values are, respectively, referents to attributes 9—“The stop locations must be safe”, 8—“Public transport should provide security as accidents and assaults”, linked to “security” construct, and 5—“The bus must be punctual”, regarding to “reliability” construct. In this sense, it is important to highlight that high values referent to expectations mean great importance to the customers. Therefore, these attributes (9, 8, and 5) are relevant to clients, but the performance (perception) for these attributes is low if compared with other attributes, mainly referent to the ninth and eighth attribute. This finding is obviously worrying because for these more important attributes the management of public transport should prioritize actions exactly achieve the best performances.

Table 1 also shows that parameters relative to the variation coefficient (VC). In relation to the VC, it is important to emphasize that this information is a statistic unit that corresponds to the standard deviation in average’s percentage, being the statistic parameter mostly used by researches in relation to the accuracy quality of experiments [1]. Conform Gomes [10], in the field experiments, if the coefficient of variation is less than 10%, the same is low, between 10 and 20% is median, between 20 and 30 is high and above 30 is considered too much high.

Shimakura [11] underline that if we have low levels of VC this means that is more homogeneous data set. The VC is low when it is lower or equal to 25%. However, this standard can be different according to the application. It is hard to classify a variation coefficient as low, median, or high, according to Shimakura [11], but this can be good when you compare two variables or two groups which are impossible to establish comparisons.

Based on Table 1, we can observe that the values for the coefficient of variation (CV) are relatively low to the attributes of the user’s expectation of public transport. However, these coefficients of variation become high when the attributes of the perception of users are taken into consideration.

The coefficient of variation to expectation’s values is on average 14.37%, the average perception increases to 49.92%. Therefore, the values referent to expectations

are low or medium and the values of the perceptions are high. Based on these findings, regarding expectations values, most of the attributes present moderate variation coefficient, with values between 10 and 20%. For the other hand, the mostly values referent to the perceptions are high (above 40%), i.e., these perceptions, in terms of values, are more heterogeneous than expectations' values.

Finally, referent to the scale reliability analysis was calculated the Cronbach's Alpha coefficient. The value found was equal to 0.73. It means that the reliability of the scale is acceptable. According to Malhotra [8], the minimum value to be considered for this parameter is 0.60, for values lowers than it the reliability is considered weak.

### ***3.2 Comparative Analyses Between Importance Levels and Performance***

As commented before Table 2 shows the relative weighting and the relative importance inherent each construct.

According to Table 2, we can observe that the most important construct (security) has the lowest performance among all constructs. The referent performance to the second most important construct (frequency) is third lower among all constructs. The third most important construct's performance is the second lower.

For the other hand, Table 2 also shows the lower importance constructs. In this group are "courtesy/customer service", "road quality", and "connectivity". However, the performance inherent of these constructs is relatively superior if compared with others.

The findings obtained from Table 2 show a paradoxes situation, i.e., for high importance there are low performance and for low importance we have relatively high performance. Actually, we obtained similar find before when we compared the expectation levels with performance levels.

## **4 Conclusions**

The purpose of this paper is to describe and analyze the customers' expectations and perceptions levels referent to the public transport service as well as identify importance levels of this service from customer's opinions.

In this sense, one can conclude that in general, the customers are unsatisfied with the public transport services, referents mainly to security and busload aspects. One can conclude also that the most important attributes are linked to "security" and "reliability" constructs. It means that these dimensions are the most relevant to clients. However, the performances (perceptions) inherent these dimensions are low if compared with others. This finding can be showing that the management of public

transport is prioritizing the wrong aspects in order to promote the best services to customers.

Regarding coefficient of variation, it was observed that the values referent to the perceptions are more heterogeneous than expectations' values. In terms of scale reliability analysis, the value found (Cronbach's parameter) shows that the reliability of the scale is acceptable.

Finally, we have established comparative analyses between importance levels and performance. In this sense, we perceived that to the most important constructs the performances are low and for the less important constructs, the performances are relatively high if compared with other performances. This finding corroborates the conclusion anterior obtained from the comparison between the expectation levels with performance levels.

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# New Product Development in the Context of Industry 4.0: Insights from the Automotive Components Industry



Jorge Oliveira , Manuel Nunes  and Paulo Afonso 

## 1 Introduction

The technological evolution of recent years has allowed automotive component companies to become more competitive by developing innovative and technologically advanced solutions, improving quality and time-to-market and lowering the cost of a product. The growth of these companies in recent years is strongly based on the industrialization of research and development projects what increasingly allows to sustain their growth in differentiation by innovation.

In the automotive components companies there is a focus on quality and technology, which are important principles in developing a culture of innovation that is based on the qualification of their human resources, in new product development (NPD) (at the aesthetic and technical level) and in the continuous improvement of the development and production processes.

The merger between the automotive industry and technology is constantly evolving and the inclusion of technological innovations in automobiles is increasing. The automotive industry is becoming increasingly complex and competitive due to evolving of the nature of the product, increasing numbers of models, and rising development costs. The original equipment manufacturers (OEM) and component suppliers are exploring newer ways to enhance the development process due to increasing competition and pressure to reduce cost and development time [1]. Some examples of

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OEM in the automotive industry are Toyota, Volkswagen, General Motors, Hyundai, Ford, Nissan, Fiat, Honda, Suzuki, and Peugeot Citroen.

The automotive industry is one of the most important worldwide drivers of growth, employment, and technological and managerial innovation [2]. The NPD is one of the main ways to gain competitive advantage for a company [3]. Due to an increasingly complex and competitive global marketplace, automotive companies are looking at new ways to improve their operation in order to remain profitable [2]. Cost management in NPD is important and necessary in order to optimize the performance and cost of a product [3]. Indeed, most of the product costs are defined during the development phase and after this phase cannot be influenced significantly anymore [4].

In this sense, NPD has become crucial in the strategies of many companies. The objective of product development is to transform an idea into a product. So, NPD processes comprise several phases, for example, planning, concept design, product design and testing, and production startup [5]. These phases can be performed sequentially (in parallel) or concurrently/overlapping (in this case, design phases occur simultaneously and in a nonlinear manner) [6].

The market has been pushing companies to offer competitive new products simultaneously in quality, functionality, and price, contrary to the traditional trade-off between quality and price [3, 7]. This process occurs in many industries asking for increasingly complex and dynamic production and business models. For example, in the automotive industry, new products are being developed to replace existing products or to add completely new product lines [2] in processes where increased coordination and synchronization is required. Furthermore, modern cars are characterized by having different components (e.g., electronic, mechanical) in which software has gained increasing importance [8].

The automotive component industry is increasingly marked by integrating new technologies into their products and there is a greater need to adapt or evolve cost management in NPD and to optimize processes that were considered “optimized” until now. There is a continuous endeavor by automotive industry for further improvements in the process [1]. OEMs are increasingly involving their suppliers in new developments [9–11] and the collaboration skills in NPD are an important aspect of companies’ ability to access technology and complementary assets [12].

Digital transformation has had a strong connection with the industry since the Third Industrial Revolution. The Industry 4.0 represents the Fourth Industrial Revolution and focuses on the end-to-end digitization of all physical assets and integration into digital ecosystems with value chain partners [13]. The Industry 4.0 is characterized by emerging technologies such as internet of things, mobile internet, wireless sensor networks, big data, cloud computing, embedded systems, nanotechnology, interconnectivity of machines, and artificial intelligence [14]. The intelligent products and machines (driven by real-time data, embedded software, and the internet) are organized as autonomous agents within a pervasive and agile network of value creation [15]. Different technologies are exponentially growing and radically changing industrial processes, accelerating them and making them more flexible and smarter [16].

These concepts such as embedded software, connectivity, and software tools are deeply rooted in industrial processes of automotive components industry. Companies in the automotive components industry are considered a benchmark relative to other industries since the best practices of cost management in NPD are implemented. The optimization of mature development processes is a challenge but Industry 4.0 is changing NPD in the automotive component industry toward new frontiers.

Next section explains the research methodology and in the following one, the main results are presented and discussed. Two dimensions are highlighted: rapid prototyping and manufacturing, and concurrent NPD processes. The main conclusions and opportunities for further research are presented at the end.

## 2 Research Methodology

This research followed a qualitative approach aiming to address the complexity and detail of the NPD process in this context of Industry 4.0. The data collected was qualitative once the interviews were semi-structured (questions with open answer). The methodology process followed four steps: development of the semi-structured interview, the guide application of the interview, the analysis of data, and sending a personalized report with the most relevant aspects of the interview for validation. So, written informed consent was obtained from the participants for recording the interviews and use of the information collected.

A set of companies of the Portuguese Association of Automotive Suppliers (AFIA) was approached. AFIA is the association that links and represents the automotive suppliers, both at the national and international level, including national manufacturers of components, parts, and accessories. Besides that, AFIA is a member of CLEPA (European Association of Automotive Suppliers) and aims to boost the competitiveness of industries linked to the sector.

The semi-structured interviews were applied in large-sized companies of the automotive components industry with product development in Portugal. The automotive components industry is considered a benchmark industry in relation to the implementation of best cost management practices and plays an important role in the Portuguese economy for several decades.

The semi-structured interviews had a duration between 45 and 120 min. Most of the interviews were tape-recorded and those in which no permission was granted for recording were taken notes. The interviews have been conducted following the interview guide that was previously sent to the interviewee of the company and throughout the interview underwent some changes in its development, such as (1) asking for examples of some project situations that did not go well, (2) how this was overcome, (3) what implications it had for future projects, (4) examples of successful problems and solutions.

Later, interviews and notes were transcribed word-for-word, to digital format for the analysis, which was supported by the qualitative data analysis software NVivo.

**Table 1** Study sample

Company	Industry	Interviewees
A	Electric/electronic	Engineering project office team coordinator Development department manager
B	Plastics, rubber, and other composites	Product industrialization manager
C	Metallurgy/metalwork	Project manager
D	Textiles and other trims	Product industrialization and logistics manager
E	Metallurgy/metalwork	Engineering and development supervisor Technical director
F	Textiles and other trims	Research, development, and innovation director
G	Plastics, rubber, and other composites	Product manager

They were realized 9 interviews in 7 firms of the automotive industry components sector. It is estimated that about 10% of the companies of the automotive components industry in Portugal have proper NPD process. Therefore, the sample of this study should represent approximately 30% of the companies with NPD.

In the Portuguese automotive industry components sector, small companies are just production plants and these companies do not develop products because they do not have skills for that. These companies, as they are production companies, control costs in the production phase because they are pressured to find solutions to reduce costs. Therefore, these companies focus only on continuous improvements in production, in order to optimize processes and reduce costs (kaizen costing approach).

In Table 1, the sample of this study is characterized.

Five companies are first-tier suppliers and two are second-tier suppliers. In relation to the activity sector, the companies are classified as follows: electric/electronic (one company), plastics, rubber, and other composites (two), metallurgy/metalwork (two), and textiles and other trims (two).

Rapid prototyping and manufacturing and concurrent NPD process were particularly evidenced as elements of change of NPD in the automotive components industry. Next section focuses on these aspects.

### 3 Results and Discussion

The automotive components industry concentrates on many multinational groups in Portugal. Multinational companies have an important role in the world economy and trade. In the past, one of the failures of the Portuguese economy was its inability to integrate into the large global value chains, especially in the phases where

they have greater capacity for transformation, that is, first in the NPD phase and later in its commercialization. However, in recent years there has been a significant interaction among national companies, universities and research centers, and large multinationals. This strengthening of the interactions and partnerships among the different market players is leading to a paradigm shift in the Portuguese economy, from the paradigm of “made in” to “invented in”, “developed in”, or “created in”.

Automotive component companies sell products to OEM and such components are used in the final product. Small companies in the automotive components sector do not develop new products (focus only on production) and some large companies belong to large international groups (multinational) and have part of NPD (and cost management in this process) outside Portugal, that is, they are manufacturing units of multinational groups. Most of the large companies are production plants and only a few companies develop new products. When companies grow and become very large, entropy increases and companies lose agility. Companies become more formal and process optimization is required.

In the automotive component industry, the product development process may occur on the firm’s own initiative but it is mainly at the customer’s request. However, product development on its own initiative (innovative products that do not exist in the market) has gained some importance because companies want to be the drivers of the market. The most common development is something that already exists and the client requests new features, more connectivity, a new design (the design is usually customized, for example, the level of mechanics), faster processors, etc. Therefore, in this case, it is also necessary to make the entire development process. The introduction of new functionalities or the change of functional and physical characteristics may also cause changes or adaptations of existing functionalities. The process of launching new products is a cyclical process and due to the pressures of the clients/market, the competition and also the company itself, it is necessary for the company to differentiate through the NPD.

NPD at the request of clients has a higher weight than the autonomous NPD, but the tendency is for the autonomous NPD to have an increasing weight. There is greater control on projects at the request of clients than in autonomous projects. Autonomous projects are usually financed by the Government and companies are forced to execute the budget at 100%. Projects at the request of customers are more controlled in terms of bureaucracy, deadlines, costs, and quality.

The advent of Industry 4.0 is imposing several changes and challenges on industrial processes in general and on NPD, in particular. Software embedded and software tools are making the NPD process more and more simultaneous and, consequently, more complex and shorter. Rapid prototyping and manufacturing are emerging approaches in the automotive components industry and are referenced in the literature [e.g., 17].

### 3.1 *Rapid Prototyping and Manufacturing*

The prototyping phase is of high importance, mainly in car safety products:

On average, 3 to 4 prototypes are made for each product. The prototype is tested and if does not meet the requirements back to the initial stage. What changes from one prototype to another are the product specifications (braking in dry or wet conditions, rolling resistance, comfort, tire adhesion, ...). There are several characteristics in developing a tire that come into conflict with each other. Often, when a company solves a feature of a product [that] might create negative results to other features. (Interview extract 1; Company B; Product Industrialization Manager)

Tests are very heavy (for example, the product is subjected to vibration and temperature tests due to customer requirements and these requirements have been kept stable) and evaluate the product under extreme conditions.

However, it is the phase where companies in the automotive components industry achieve brutal savings by eliminating unnecessary prototypes. Customers have forced companies (suppliers) to make the process of NPD faster and faster, eliminating steps that were considered to be consecrated in the traditional NPD process, such as prototyping and preproduction.

In the past, companies prototyped, corrected and then launched industrialization. Now the prototyping phase has almost disappeared, they make the layout very fast, but the prototyping phase no longer exists or there is very little. (Interview extract 2; Company C; Project Manager)

This firm does not do pre-series. Once the prototype is very important for the firm, from the moment that the prototype is approved by the internal tests and the customer, the company begins the series production. The prototype development is accompanied by the customer. The prototypes are expensive and the development of many prototypes brings high costs. Then there is the involvement of various stakeholders in order to reduce the development stages and costs. The development timing is two years (since the initial phase of requirements identification until to product presentation to the client). (Interview extract 3; Company B; Product Industrialization Manager)

The prototyping phase is losing influence in the NPD process because it takes a long time, consumes lots of resources and is very expensive. On the other hand, new approaches, such as simulation, are emerging that may challenge this validation methodology and can make the process much faster. The validation tests can be replaced by the simulation to simulate a series of conditions to which the product is submitted, reaching the same results in a shorter time.

Prototyping is very expensive. Prototypes are almost eliminated and only prototypes are made in automotive safety components. Components that are not considered safety pass almost immediately to industrialization. (Interview extract 4; Company C; Project Manager)

The shorter the time-to-market in projects, the greater the frequency of elimination of prototypes and phases of validation and preproduction. In these cases, after the validation of the client, the companies advance to mass production.

Usually, companies develop several prototypes by increasing levels of functionality and the elimination of some of these prototypes becomes a reality to make the process faster and less costly.

In some cases we cut a sample phase, for example, moving from samples A to C (tool samples) directly. Samples B are developmental samples [...] This whole cycle of samples A, B, C and D, with many validations, gives an effective robustness to the product because we are testing the real product. The disadvantage is that it takes a lot of time, it consumes a lot of resources and, moreover, these validations are expensive. Today, new approaches, such as simulation, are emerging. These new approaches may question the traditional methodology and make the process much faster. If we use the simulation instead of doing all tests, we are probably able to achieve the same results in 2 or 3 days because we are simulating a number of conditions to which the product is subjected. (Interview extract 5; Company A; Development Department Manager)

In some cases, we find that from the moment the prototype is approved by the internal tests and customer, the company starts production in series (eliminating the preproduction phase). The prototype is usually accompanied by the customer (more than the start of production) because the more prototypes are made, more costs have companies.

The rapid prototyping or elimination of unnecessary prototyping and elimination of preproduction are influenced by the use of advanced materials [17]. The new technologies allow to develop advanced materials with a huge innovative and transformative potential [17]. The use of software tools (for example, 3D CAD software and finite element method simulation and optimization) that can realistically simulate material forming processes enables the elimination of prototype tools in production and testing stages of development process [18, 19].

Rapid prototyping has advantages but a much more radical change can even be considered. Rapid Manufacturing changes the development process through the elimination of prototype and preproduction stages [20, 21]. New technologies allow to construct advanced materials and more sophisticated solutions allowing a more efficient and effective product validation (Fig. 1).

Pressures to lower product cost led to a reduction in the number of tests, in order to reduce the product cost without compromising profit margins.

In addition to rapid manufacturing, the automotive components industry is driven by the philosophy of continuous improvement. For example, the kaizen costing methodology focuses on reducing costs through continuous improvement during the production phase of the product life cycle and involves internal employees of the company and its suppliers [22, 23]. In this process, non-value-added cost activities are reduced or eliminated.

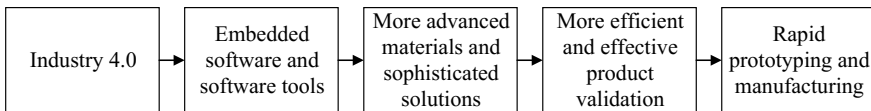


Fig. 1 Contribution of Industry 4.0 to rapid prototyping and manufacturing

### 3.2 *Concurrent NPD Process*

In the automotive components industry, the NPD process may occur on the firm's own initiative but it is mainly at the customer's request. However, product development on its own initiative (innovative products that do not exist in the market) has gained some importance because companies want to be the drivers of the market. The most common development is something that already exists and the client requests new features, more connectivity, a new design (the design is usually customized, for example, the level of mechanics), faster processors, etc. Therefore, in this case, it is also necessary to make the entire development process. The introduction of new functionalities or the change of functional and physical characteristics may also cause changes or adaptations of existing functionalities. The process of launching new products is a cyclical process and due to the pressures of the clients/market, the competition and also the company itself, it is necessary for the company to differentiate through the NPD.

NPD at the request of clients has a higher weight than the autonomous NPD, but the tendency is for the autonomous NPD to have an increasing weight. There is greater control over of projects at the request of clients than in autonomous projects. Autonomous projects are usually financed by the Government and companies are forced to execute the budget at 100%. Projects at the request of customers are more controlled in terms of bureaucracy, deadlines, costs, and quality.

An autonomously developed product only passes to the mass production phase if there is a customer for it. For the first-tier suppliers, customers are the OEMs. In another type of business (where customers are individual people), companies do not know how the market will react. In these cases, there is a sales team that studies the market and customer needs but the business model of the automotive components industry is slightly different because they sell to OEMs and there is a contract where it is referenced, for example, price and quantities negotiated.

In addition, NPD can be a sequential or simultaneous (concurrent) process. Most companies use concurrent or simultaneous NPD and the overlapping between phases is evidenced in most companies:

There is much overlapping. The recursive nature of product development is one thing that no one can say does not exist. It is impossible to say: I have now closed phase 1, now phase 2, ... There are always things that come back to the previous phase. The phases are sequential but there is always overlapping between phases, it is impossible to say that there is one that closes for the other to open. There is always a gray area where I have not closed one and I will open the next one, or I have already opened the next one and I have to go back. (Interview extract 6; Company F; Research, Development and Innovation Director)

In the companies studied, the use of simultaneous or concurrent engineering is verified, for example, the product and the process are developed simultaneously. Obviously, there are phases and outputs of the process that are precedent of others. The phases exist, are formal, have outputs and the plan is measured in relation to the outputs.

However, in some cases, the process is more sequential than simultaneous. When the product cannot be made by parts, such as commodities (development of a raw



material through the conjunction of various raw materials), the process of product development is always sequential:

Parallel development at the product level does not exist because it is always the same raw material that is being worked. In these cases, the resolution of a feature creates negative results to another feature because different characteristics require different materials. (Interview extract 7; Company D; Product Industrialization and Logistics Manager)

In fact, this is proven by the literature [24, 25]. Koishi and Shida [25] who mentioned that functions have tradeoffs and, therefore, “understanding the relationship of tradeoffs helps to plan the best design that satisfies the target performance” (p. 173). So, an optimal solution is not unique. When these limitations (e.g., a product cannot be made by parts) do not exist, the use of concurrent or simultaneous NPD was always verified. The use of software tools allows companies to shorten development time, performing simultaneous engineering and accelerating, for example, the prototyping process through advanced tools such as simulation systems.

In recent years, there is a clear tendency to reduce the development time, increase complexity (complexity has been increasing brutally and more and more products have embedded software, incorporation of functions and more complex systems) and make smaller iterations (sprints) to verify if the product is in accordance with what the customer intends.

The way for a company to grow and have a healthy growth is to develop products with greater complexity and more value added. In very simple products, the margins are too tight and, therefore, any deviation that occurs poses a problem for businesses.

In order to grow and have a healthy growth (up 7%) we must have products with greater complexity and more value added. (Interview extract 8; Company A; Development Department Manager)

The quality targets that are imposed do not depend on the product category (they are usually the same), that is, in simpler products, companies cannot avoid certain control processes that allow them to be more relaxed about quality. Therefore, companies move away from developing products too simple or too cheap.

Growth in the automotive components industry, mainly in the field of electric/electronic, has been greatly boosted by the incorporation of software, and in some cases, it represents for between 60% and 80% of the cost of product development.

Products increasingly have embedded software... The software represents 60 to 80 percent of the cost of product development, dependent on projects because there are projects with more software than others. (Interview extract 9; Company A; Development Department Manager)

The Scrum methodology focuses on the need to adapt software development to changing customer requirements. A project is divided into cycles, which are called sprints, and the sprint represents a time box in which a set of activities is executed. The functionalities to be implemented are kept in a list called the Product Backlog and then prioritized. At the end of each sprint, there is a meeting with the customer to see if there are any changes to make. This methodology has more validations throughout the process. Then, a new sprint is defined, and there is an iterative approximation in

relation to the client's goal. This methodology is widely used in the software industry and as the products of the automotive components industry are increasingly containing embedded software, the development process in these two types of industry will become more similar. That is, Industry 4.0 is changing NPD processes that were considered already very optimized.

Time pressure influences product development, which often forces companies to use prototyping tools:

If the customer wants the product quickly, we often cannot do it with a definitive tool and then we have to make the product with tools that are called soft tools, which is not a definitive way yet. A definitive tool would delay the normal industrialization time. So we use prototype tools, but product geometry is not a prototype. It is a prototype that is made in a prototype tool but the geometry is already very approximate to the final quality requirements of the product. This happens a lot. (Interview extract 10; Company C; Research, Project Manager)

The inclusion of Industry 4.0 concepts in the automotive components industry allows the development of highly innovative products with higher added value. In addition, Industry 4.0 can be considered the main driver for the future of the manufacturing value chain. In fact, it allows for an evolution of industrial production systems, providing benefits such as developing more complex and innovative products, improving process efficiency, reducing costs, and reducing time-to-market.

## 4 Conclusions

With Industry 4.0, we are assisting in an evolution of the mature industrial production systems, enabling companies to improve operational and performance ratios and indicators. The combination of low cost, reduced time-to-market, and high quality determines the success of new products and the Industry 4.0 plays an important contribution in this trade-off.

Industry 4.0 contributes to the growing of the complexity of the products, increasing the uncertainty in the business environment and leading to the appearance of methodologies such as rapid prototyping and manufacturing. Customers require suppliers to become the NPD process fastest, less costly, and the best possible quality. Thus, the suppliers of the supply chain are obliged to eliminate some stages of the development process that were considered consecrated in the traditional NPD process.

NPD has more and more embedded software and this process has become increasingly iterative. The integration of software systems in products for certain areas, such as safety and connectivity is increasingly becoming one of the most important differentiating factors for the automotive industry. Digital transformation and incorporation of technology into both products and production processes can contribute to better product performance, business results and greater consumer satisfaction. Automotive components companies are under continuous pressure to reduce costs, improve fuel efficiency, reduce emissions, optimize processes, and develop more

complex products, leading to consolidation and new forms of partnerships among business players and partners. Factors such as connectivity, embedded software, and interdependency between companies in global optimized supply chains are influencing NPD in the automotive components industry. This research is an important contribution for companies, especially those that compete with mature companies and with optimized processes.

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# Risk Analysis of a Scientific Conference Organization: A Brazilian Case



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## 1 Introduction

Several scientific events are held annually with innumerable participation of students, professionals, and scientists who meet to present their latest research that will contribute to the development of science in its most diverse areas [1]. This type of meetings provide favorable conditions for the exchange of information and creation of knowledge through the creation of relationship networks with both peers and leaders from related areas, participation in workshops, access to mentorship, scientific sessions and the most recent job openings in academic and industry, career progression, and hints on publishing [2].

Conducting this kind of events, especially if it is a large conference, requires detailed planning for its execution, considering that being a “live” event any failure would compromise the concept/image of the organization in charge of the production, and of its organizer. In order to have fully achieved objectives, it is important to monitor and control ongoing activities, as well as to establish planning criteria that involve: objectives, audiences, strategies, resources, and factor implementation [3].

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After a search in the literature, were not found references regarding to application of tools in analyzing potential failures and preventing them from occurring during a conference; in this way, this study presents an analysis of probable causes and effects generated by failures during the Brazilian Conference of Production Engineering (ENEGEP by its acronym in Portuguese), the largest conference related to the Production Engineering in Brazil. To achieve this the Failure Mode and Effects Analysis (FMEA) method was used, aiming to demonstrate the feasibility of using this technique in the determination of preventive actions during the planning and execution of a conference, and thus shows the impact of digital transformation on risk management [4].

FMEA has been proven to be an effective risk management tool and has gained popularity in the industry sector. However, its applications can also be found in a scarce way in the service industry [5]. For this research, the risk analysis index called RPN, a key element to the success of FMEA will contribute to answer the following research questions: Q1. What activities should be considered elevated risk during the planning or execution of a conference? Q2. How do failures during a scientific conference affect the satisfaction of its stakeholders?

## 2 Literature Review

### 2.1 *Management of Scientific Events*

The importance of conferences lies in the creation of platforms to disseminate knowledge through meeting of a community of researchers of common areas. Currently, this type of events offers opportunities to interact in both planned or spontaneous interactions based on the discussion of topics of interest that may impact their professional career [1].

Thus, it is evident that the management of scientific events demands a great commitment on the part of the organizers. It requires a series of sequential activities based on deadlines schedules for the fulfillment of their purposes, which are evaluated during their planning, execution and post-event process. In this context, it is possible to define a scientific event, such as a system, and being a system, the conference is prone to experiment with uncertain conditions that may or may not have a negative effect on one or more of its objectives [6].

Although these processes must be managed by the organizers, joint efforts must involve internal and external stakeholders whose contributions are imperative in achieving the desired objectives in the functions of the conference [7]. The organization itself should be thought of as grouping of stakeholders and the purpose of the organization should be to manage stakeholder's interests, needs and viewpoints [8]. For scientific events managements, the stakeholders to be considered are customers (participants), employees (organizers, coordinators, referees, and staff mem-

bers), local communities, suppliers and distributors, nongovernmental organizations, sponsors, government, regulators and policymakers [9].

## ***2.2 Risk Management***

Risk is defined as the effect of uncertainty on objectives, according to ISO 31000: 2009; the document published by the International Organization for Standardization (ISO) in 2009, groups a series of rules and policies related to risk management of easy adaptation and monitoring in any type of organization, since its purpose is the access to information regarding the guidelines related to this type of management [10].

Risk management, on the other hand, is a complex, interactive and dynamic decision-making process on the use of resources which requires effective and strategic analysis during the process of producing an event [11]. Companies must have an intrinsic motivation to be able to identify, prioritize and deal with risks so that they can reduce or even eliminate the negative consequences of the risks that are incurred [12]. In time of digital transformation, investment in innovation may be related directly to risk management effectiveness [13].

Corporate governance practices give importance to risk management by creating bases for preserving and enhancing the value of the organization by reducing the probability and/or impact of loss events; promoting transparency in risks and its preventive policies and creating and applying processes that contributes to the definition of a robust methodology for measuring and prioritizing risks through the identification, monitoring and mitigation of the relevant risks through internal control tools [14].

## ***2.3 Risk Analysis of Scientific Events***

Any moment can be considered a moment of crisis, and in the execution of scientific conferences, the smallest details can generate unexpected events. In most cases, organizers show negligent behaviors when doubting of possible failures that may occur [15]. James E. Lukaszewski, one of the most sought consultant after crisis management, proposed a crisis plan list with emergency regulations, although his paper was published in 1989, the document titled “How vulnerable are you? The 20-question crises plan checklist for your company” can still be considered as an important source of information in risk management at scientific conferences.

As a basis for identifying possible failures, the list includes factors related to assume responsibilities, managing information, deal with crisis, involving directors or senior managers, coordinating aid mechanisms, and managing the needs of human factor [16]. In addition, establishing an improvement method by applying a failure and effect analysis for a service process may contribute to the elimination of potential

errors [17–19]. In addition, recent research includes the need for innovation that will contribute to the advancement of strategic corporate social responsibility programs that go beyond risk management [20].

For this research, FMEA focuses on exploring all types of potential mistakes in scientific conference execution. This methodology is also commonly used for preventing service failures [21]. When applied to service quality, FMEA can identify various service failures by measuring risk factors, and then analyzing their impact or severity on the failure, probability on failure occurrence and capacity to detect failure before it occurs [5].

## 2.4 Failure Mode and Effects Analysis

Failure Mode and Effect Analysis (FMEA) is a systematic auxiliary tool used for the identification of problem areas affecting a system through the analysis of potential failure modes their causes and effects. This tool provides a structured process while searching for errors, the probability, and severity of failures, resulting in the mitigation of the effects of failure through corrective actions [18, 21].

The FMEA technique has been widely used in numerous industrial areas since it is based on finding, prioritizing and minimizing the failures. Before reaching final consumers, the method defines, identifies, reduce and eliminates potential and/or known failures and errors from systems which might negatively impact the results of production processes or services, or cause severe damages to the organization [22–24].

As a result of prioritizing failure modes, the FMEA contributes significantly in the decision-making process of many areas of organizations, such as the introduction of new products or plans for the development or modification of existing production processes to improve quality; strategic hiring plan of suppliers; optimization of infrastructure and equipment maintenance plans; preparation of plans for the control of new production processes; and as a tool for organizational learning [25, 26].

In general, FMEA quantifies the impact of a failure mode and provides a rank of risk priorities of failure modes and a list of corrective actions to remove them. The FMEA procedure starts by analyzing step by step all the systems and subsystem functions shown in Table 1. Its structure depends basically on the identification of the system, the potential failure mode, the potential cause and effect of failure, and the design verification actions [28]. Likewise, three measures (from 1 to 10) are considered [29], the impact or severity of the failure (S), the probability of failure occurrence (O), and the capacity to detect failure before it occurs (D). The multiplication of these measures generates the RPN. Equation 1 represents how RPN number will be calculated:

$$RPN = S \times O \times D \quad (1)$$



**Table 1** FMEA system elements [27]

System element	Description
Potential failure modes and causes	The failure mode of each system should be defined clearly
Potential effects of failure	The consequence of each failure mode should be carefully examined and recorded
Failure detections and compensation	All the detected failures should be corrected to eliminate the cause and to maximize reliability
Assigning severity, occurrence, and detection	The current work's severity ranking is developed

**Table 2** Severity rating scale [27]

Rating	Description	Definition
10	Extremely dangerous	Failure could cause the death of a customer (patient, visitor, employee, staff member, business partner) and/or total system breakdown, without any prior warning
9 8	Very dangerous	Failure could cause a major or permanent injury and/or serious system disruption with interruption in service, with prior warning
7 6	Dangerous	Failure could cause a minor to moderate injury with a high degree of customer dissatisfaction and/or major system problems requiring major repairs or significant rework
5	Moderate danger	Failure could cause a minor injury with some customer dissatisfaction and/or major system problems
4 3	Low to moderate danger	Failure could cause a very minor or no injury but annoys customers and/or results in minor system problems that can be overcome with minor modifications to the system or process
2	Slight danger	Failure could cause no injury and the customer is unaware of the problem; however, the potential for minor injury exists. There is little or no effect on the system
1	No danger	Failure causes no injury and has no impact on the system

The index of severity (S) or deterioration of risk is only possible to reduce through changes in process and how to do activities [23]. The ranking severity is shown in Table 2 based on services and business operations.

Occurrence (O), on the other hand, specifies that a potential error occurred with a specific frequency. Thus, prevention or control of one or several mechanism errors is the only way that can decrease the occurrence of the degree, in other words, only with eliminate or reduce the causes or mechanisms of each hazard can hope to reduce the number of occurrences that the probability values shown in Table 3 [23].

The probability of detection (D) is a kind of analysis that exists for identifying a cause/mechanism of risk that means that controls must be evaluated, especially those

**Table 3** Occurrence rating scale [27]

Rating	Description	Definition
10	Certain probability of occurrence	Failure occurs at least once a day, or failure occurs almost every time
9	Failure is almost inevitable	Failure occurs predictably, or failure occurs every 3–4 days
8 7	Very high probability of occurrence	Failure occurs frequently, or failure occurs about once per week
6 5	Moderately high probability of occurrence	Failure occurs approximately once per month
4 3	Moderate probability of occurrence	Failure occurs occasionally, or failure occurs once every 3 months
2	Low probability of occurrence	Failure occurs rarely, or failure occurs about once per year
1	Remote probability of occurrence	Failure almost never occurs; no one remembers the last failure

**Table 4** Detection rating scale [27]

Rating	Description	Definition
10	No chance of detection	There is no known mechanism for detecting the failure
9 8	Very remote/unreliable chance of detection	The failure can be detected only with a thorough inspection, and this is not feasible or cannot be readily performed
7 6	Remote chance of detection	The error can be detected with a manual inspection, but no process is in place, so that detection left to chance
5	Moderate chance of detection	There is a process for double-checks or inspections, but it is not automated and/or is applied only to a sample and/or relies on vigilance
4 3	High chance of detection	There is 100% inspection or review of the process, but it is not automated
2	Very high chance of detection	There is 100% inspection of the process, and it is automated
1	Almost certain chance of detection	There are automatic “shut-offs” or constraints that prevent failure

that are done during the process of the development projects in the earliest possible time [23]. Table 4 shows the rating required for the detection index evaluation.

As mentioned before, the risk priority number (RPN) is calculated for each failure mode, based on the product of these three factors “severity  $\times$  occurrence  $\times$  detection” in a range from 1 ( $1 \times 1 \times 1$ ) to 1000 ( $10 \times 10 \times 10$ ) [30]. The RPN gives a failure ranking for any evaluated failure mode relative to the other failure modes, in other

words, a higher RPN means that a more urgent preventive action is needed because it is more likely that the mode will fail [21].

### 3 Method

The methodological procedures used in this paper consists of an exploratory and descriptive research [31], with a qualitative and quantitative approach based on the case study method. In descriptive research method, correlational, developmental design, observational studies, and survey research are used [32]. What justifies the use of the case study method is the fact of fulfilling the conditions required to test the objectives proposed in the research and being a contemporary and current event. The case study method typically combines methods of data collection, such as archives, interviews, questionnaires, and observations [33].

The Brazilian Conference of Production Engineering (ENEGEP by its acronym in Portuguese) was selected as the unit of analysis for this research, for having a long trajectory in the dissemination of technical and scientific production related to the production engineering and for being the largest conference related to this area in Brazil. In 2017, ENEGEP celebrated its 37th edition with 2000 participants approximately, and it is considered as a main forum for discussion of issues pertinent to Production Engineering at national level, at each edition, a varied agenda is executed, including national and international lectures, workshops, work groups, panels, mini-courses, and technical visits; grouping in its activities the academic community, researchers, teachers, and students, entrepreneurs, consultants, engineers, administrators, and other professionals involved with Production Engineering [34].

ENEGEP was chosen as the case study to implement the FMEA method, the data collected were obtained by the organizing committee in order to calculate using the formula of RPN the index of risks and failures that may occur during the planning and execution of the conference.

### 4 Case Study

Although researches applying FMEA to analyze common failures in the execution of scientific events remains scant, it is known that the possibility of failures in this process is quite high considering the different activities carried out in different areas in parallel. Moreover, this type of failures can be controlled by corrective actions and preventive maintenance. Thus, applying FMEA during planning and execution of such an event to evaluate all the possible consequences of failure modes, can be a useful technique to present recommended actions which might support the decision-making to decrease a large variety of possible failure modes.

Before beginning the data collection stage, a literature review has been used, including related research papers, books, and thesis. This process resulted in the use

of quality tools such as Pareto and flow charts, fishbone diagrams, and brainstorming technique. From here, working sessions were scheduled with the organizing committee of the conference in order to collect data through interviews and questionnaires to be subsequently analyzed and evaluated.

After identifying the possible causes and effects of failures during the conference, the homogeneity in some of the activities led to the categorization of nine areas to be evaluated: agenda, communication, organizer/staff, paper submission, participant, speakers, sponsors, suppliers, and venue. Each area generated a series of process classified to the related failure modes. After this practice, priority of failures due to their disaster effects were ranked by the organizing committee through the Risk Priority Number (RPN) as shown in Table 5.

This result will allow the organizer to focus on high RPNs immediately rather than all failure modes due to the highest priority. Moreover, they can prevent the disaster based on the analysis of priority items [35].

## 5 Results and Discussion

### 5.1 Evaluation of Risks

After analyzing data, 46 failure modes were identified and grouped into their respective categories of process or action. The risks associated with these failure modes were ranked using the RPN, selecting the five highest results. These five failure modes correspond, respectively, to processes related to suppliers, communication, organizers and staff, participants and agenda; and indicate the most important failures to be considered when planning and executing the event. As is shown in Table 6, an analysis of potential effects and possible causes of each of these results were made.

Recognizing the importance of these five failures, current controls are being applied to each edition of the ENEGEP. Regarding technical and operational accidents, the conference offers medical coverage during the entire event, including assembly and disassembly process; activity management tools are being applied by staff members to avoid communication and scheduling failures; on the other hand, training and recognition of work areas are done in advance to avoid confusion between staff members and organizers.

Although the rest of the failure modes evaluated did not reach higher indices, this does not mean that the importance of their potential causes is being neglected. Preventive actions have been taken during the planning of the conference, activities related to venues are being increasingly detailed based on evaluations during technical visits of host cities; new and more effective channels of communication between stakeholders are being applied in order to improve the noise generated during this process; high experience in the areas to be covered during the congress are being considered during the hiring process of staff members; permanent partnerships with possible sponsors are evaluated by the organizers even during the extra-conference

**Table 5** Failure modes and comparative criticality indices

Processes or actions related to	Failure mode	S	O	D	RPN
Agenda	Central theme unattractive or outdated	6	4	2	48
	Activities unorganized	5	5	5	125
Communications	Outdated information on communication channels	5	5	6	150
	Conference reports issued after the deadline	6	4	2	48
	Communication noise with suppliers	6	4	2	48
	Communication noise between organizers and staff members	4	7	3	84
	Communication noise in paper's evaluation process	8	5	1	40
Organizers/Staff	Hierarchy not defined	7	5	4	140
	No experience in managed areas	4	7	2	56
	Limitation of equipment for the execution of activities	4	2	2	16
	Delay in issuing certificates or documents of payment and registration	7	3	1	21
	Delay or not to send acknowledgment letters to supporters	4	2	2	16
	Delay in the preparation of the final report of the results of the conference	4	7	2	56
Paper submission	Technical system failures	8	3	1	24
	System failure by users	4	5	4	80
	Coordinators/Referees with no interest in participating in evaluations	6	2	2	24
	Paper not included in the annals of the conference	9	2	2	36
Participants	Low participant response rate	4	5	2	40
	Access control	7	8	1	56
	Evacuation failures	10	3	3	90
	Criminal acts within the premises of the event	10	1	9	90
	Limited number of security agents	9	2	3	54

(continued)

**Table 5** (continued)

Processes or actions related to	Failure mode	S	O	D	RPN
	Intrusion of strangers to the conference	8	2	8	128
	Illness or death during the conference	10	1	2	20
Speakers	Delay or no show	7	3	4	84
	Unprepared speaker	6	3	2	36
	Mild disease (during the conference)	8	2	1	16
	Severe illness or death of the speaker (before the conference)	7	2	1	8
	Severe illness or death of the speaker (during the conference)	5	1	1	5
Sponsors	Out-of-term sponsorship request	8	2	1	16
	Request not approved	9	4	1	36
	Lack of benefit from sponsors	8	3	1	24
	Delay in submitting report	5	5	3	75
	Incomplete accounting reports or supporting documents	7	3	1	21
Suppliers	No show	8	1	1	8
	Hiring of suppliers without experience	6	3	4	72
	Breach of contract (no service provided or non-delivered)	9	3	2	54
	Provide different products or services	6	2	2	24
	Low quality	6	3	3	54
	Loss of rented products or equipment	6	2	3	36
	Accidents during the provision of services	10	3	10	300
	Insufficient products or services to meet the demand	6	2	3	36
	Delay in payment or issue invoices	6	2	3	36
Venue	Inadequate infrastructure	8	1	1	8
	Limited accessibility	6	3	1	18
	Few evacuation exits	10	4	1	40

S = Severity; O = Occurrence; D = Detection; RPN = Risk Priority Number

**Table 6** The five highest risks failure modes

RPN	Failure mode	Potential effect	Potential causes
300	Accidents during the provision of services (suppliers)	Chaos, stress and uncertainty among participants	Technical/operational failures by suppliers
150	Outdated information on communication channels	Confusion among stakeholders, high number of complaints, impact on the level of credibility of the conference	Deficiency in internal planning or procrastination by staff members
140	Hierarchy not defined	Staff without knowledge of activities/without interest during execution of activities	Lack of general and detail information at the start of the conference by the organizers
128	Intrusion of strangers to the conference	Intrusion of uncredited persons during lectures, symposia or social gatherings between researchers, speakers and other participants	Logistical failure by the contracted security company
125	Activities unorganized	Confusion about the activities of interest. Conflicts of schedules and locations	Deficiency in logistic sector and internal planning

period; finally, the organizers have invested in updating and maintenance of software related to the submission of scientific papers.

## 6 Conclusions

The FMEA method was considered to this research for contributing to quality planning in projects, allowing the evaluation of interconnected process designed to provide an adequate structure for the execution of a scientific conference. The application of FMEA resulted in actions to address the causes, determining that risks during the execution of a conference might be reduced through the development of preventive action plans to promote process improvement; similarly, recovery strategies must be created in advance if any of the failures occur. On the other hand, policies of immediate removal of the risk source could be implemented according to the level of priority of the risk.

Although the highest RPN index was related to supplier activities, many failures found were associated with the management of internal process, mainly related to lack of training or lack of commitment of the human resource. In this way, it could

be recommended to implement professional incentive programs according to the different areas or activities performed by staff members.

With the previous results, it is possible to conclude that both research questions were answered, considering that the FMEA method was used to avoid errors, improve the quality of processes, identifying potential failures, and enable the learning of the organizers of scientific events for the development and prioritization of improvement strategies during their activities.

Finally, it is expected that this research contributes to planning and execution activities of scientific conferences, providing a point of view scarcely studied, regarding the impact generated by failures during the production of this kind of events.

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# QR Code Based Signage to Support Automated Driving Systems on Rural Area Roads



Erol Ozan

## 1 Introduction

Automated Driving Systems (ADS) and connected vehicle technologies show significant potential to augment the safety and efficiency of transportation networks. The seamless and reliable operations of ADS depend on the information technology infrastructure, capable of handling the requirements of this new technology. In many cases, full implementation of ADS necessitates that the acceptable infrastructure coverage is adequate and it is well supported throughout the road networks of a country including the rural areas. However, a significant portion of the rural areas in developing countries (as well as in certain parts of many developed countries) are unable to provide electricity and data communication capability that are needed by road side equipment (RSE).

An alternative way to provide data about the local road conditions in rural areas can be achieved by low-cost machine-readable static signage, which does not require power or active data communication capability. To achieve this goal, this paper explores the feasibility of using Quick Response (QR) codes as static road side signs. It particularly analyzes the applications of Map Data (MAP) messages in intersections. MAP messages constitute a common form of data communication method that conveys roadway geometric information. Those messages typically alert and inform human- or machine-based drivers about the physical features of the road and intersection configurations ahead. Since the existing experimental systems require road side equipment which relies on the existence of the power and data communication capability, they are not always applicable in rural areas.

Static signage does not require power and data connectivity, therefore its operational costs are minimal. This paper explores a specific case where road side static signage is in the form of a QR code where they are read by the image processing

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systems installed on vehicles. The capacity of QR code and the typical payloads of MAP messages are compared to assess the feasibility of the approach.

## 2 Fundamentals of QR Codes

In this section, the basic building blocks of a QR code are introduced. A detailed review of QR code technology can be found at [1, 2]. Here a summary is provided to give an account of the main characteristics of the technology.

The concept of QR code was first introduced in 1994 and has gained popularity since then. It has been applied to a wide variety of areas including, warehouses, billboards, product tagging, patient identification in healthcare, and many others. A QR Code is in the form of a two-dimensional matrix that is typically printed and attached to a surface. A black and white QR code stores data by representing data with dark and light elements. Those individual units are referred to as modules. They are stacked in rows and columns forming a 2D matrix of dark and bright areas.

A QR code features seven areas that contain specific information areas and guidance points. Those areas convey information on the following elements: version information; format information; error correction data; special patterns for position detection; a special pattern for alignment; timing patterns, and quiet zone that encapsulates the active code area. Figure 1 depicts an example showing the locations of position detection and alignment patterns. Position detection patterns are in upper two corners and also lower left corner of the code surface. Those patterns enable scanning from different angles and perspectives.

**Fig. 1** Locations of position detection and alignment patterns



### 3 Encoding Map Messages

Signalized interactions provide many opportunities for introducing vehicle-to-infrastructure and infrastructure-to-vehicle data exchange capabilities. In a number of urban-based experiments and testbed implementations, real-time control of traffic Signal Phase and Timing (SPaT) information is disseminated to the vehicles that are in the vicinity of the intersection. SPaT is one of the methods used to facilitate the cooperation between vehicles and the infrastructure. The main objective of SPaT is to improve safety and improve the flow of vehicles in the traffic. SPaT data is typically transmitted via the use of short-range radio communication or the cellular network data coverage [3].

As summarized in Table 1, SPaT messages are composed of four components [3]:

- Signal Phase and Timing (SPaT) is a real-time data that relays the description of signal states of the intersection and the duration of each state as it applies to every direction and lane.
- Map Data (MAP) constitutes the static portion of the message and therefore, it is suitable for static road side signage. MAP typically provides data on the following elements; the geometrical configuration of one or more intersections; lane geometries; the allowable vehicle movements for each lane; locations of barriers, pedestrian walkways, shared roadways and rail lines that may affect vehicle
- Signal Request Message (SRM) contains messages that request preemption or assigning priority to select vehicles.
- Signal Status Messages (SSM) is intended to increase the efficiency of the intersection to optimize capacity use.

Among the four components listed above, only the MAP is static, therefore, it is suitable to be used in this study. Other three elements, SPaT, SRM, and SSM are dynamic and need to be updated in real time, therefore, they cannot be conveyed in a system that uses static road side signage.

MAP messages do not change frequently. A static sign can be used to relay MAP data from infrastructure to vehicles. MAP data are typically used to inform the vehicles about the changes in the road configurations and various physical aspects of the roads in the vicinity of the coverage area. The messages are also issued for alerting vehicles about potential hazards.

**Table 1** Components of SPAT data

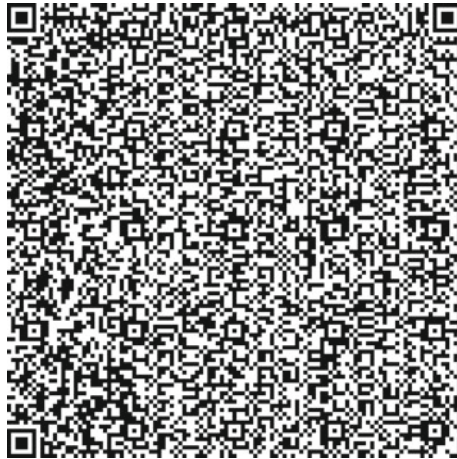
Component	Description
Signal phase and timing	Describes signal states in intersections
Map data	Geometry of lanes and roads
Signal request message	Requests priority for certain vehicles and/or preempting
Signal status messages	Optimizes the intersection throughput capacity

A number of sample messages can be found at [4]. The size of MAP messages can vary depending on the specifics of the data being disseminated. An average payload size of a typical MAP message is likely to be between 600 and 1100 bytes. MAP messages are transformed into an array of hexadecimal numbers before transmitting to the users.

## 4 QR-Based Static Signage

Figure 2 shows a sample QR code that corresponds to a MAP data containing the data involving the intersection located at Curtner Ave at El Camino Real, Palo Alto, California. The sample data is available at (MAP data source [4]).

Figure 3 shows the content of the intersection data in hexadecimal numbers containing the information for the same example as in Fig. 2. Machine readability of QR code becomes more difficult as we increase the number of modules stored in signs. Therefore, breaking up the data into multiple QR codes can provide a more effective solution. Figure 4 shows the four QR codes that contain the same data as stored in Fig. 2. The combination of those four codes renders the same data payload.



**Fig. 2** Example of a QR code containing a 543 byte long MAP data

```
0012821B28083119000003EE00A5F93163113F0238883D014A0288BC04800450  
000406400315877838EE4FA992591398812EF20B5497B2EE8E290E20004484A0  
0020C0111000081000062C1EE5E1DC37572482B331D25DAFB3E92F50DE78C800  
001F70152FC98B1889F811C441E80A501461C1A58066800020520008B38A77C7  
7BF5908F3DC979148740003240880018B010D000040800011614C58EF5AAFE1  
E8512D0090F800062C0534000102000043DE1D28EF26B061E76931A091080006  
2C0634000100400043AFD448EEC0AF81E7FD3380909100011C07420001020000  
4509448E3C2C2A58797C4E48442A002000007DE38108400020400008A334DC87  
8745498F2F09CE0885C00400000FBC70250800040800010D7A13A3C1FAA84797  
74EE84432002000007DE5814E8000204000108C0559C8488DE0632A05CEC6441  
BF50241E00008B02DD0000408000211CFB4E90933BC20652FB9F8C8F17BE0484  
4000116063A000081000041086F5884B2DE0C328DDC50647CBE30242600008B0  
35D0000405000108D2A4E217DC461A476902290240005488080028E074100008  
100004273DDFB213C970E8CA3971A192BAEE01103800800001F68E07C1000081  
00004267BC66213EF7328CA2D73D1928AF5E1104800800001F68E08410000810  
000413B7D4084D9DCBA3285DD2064A5BD804416002000007DA4400000FB81297  
E4C58C44FC08E220F4032000804B180024C000222D034415847440AA5B5FC0
```

Fig. 3 The content of the Map data conveyed in the QR code shown in Fig. 1 in hex

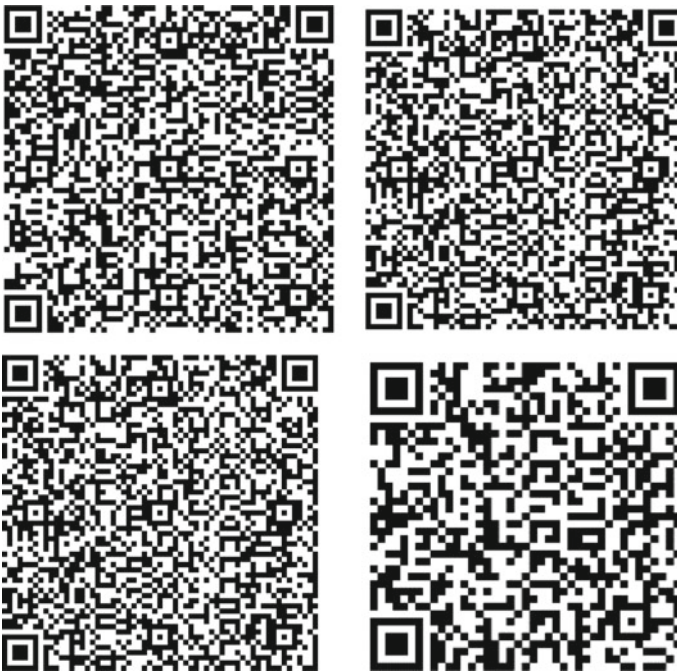


Fig. 4 Same message split into four QR codes

## 4.1 Scanning Distance

Developers of QR code based road side signs need to consider a number of design constraints and challenges to build effective solutions. Scanning or reading distance is one of those elements and it is defined as the distance between the sign and the camera. Maximum scanning distance for a QR code can be calculated by using the following equation.

$$\Delta = (p \cdot s) / [2 \cdot q \cdot \tan(\alpha/2)] \quad (1)$$

In Eq. (1),  $\Delta$  is the maximum scanning distance,  $\alpha$  is the field of view for the camera,  $q$  is pixel width resolution required to read the code,  $p$  is pixel width of the camera's image sensor, and  $s$  is the width of the QR code signage. As the Eq. (1) indicates scanning distance is proportional with sign size and camera resolution. On the other hand, as the size of the QR code matrix increases, the system requires shorter scanning distances. The cameras with wider field of view provide longer reading distances.

## 4.2 Color-Coded QR Codes

The use of color-coded QR codes can decrease the matrix sizes and can enable the signs to be read from longer distances. The color-coded QR code technology is discussed in [5, 6]. Table 2 shows the comparison of different levels of color encoding and the estimated matrix size and maximum reading distances. The values are based on a capacity of 862 characters QR code with 28% error correction level. Reading distance is calculated for QR code based signage surface that is 1 m by 1 m. The calculations are based on a camera field of view of 60°. An image sensor resolution of 4032 by 3024 pixel was used as it corresponds to the specifications of high-end smartphones [2, 6, 7]. It is assumed that a minimum of 4 by 4-pixel area is required to detect each module in the QR code. As it is shown in Table 2, a reading

**Table 2** Matrix size requirements and maximum reading distance under different color coding schemes

Estimated QR code matrix size	Number of colors used for encoding	Maximum reading distance (m)
88 × 88	2 (B&W)	7.5
65 × 65	4	10.2
48 × 48	8	13.8
37 × 37	16	17.9

distance of 17.9 m can be achieved by using a 16-color QR code scheme. Increasing the maximum reading distance has potential to improve the scanning accuracy since the system would have time for multiple scanning attempts before the signpost was passed.

### ***4.3 Operational Considerations***

The positions and placements of the signs have potential to impact the accuracy of the scans. It is possible for one vehicle to obstruct the other vehicle's camera and disrupt the code scanning. To overcome this obstacle, redundancy can be employed. Using multiple copies of the same QR code in various sides and positions of the road can improve the scanning efficiency. The angle of the signs can also be adjusted so that they face towards the possible locations of onboard cameras. The material that is used in printing the signs is also important. Reflective print surfaces and high contrast prints will render better results.

Since the QR code based signage is typically read while vehicles in motion, the problem of motion blur in captured images poses a challenge for scanning performance. There are number of ways that the problem can be mitigated. One approach is to optimize the image quality to minimize the blur at the time of the capture. This can be achieved by targeting and focusing on the sign and decreasing the shutter speed.

There are environmental factors that add to the complexity of the problem. Various weather events (rain, snow, fog, etc.) can reduce the visibility and clarity of the images acquired by the onboard cameras. One way to address this issue is to increase the error correction factor in QR code. However, this translates into larger module sizes and impacts the feasibility. Night time operations can pose less of a challenge since the vehicles are expected to provide adequate level of illumination with their headlights. The use of camera flash can improve scanning performance in low light situations.

## **5 Conclusion**

This paper conducted a theoretical analysis of the feasibility of using QR codes in developing static signage that conveys intersection data in rural areas that lack power and communication infrastructure. It is concluded that QR code technology provides applicability for this specific design problem. This article discussed various challenges that need to be tackled by the developers to ensure reliable operations. The theoretical analysis indicates that the use of color-coded QR code can provide feasible implementation alternatives since they allow better scanning performance with higher data capacity. The performance of QR code readers also depends on the image sensor resolution, field of view, and processing capability of the scanners. As the more powerful and lower cost devices continue to evolve, the feasibility of



QR code based traffic signs is likely to improve. This study can be expanded to investigate the possible compression algorithms to reduce the size of the typical MAP data resulting in better scanning performances.

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# A Practical Study of the Application of Value Stream Mapping to a Pre-series Production Area



Joana Lamas, Carina M. O. Pimentel and João C. O. Matias

## 1 Introduction

The Lean Manufacturing (LM) system is typically recognized by its focus on cost reduction and performance improvements [6, 8]. Its applicability in repetitive production environments is well documented. However, its suitability to non-repetitive production environments, such as engineer-to-order (ETO), is sometimes questioned [3]. The ETO product development process starts with customer requests and specifications for each order and usually ends with an engineering design or manufacturing, assembly and delivery of the designed items [2]. Typical features of the customized products are defined through ongoing negotiations [4]. Because of its nature quite often the ETO product development process involves long lead times from order placement to shipment. In this type of environment, companies are constantly pushed toward fulfilling the specific requirements of customers flexibly in shorter lead times to remain competitive [9]. So, in this paper, we seek to contribute to the literature by showing the effectiveness of the application of LM VSM tool in a project manufacturing environment. In order to accomplish this objective, the following research question was considered to guide the study:

RQ 1: How can VSM be applied in an ETO environment so as to improve customer satisfaction?

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The study objective was reached through a project, using a case study methodology, with the active participation of one of the authors of the paper. Case study methodology was considered because as stated by Benbasat, et al. [1] it allows: (1) To study the phenomenon in its natural setting and meaningful, relevant theory generation from the understanding gained through observing actual practice; and (2) the questions of why, what and how to be answered with a relatively full understanding of the nature and complexity of the complete phenomenon.

This paper is structured in four sections. Section 2 is dedicated to a brief presentation of the case study framework. In Sect. 3 the VSM implementation and the achieved results are presented. Finally, in Sect. 4 some concluding remarks are offered.

## 2 Case Study Framework

This project emerged from the strategic reorganization of a successful Portuguese automotive supplier group, specialized in the production of injected plastic components. Due to the acquisition of new projects, the group decided to decentralize its pre-series area, by establishing a pre-series area in each factory of the group operating in Portugal. Previously, the projects were developed by a central department and released to each factory upon the start of serial production (phase 5 of Fig. 1). This led to the need to implement a pre-series area in each factory of the group. So, each factory was challenged to implement a pre-series area and to organize the corresponding industrialization process of new projects. The case study described in this paper was approached in one of those factories. This company has implemented the Lean Manufacturing system and aimed to implement the new pre-series area and corresponding processes following the lean manufacturing principles and practices, so as to ensure that the standards are maintained along all the factory processes and areas. So, in the development of the new area, several lean tools were used. In this paper, in Sect. 3, we demonstrate the application of the VSM tool, as well as the benefits of using it along the project duration.

The project implementation was approached through the creation of a multidisciplinary team involving the participation of a launch leader, of a pre-series department representative and of the process engineering, production planning, logistics, and quality departments. One of the authors of this paper integrated this team since the beginning of the process.

The pre-series area is characterized by a project manufacturing environment, being each project constituted by a set of parts. Moreover, each project is supported by a file containing all relevant data about the project specifications, such as production sequences, reworking sheets, customer complaints, operators' polyvalence matrix, etc.

The pre-series area is responsible for producing, testing and controlling the first parts of a project, taking place between the prototype phase and the series phase (Fig. 1). The main productive processes occurring in this area are plastic injection,

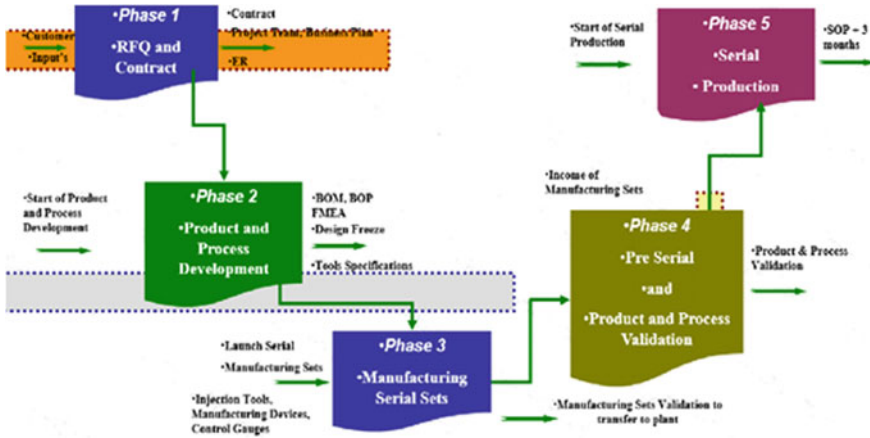


Fig. 1 Project phases in the case study company

manual assembly, and painting. Moreover, two additional operations exist related to quality assurance: parts reworking (the parts in the first test runs typically have not an appropriate quality level, requiring small reworks) and quality control (quality wall). The parts manufactured are then sent to the customer and to equipment suppliers to conduct tests. In brief, the process flow is the following: materials reception; production order emission and materials release; mold testing; storage of injected parts; standard parts production; assembly planning; assembly; quality wall; storage of final parts; dispatching and invoicing.

### 3 VSM Implementation

Value stream mapping is a lean manufacturing tool that is used to map every step involved in the material and information flows need to bring a product from order to delivery [5] helping to see and understand both flows. Values stream maps are typically drawn for different points in time as a way to raise consciousness of opportunities for improvement [5] by wastes identification. A current state map follows a product’s path from order to delivery to determine the current conditions. Afterwards, a future state map deploys the opportunities for improvement identified in the current state map to achieve a higher level of performance at some future point [5]. Both the current state and future state maps are established using diagrams and a particular symbology [7]. According to Liker and Meier [6], VSM is more than a neat tool to draw pictures that highlight waste, though that is certainly valuable. The same authors argue that it also helps to see linked chains of processes and to envision future lean value streams. In our case study, VSM was used in order to map the current state of the pre-series area. Through the current state map analysis, a set

of wastes were identified. In the subsequent step, a future state map was projected, representing the ideal state after the wastes elimination or improvement. A detailed description of these steps is presented in the following sections.

### ***3.1 Selection of a Project***

In a typical VSM implementation the process starts with the selection of a representative product family [7]. In our case study, the project team decided to choose project XYZ because it involves a comprehensive production process and was considered demonstrative of the pre-series flows.

### ***3.2 Current State Map***

In the first stage, the pre-series area was installed in a small area outside the factory, although within its limits. The area was established with three workstations with two operators fully committed to the pre-series process. Moreover, this area worked in one five-day shift plan. The two operators were responsible for the production/assembly, some logistics, and quality assurance processes. Also, some logistics processes are tackled by the logistics personal of the series area. The current state map was devised under these conditions.

The boundaries of the current state map range from the supply of the main raw materials (plastic injection materials) to the delivery of the parts to the customer. The mapping started with the characterization of the customer orders (upper right corner) and with the calculation of the customers' takt time, through the ratio between the available working time per month over the average customer demand rate per month. The resultant takt time value was equal to 1172.7 s per part, meaning that the pre-series area would have to guarantee that approximately every 1172.7 s a new part of project XYZ is ready to be sent to the customer. The average customer demand rate per month was determined considering the customer demand over a period of 5 months. Also, in order to evaluate the consistency of the demand profile along the 5 months the coefficient of variation (CV) was also calculated. The CV is a standardized measure of dispersion being a dimensionless number that is calculated as the standard deviation divided by the mean. The achieved value was equal to 22.3%. In the next step, the supplier information was organized. The main raw materials used in project XYZ are plastic materials. This is the main sourcing material of the factory with regular deliveries of huge amounts to the factory. Considering this, a variable X was included in the current state map that corresponds to the number of days of raw material inventory assigned to project XYZ. Afterwards, the internal material flows associated to project XYZ were included in the current state map. The next step was the mapping of the information flows, from the customer through the central logistics department until the supplier. Finally, the total processing time and total

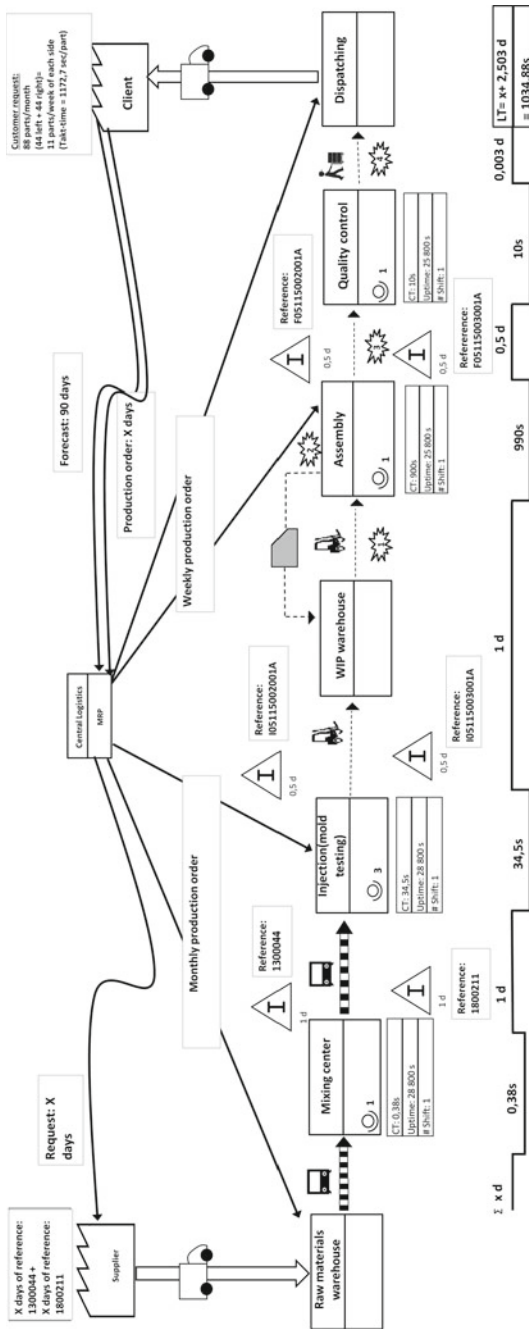






Fig. 2 VSM—current state map

**Table 1** Wastes identification

Waste number	Waste
	High parts waiting time until the start of processing and transportation time between the WIP warehouse and the assembly process
	Manual assembly of parts increasing significantly cycle time
	High inventory of finished parts upstream the quality control process
	High transportation/waiting time between the pre-series area and the dispatching process

lead time were determined and represented through the timeline under the diagram. This timeline represents the total time it takes one part to make its way through the pre-series process, beginning with the arrivals of raw materials through to shipment to the customer. The current state map can be found in Fig. 2.

Four main wastes were identified from the current state map (see Table 1).

### 3.3 Future State Map

Grounded in the current state map and the main sources of wastes that derived from it, the project team defined a new value stream, reproduced in a future state map (Fig. 3), aimed to be achieved in a short-term. The main goals were: (1) to approximate processes thus reducing movement and transportation wastes; (2) to reduce WIP inventories; and (3) to reduce lead times.

The following three questions helped to guide the development of the future state map:

- (1) How to reduce WIP waiting times/levels?
- (2) Is there any task that can be eliminated?
- (3) How can the assembly cycle time be improved?

The following four main changes were implemented in order to improve the pre-series process:

- (1) Change the location of the pre-series area: the pre-series area was installed inside the factory, resulting in a reduction of the distances and times to perform

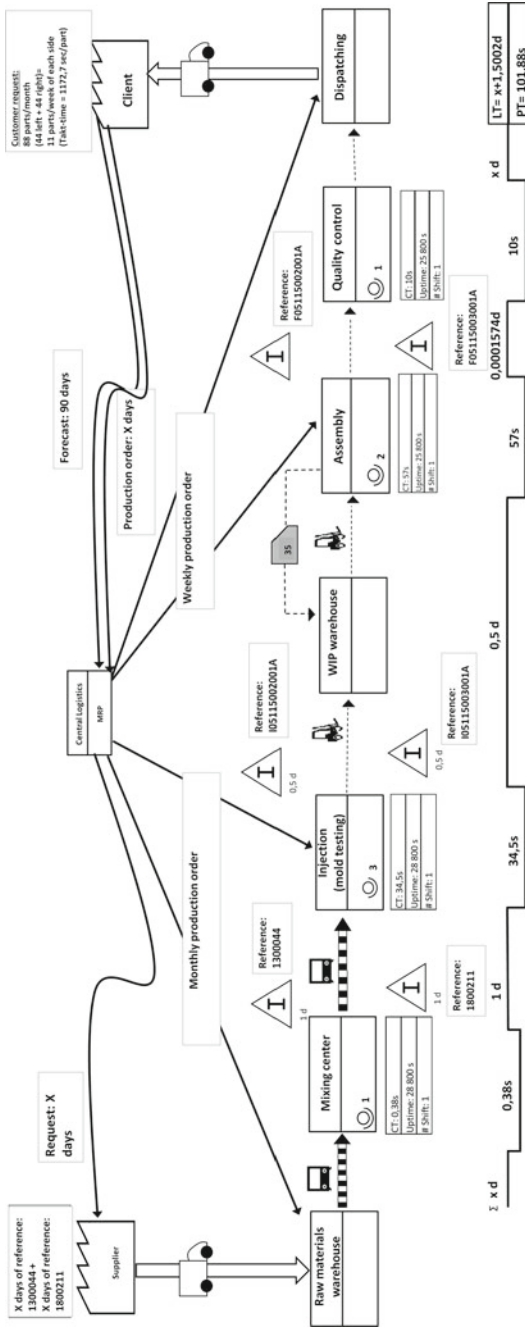


Fig. 3 VSM—future state map



the logistics operations, such as an example the distance/time from the quality control process to the dispatching area, and in a better area organization.

- (2) Introduction of a logistics operator: with dedicated logistics operators in this area the dependence of the pre-series production operators on the series logistics operators was eliminated and thus the waiting times.
- (3) Introduction of a quality control operator: the high level of inventory between the assembly and quality control processes occurs because the production operators are also responsible for quality control. In the new situation, the operator after finishing the assembly process moves the part(s) to the quality control process, taking in average 10 s. The part(s) is(are) placed in a queue and controlled as soon as possible, depending on the quality control workstation load and dispatching priorities.
- (4) Introduction of an assembly equipment: the automatization of the assembly process allowed a considerable reduction of the assembly time.

### **3.4 Results**

After the implementation of the improvement opportunities, identified through the VSM analysis, a reduction equal to 933 s was achieved in the total processing time of project XYZ. The huge reduction of the total processing time was mostly due to the automatization of the assembly process. Moreover, the pre-series lead time reduced from 2.5 to 1.5 days, mainly due to: WIP elimination between the assembly and quality control processes; introduction of dedicated resources that allowed the reduction of the production operators overburden, resulting in production delays; change in the location of the pre-series area that approximated the processes and resources. Other improvements resulting from the above-presented changes were: better organization of the working space and workstations; significantly improvement of the production and assembly processes; reduction of the customers' complaints; reduction in late deliveries and in the need to use express transportation services.

## **4 Final Considerations**

Based on a theoretical background about VSM tool, we used it to analyze the material and information flows of a pre-series area through the selection of a representative project. Our aim was to show the effectiveness of this tool in a project manufacturing context. The achieved results proved that this tool, with proven results in repetitive environments, could also be of great interest to the identification of improvement opportunities in an alternative context, such ETO. As a suggestion of future work, it would be interesting to use other lean management tools, as a continuous improvement process, namely, to improve the area organization and the area layout.

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# Implementation of a Software Program for the Optimization of an Oil Pump Assembly Line



Leonardo F. M. Lemos, Radu Godina and João C. O. Matias

## 1 Introduction

The automotive industry is in an increasingly competitive environment, constantly facing new challenges, pressuring organizations to a greater need to innovate and develop techniques which make their production processes more efficient [1–3].

Changes in the complex business environment such as increased competition, new stakeholder requirements, the emergence of new technologies, among others, have driven organizations to respond to these rapid and significant changes, to constantly strive to improve, as well as manage the processes more efficiently [4]. In order to respond to these rapid changes, several companies, mainly in the automotive industry, use various types of software in order to improve the quality of their production. It is critical for the companies to be able to maintain a high level of productivity in order to meet the preestablished production objectives, thus not compromising customer orders [5].

With electronics playing an increasingly important role, due to the need to find sustainable solutions and to create platforms that allow sharing information across sectors, it has made information systems increasingly present in organizations [6].

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Therefore, one way to enhance continuous improvement is by using certain types of software that aid the enterprises in decision-making by providing reliable and easily interpretable information [7].

SAM is a type of software used for improving the performance of the production lines. It is a very wide-ranging tool that provides numerous features, allowing a detailed and real-time analysis of a production line [8]. SAM is very intuitive and easy-to-use software that allows collecting the necessary data easily in order to explore and process it with simplicity.

This paper aims to describe the implementation of the SAM software in order to improve the performance of a variable displacement oil pump assembly line. The article begins with chapter “Internet of Things (IoT): Technological Indicators from Patent Analysis” in which the theoretical background where the Lean Manufacturing, standard work, visual management, and information systems are addressed. In chapter “Flexibility Practices in Disaster Response—A Process Approach Based Evaluation” the contextualization of the problem and the presentation of the objectives are made. The utilized methodology and obtained results are addressed in chapters “A Literature Review of Mathematical Programming Applications in the Fresh Agri-Food Supply Chain” and “A Bibliographic Review on Social Technologies”, respectively. Finally, the conclusions of the overall study are drawn in the chapter “The Importance of Education in Enhancing the Innovation Capacity in Serbia”.

## 2 Theoretical Background

### 2.1 *Lean Manufacturing*

The Toyota Production System (TPS) was developed by Taiichi Ohno in 1950 and was applied to Toyota industrial units, being considered one of the main factors of success of the company [9].

This new production system has been adapted to a new reality: customers who demand innovative products in a short time, with the highest quality and at a lower price. To do so, it was necessary to reduce lead times, and it was necessary to adopt two concepts. The first one is to stop the machines if there is an anomaly in their operation, in order to avoid the production of defective products. The second concept is to reduce stocks and schedule production, not in terms of sales forecasts, but rather in terms of what the customer actually wants [10].

After a revision of the TPS system, the term Lean Manufacturing was introduced in 1988 [11]. This methodology is based on the elimination of waste and processes that do not add value, in order to produce high-quality products, at the right time, and thus avoiding any type of waste [12]. Lean Manufacturing is closely related to JIT production and TPS [13]. This relationship can be described as follows: Lean is a management philosophy dedicated to adding value, eliminating wasteful processes and meeting customer needs, Just-In-Time aims to improve the logistics activities

and eliminate production problems and finally the Toyota Production System is a philosophy that emphasizes a continuous improvement, the involvement of all employees and standard work methods [11].

### **Standard work**

Before starting any continuous improvement practice, it is necessary to create standards in order to stabilize a given process. A standard acts as a baseline from which all improvement activities partake in the continuous improvement process [14]. Standardization is defined as an activity of establishing, communicating, following and improving standards. The standard work consists of a set of working procedures, where the methods and sequences are established for each process [15].

The standard work provides a foundation for achieving consistent levels of productivity, quality, and safety since it is the culmination of the Lean production process. If it is well applied, it can bring a number of benefits such as defining a reference point from which to improve, controlling the process and reducing variability, improving quality. It also has greater flexibility, more stability and greater visibility of anomalies [16].

### **Visual Management**

Visual devices are used in production environments in order to share information and reduce potential errors and losses in a given process and/or operation [17].

According to Koskela [18], these visual devices are one of the most simple ways to communicate and share information between different processes and people in a clear way [17].

Visual management systems are an integral part of one of the principles of the Toyota production system. Lean Manufacturing uses visual process management systems which end up influencing human behaviour, present rules and mediate visually, control stocks, improve the safety, organize spaces, present organizational goals and strategies, reduce displacements, and manage human resources [19].

Among the main advantages offered by visual management, one is the improvement of disclosing the necessary information and the ease of assimilation of such types of information in the work environment. The visual management helps making the process more organized, cleaner and easier to control and improve [17].

## ***2.2 Information System***

One of the major challenges associated with the study of information systems (IS) is that there are several definitions for the term IS. These differences are mainly due to the fact that people study information systems from different perspectives [20].

The concept of information system is defined by O'Brien [21] as an organized combination of people, hardware, software and resources that collaborate in collecting, processing, and dissemination of information in an organization. Laudon and Laudon [22] describe IS as a set of interrelated components that collect, process, and share information to support the decision making and control of an organization.

They further affirm that information systems can help workers analyze problems and create new products. According to [23], IS represent an automatic or manual collection of people, machines and/or methods for collecting, storing, processing, transmitting and disseminating data. From the definitions presented, it is possible to infer that an IS has a technical component, which includes hardware and software and a social component, that is, people and procedures. Like any other system, the IS is formed by inputs, data processing, and outputs. The information system processes the inputs, transforming them into outputs that are subsequently made available to the end user. An IS is supported by information technology for collecting, processing, storing, and sharing information [24] while information technology (IT) is a support element or the group of tools used to support IS, that is, it is specifically the technological support of information systems. It is the IT that provides the means to build an information system. Information technologies include software, hardware and data storage [25]. It is important to realize that information systems have emerged first as information technologies in organizations. However, with today's organizational complexity, most IS depend on IT [25].

### 3 Problem Contextualization and Objectives

In order to adapt to the new requirements of the market and to increase the performance indices, the factory under study decided to implement a new and more automated assembly line for the variable displacement oil pump. This is a line with a recent manufacturing agreement that is in a RAMPUP phase and consequently has several associated reliability issues. There is no domain of organizational impacts, there is no clear perception how the organization of the operators may be influencing the line's performance, and the current performance monitoring system does not allow an exhaustive analysis since it only follows the monitoring of the buffer machine. As a consequence of all these factors, the operating yield of the line is not in the expected values being at the 46% mark.

This study case aims to implement the SAM software in the production line of the variable displacement oil pump, a very important tool to help the improvement of the operational performance of the line. Before the implementation of SAM, the operational performance was not very promising given the requirements of the organization.

The software is already used in other factories of the group and has played a key role in achieving their objectives. The tool allows faster characterization, better characterization of stops, better precision in stopping times and even better coordination between operators and line managers, besides this allows the operator to follow and develop the system, alert to new stopping situations to later create a message in the system and finally will contribute to a better dynamic of the process. With SAM, it is possible to program the pauses of the teams as well as the times of inactivity of the line. The scheduling of these times is of extreme importance in order to not

distort the productivity indicators, which must be done with one day in advance since otherwise the results of the indicators will be considered false. This tool gives a large number of indicators which allows assessing how the performance of the assembly line or machining line is evolving.

## 4 Methods

A research method aims to guide a researcher to find the necessary answers to the proposed research problem [26]. The method used in this article was action research. Action research is a research method whose design and construction must occur in close connection with the resolution of a collective problem in which researchers and participants are involved in a cooperative way and participatory. In general, it aims to address a research problem within an organization. Researchers use this methodology when dealing with research topics and organizational challenges rather than with hypotheses [26]. This research methodology involves three phases. First, it is necessary to understand the context of the research that will be carried out, as well as the purpose of the work. The second stage consists of collecting the data, analyzing it, planning the actions, implementing the same actions and finally evaluating the results. The third and final step is a check of the previous two steps, to identify what was assimilated with the conduct of the investigation action [26].

Regarding the methodology adopted, it was necessary initially to make a detailed recognition of the whole process of the assembly line.

Subsequently, the data collection phase was essential for the implementation of the software. A survey was made of the cycle time of all the operations in which ten registers were collected for each one of them and afterwards an average of the measurements was made. Next, a list with the main defects of each machine was made in order to make the automatic coding of stops in the SAM. This information was given to an automatism in order to implement it in the software.

After the implementation, the next step was to define the indicators to be extracted from the SAM. Since SAM is a type of software that provides numerous indicators, there was a need to make a selection of what would be used for analysis. The indicators defined as the most appropriate to identify the detrimental operations were the availability, which consists of the time when the machine is ready to operate without any type of failure and is given in percentage, and the stop time, defined as the effective stopping time due to malfunctions.

Establishing the indicators to be used in the next step consists of defining the sequence of steps to follow in order to extract the data and then make the corresponding analysis. In order to standardize this process, a flowchart has been elaborated which includes all the steps to be taken.

Finally, it was necessary to create an animation board next to the assembly line, in order to expose all the data resulting from the analyzes that were made and subsequently create action plans in accordance with the existing problems.

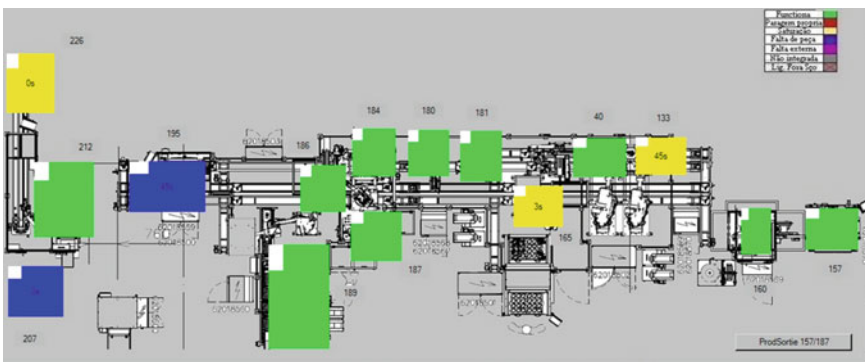
## 5 Results

The implementation of SAM software in this industrial unit was successful. In Fig. 1 it is possible to observe the layout of the line in SAM, where each operation has an associated color so that we can perceive the state of the machine at that moment. In Table 1, it is possible to observe the different colors that can be found.

From the page of the layout, it is possible to observe the production in real time and to compare it with the objective production. To find this information it is only needed to click on the rectangle that says “output production” and then it is possible to obtain a graph that compares these two variables. The operating time of the machines, the stop time, the saturation time, the number of stops among other types of variables can be visualized by using SAM, as can be observed in Fig. 2.

This search can be made by day, by week or by month and can be further separated by shift. The most important indicators that are possible to see in the SAM are the availability and the operational availability of each operation. These indicators allow selecting which operations should devote more attention. Operations that have the lowest availability (time the machine is ready to run without failure) are those that need more attention.

It is still possible to observe from the SAM the reasons why the machines stopped, thus allowing to observe which stops are the most detrimental and, thus, act in order to solve these problems.



**Fig. 1** The layout of the line in the SAM in which each operation has an associated color

**Table 1** The different colors and their meaning

	Machine in automatic operation
	Machine in discharged situation
	Machine in saturation
	Machine with external fault
	Machine in standby state





Fig. 2 The visualization of parameters of the SAM software

In order to exhibit the data extracted from SAM, it was necessary to create an animation board. A visual management system can help optimize a process and help reduce productivity losses [17]. The created PDCA board, as it can be observed in Fig. 3, has become essential to assist in the task of improving the performance. This was based on the PDCA cycle, given that this is a simple and dynamic model and serves as a guide to achieving a continuous improvement.

In the part of PLAN an analysis of the data extracted from the SAM was placed in which the detrimental operations were identified and the problems associated with them were identified as well. In the DO the actions that will be done to achieve the objectives are detailed. In CHECK a check is made to see if the actions taken are contributing to reach the objectives. Data collection and analysis practices are standardized in the ACT section.

With the help of the information provided by the SAM software and due to the creation of an animation board that allowed exposing the data in a simple and dynamic way the performance of the line has increased significantly.

The performance of the line is calculated according to the following equation:

$$Performance = \frac{Total\ Good\ manufactured\ parts}{Total\ parts\ theoretically\ fabricated} \times 100\% \quad (1)$$

The data presented in Fig. 4 shows the period between the beginning of the study and the end of the study.

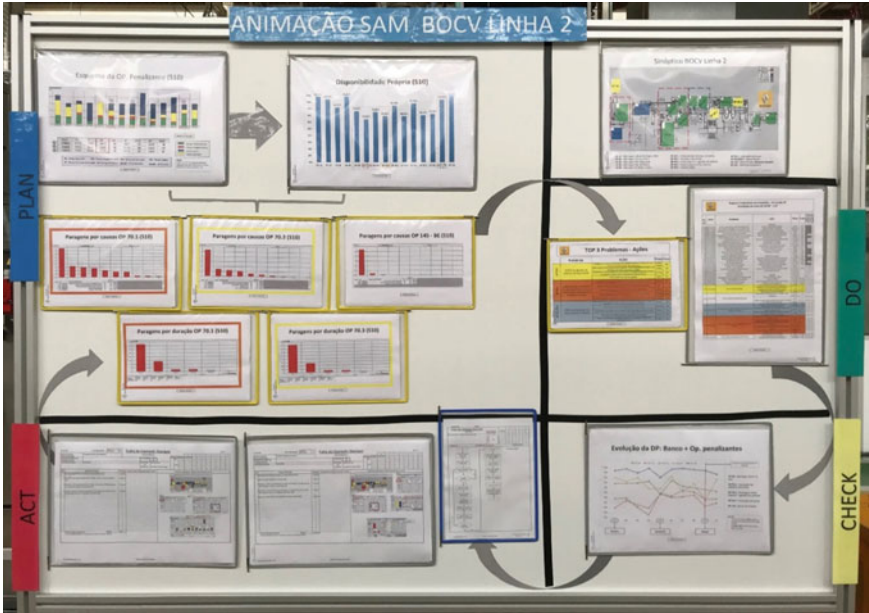


Fig. 3 The created PDCA board

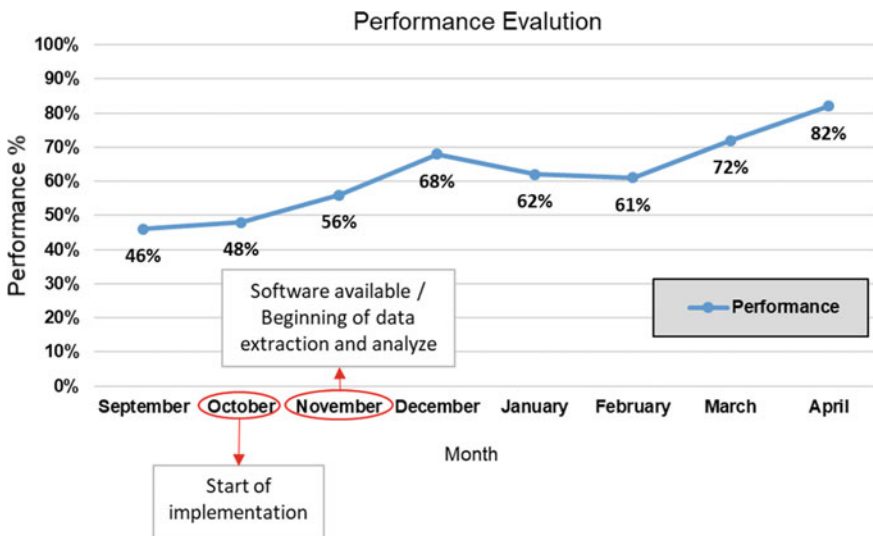


Fig. 4 Monthly evolution of the performance

Even before the software started to be implemented, the line had a very low performance, it had 46%. The SAM software began to be implemented in October 2017, a process that dragged on until the following month. It was in November that the first extraction of SAM data and its consequent analysis began to take place, with a performance increase of about 8% in relation to the previous month. In November the performance reached a value of 68%, however, in January and February, this value was reduced to 62 and 61%, respectively. This decrease was due to changes that were made in the cycle time and, in addition, in these 2 months the two references of pumps that have more problems were produced. In March the performance reached 72% and in April reached the highest value yet –82%.

From these results, it is possible to conclude that the information provided by SAM brought significant improvements to the performance. There was a 36% increase compared to the initial situation, a very good value given the numerous problems encountered in the initial phase. The fact that all the indicators are provided in real time and in a precise way allow a much closer monitoring of the state of the line. In addition, all the animation developed based on SAM data also significantly contributes to the success of this project.

## 6 Conclusions

Information is a commodity that is needed, increasingly, and in real time, in order to fuel decision processes that are faster and more effective, increasingly complex, and with a growing set of variables to analyze. As the automotive industry is one of the most competitive, it is crucial that all the information related to the production process be made available in a simple and intuitive way, in order to achieve positive results in the optimization of processes and consequently increase productivity indices in order to satisfy the customer's needs. In this paper, the use of software to help increase the performance of an assembly line was researched. The article shows that the use of certain types of software that provide reliable information becomes essential when it is intended to increase the performance of a production line. However, in addition to the use of the software it is essential that a good exhibition of the collected data is made and displayed on a board for everyone to see. Thus, all the animation developed based on SAM data significantly contributed to the success of this project.

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# Evaluating the Impact of 5S Implementation on Occupational Safety in an Automotive Industrial Unit



Joana P. R. Fernandes, Radu Godina and João C. O. Matias

## 1 Introduction

In the wake of the competitive environment that organizations are facing, several companies are attempting to reinvent and adopt innovative practices that would allow them to surmount the various obstacles they encounter along the way [1]. One of the most popular practices adopted by the business world is the *Lean Manufacturing*, which is a result of the success story of Toyota. That despite the difficulties experienced at the time, it managed to promote sustainable and continuous growth through the maximization of the value of the product by through the reduction of the waste, through the maximization external and internal variability, among others [2–4].

Lean embraces several practices like just-in-time, quality systems, team work, among others [5]. “Lean is considered by several authors like a technique to reduce waste but the truth is lean maximizes product value through waste minimization” [6].

Even though the application of Lean principles brings numerous benefits to organizations, the optimization of the productive process is not enough, there are other aspects to take into account. Among the several tools offered by lean, 5S as shown as

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the most powerful and easy to use [7]. The 5S is one of the tools of Lean thinking that helps us create discipline culture, identify problems and generate opportunities for improvement. The 5S tool not only contributes to a more efficient work environment but also ensures improved occupational safety [8].

The 5S tool allows for developing a continuous improvement in the destination of the materials. This methodology improves the organizational environment, the productivity and consequently the motivation of the employees and is divided into 5 terms of Japanese origin: *seiri*, *seiton*, *seiso*, *seiketsu* and *shitsuke* and signify “Sort”, “Set in order”, “Shine/Sweep”, “Standardize”, and “Sustain/Self-discipline”, respectively. Each of these terms seeks to call the attention to a sense of responsibility [9–11].

The intensification of the workload could lead both to higher plant productivity. However, it could also lead to a stressful and deteriorating safety environment which, in turn, could have negative effects on factory employees [12]. Thus, recently, and as an evolution of 5S, a new label has emerged: 6S. The addition of safety implies the risk identification, it aims to develop work efficiency, quality of work, safety at work and optimize the discipline [13]. This technique can be labeled as 5S + the 6thS, which is the “S” of the occupational and safety standards. Such an approach could, in fact, improve the safety and at the same time the overall situation of the industrial unit as a result of an accurate 6S implementation [14].

The aim of this paper is to present a case of study in one industrial unit of one of Europe’s largest car producers and how the implementation of the 5S methodology can add not only to the improvement of the work environment but also if it could have a significant impact in ensuring the occupational safety.

The remainder of this paper is organized as follows. In Sect. 2, the importance of improving the occupational safety is addressed. In Sect. 3, the implementation of 5S and 6S tools is described. Results are shown and discussed in Sect. 4. Finally, in Sect. 5, the conclusions are drawn.

## 2 The Importance of Improving the Occupational Safety

In March of 2018, the International Organization for Standardization (ISO) released the standard ISO 45001: 2018—Occupational Health and Safety Management Systems. This new standard is based on the same high-level structure on which safety systems (ISO 9001) and environmental (ISO 14001) are based, and it is intended to replace OHSAS 18001 [15–17].

The document provides a set of simple, effective processes and guidelines that are ready to improve occupational safety in global supply chains. This standard can be applied in both factories and in partners and production facilities, regardless of location. With this, it is expected to reduce the number of occupational injuries and diseases [18], which reached levels of serious concern [19].

An enterprise that seeks to be competitive, in these increasingly globalized markets, needs to create an environment where the employee feels satisfied while per-

forming his duties. This increasingly requires the need to invest in programs and tools that prioritize safety and the quality of life at work [20]. Thus, there is an urgent necessity to employ any types of tools that could reduce the number of occupational hazards and consequently, possible injuries. Since 6S is transversal to all other steps of 5S, with this additional sixth “S” [21], the method also ensures the focus on the reduction of work accidents along the productive chain [22].

### 3 The 6S Methodology Implementation

After the assessment and evaluation of the safety and environmental standards followed by the industrial unit, a risk assessment was carried out in the screening room. This risk assessment was elaborated on the ground through direct observation in order to monitor the operators’ daily work habits and verify their interaction with the environment that surrounds them.

In order to evaluate if 5S methodology has an impact or not at the level of safety, the 5S was implemented in site with high risks since there is very close contact between forklifts and pedestrians. The use of powered industrial vehicles can contribute to improving productivity and efficiency, but at the same time they represent major threat [23].

In an initial phase, a risk assessment was done in order to obtain a quantification of the safety in the working site. The Risk Assessment Values were obtained by multiplying the scores for the Severity and Probability values together. After this step was concluded, it was time to start the 5S implementation and to perform other risk assessments in order to compare the results with the initial situation.

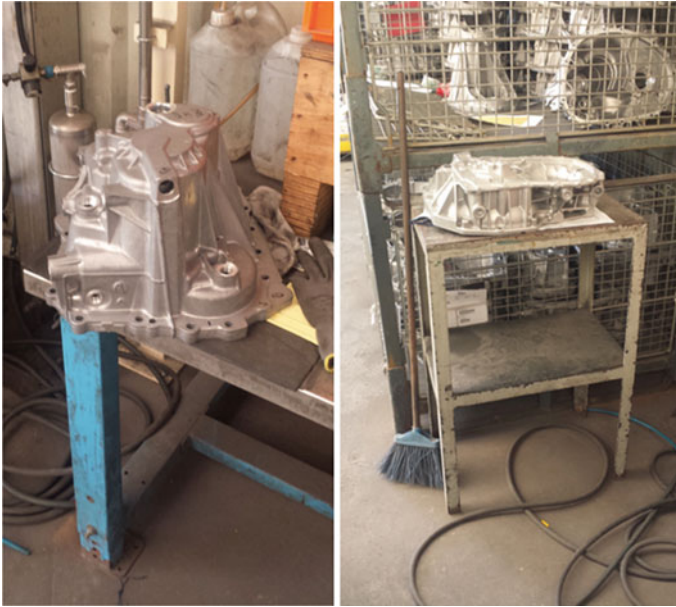
This evaluation was performed on the shop floor through a direct observation by the evaluator. Although there are some hazards that exist in the screening area (such as manual handling, ergonomics, etc.), these are not going to be considered since this risk assessment was done only in the screening zone, that is, in the physical space of the screening site.

The action of 5S implementation took approximately 25 days to complete. During the initial phase, data were collected, in addition to the risk assessment previously presented. Then, a pre-analysis form was prepared for the first three “S”. The initial state of the screening area was also recorded through photographs in order to make a comparison of before and after the implementation of the 5S.

#### 3.1 Seiri (*Sort*)

This step was initiated by listing all the objects that were in the place and by evaluating the extent to which they were necessary. Since the available space was insufficient for all the working activities, anything removed would increase the useful space and would allow making the most of it. After removing all the larger objects and





**Fig. 1** Found parts out of production flow

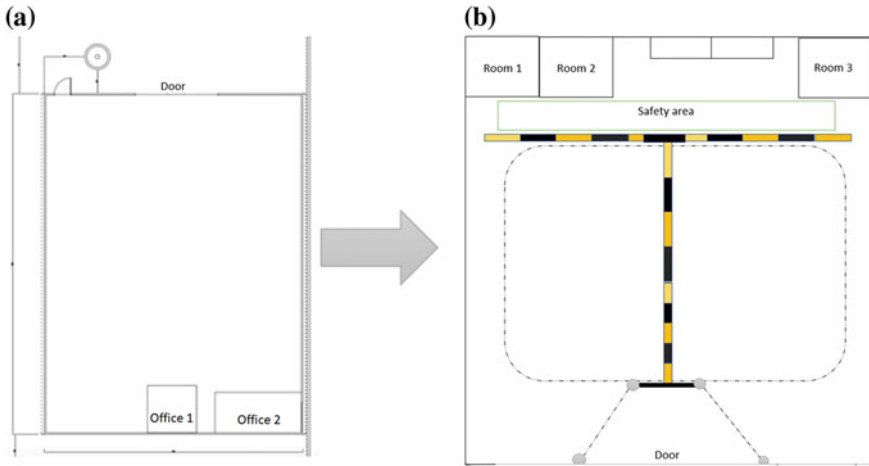
obtaining a little more space, it was time to remove small objects that were dropped and left unconsciously throughout the site. In addition to the safety risks associated with this practice, given the reduced space dimensions, it became unsustainable to store large containers. In Fig. 1, it is possible to observe pieces that are out of the production flow, without identification, that is, these do not have the appropriate label identifying if it is a conforming piece or not.

Thus, all parts outside the production flow were identified, the conforming parts were returned to the stock of the industrial unit and the nonconforming parts placed in a container to be returned to the supplier. Through all these actions, at an initial phase of implementation of 5S, it was possible to free some space in the screening site, thus, making different hazards more visible and detectable.

### **3.2 Seiton (*Set in Order*)**

The second step was to define a space for all objects and to delimit specific zones in order to maximize the existing space. Several copies of the plan of the zone were printed with containers designed to scale so that it was possible to simulate a better layout and to define specific zones.

After receiving all the suggestions it was elected the one that the engineers deemed as the best solution. The site was divided in half so that each sorting company had



**Fig. 2** Sorting area—**a** before and **b** after the implementation of 5S

its own space, as it can be observed in Fig. 2. This division was made with the aid of barriers with a maximum height of 2 m. One of the cabinets was moved to the opposite corner and the cabinets of each of the outsourcing sorting agent were placed next to the offices at the end of the site.

Through this provision, it was possible to create an area entitled “safety zone” and due to the barriers the forklift it ceased to have access. This area is intended to be used by operators during the break times for protection every time the forklift needs to access to the sorting zone for the container handling. For the setting of the barriers, a specification was drawn up. After validation of the request, the works began. The screening space was also sealed by placing a chain on the gate. Adhesive tape was also placed on the floor so as to delimit the intended spaces for loading the forklifts.

### 3.3 Seiso (*Shine/Sweep*)

One of the aspects that stood out in the eyes of those who visit the screening site is that it is really a dirty space. This is due to the high activity of entry and exit of forklifts and other vehicles. There are nonconforming parts that are being recovered through the deburring process that inevitably releases dust. In addition, the entrance gate for the fork lift trucks was constantly open. Thus, a cleaning strategy was put in place in order to address all these challenges.

### 3.4 Seiketsu (*Standardize*)

In order to maintain all the results achieved through the implementation of the first three S, several standardized sheets and documents were developed that not only contributed to maintaining, but also to improving the management of the site. The screening site was a space without any type of visual management or indication of documents that supported the activity.

Thus, a control panel was developed in order to eliminate the dispersion of information and define what is really relevant to expose and how should be the ideal site. This control panel is made up of the sorting ranges, which is essential for sorting and a dashboard with the local reference state, circulation rules and indicators.

### 3.5 Shitsuke (*Sustain/Self-discipline*)

*Shitsuke* or self-discipline is undoubtedly one of the most critical phases of successful adoption of the 5S. The 5S is relatively simple to implement. What makes it harder to adopt is to keep this principle constant and not to let old habits return. Self-discipline consists of employees doing their part without having to be called to attention [10].

To ensure that good practices remained at the site and that all the results achieved were not only provisional, a tool was used to safeguard self-discipline. This tool aims to verify if the established standards are being respected and identify the sources of non-added value of the workstation in order to improve the overall performance.

Such observations were usually made regularly at the beginning of the 5S implementation with the intent to constantly remind employees that it is important to keep these changes. After the operators nurtured and created the habit of keeping their workspace clean and organized, these evaluations turned to be made weekly.

### 3.6 Safety

As previously stated in Sect. 2, it is possible to relate the implementation of the 5S with the increase of productivity by deducing that this effect comes from the increase of the security. In this study, the focus of the 5S application was not if resulted or not in an increase in productivity since the productivity at the sorting site passes through the quantity of screened parts. However, since 6S is transversal to all other steps of 5S, it was possible to quantify the impact that this tool had on the overall safety at the shop floor.

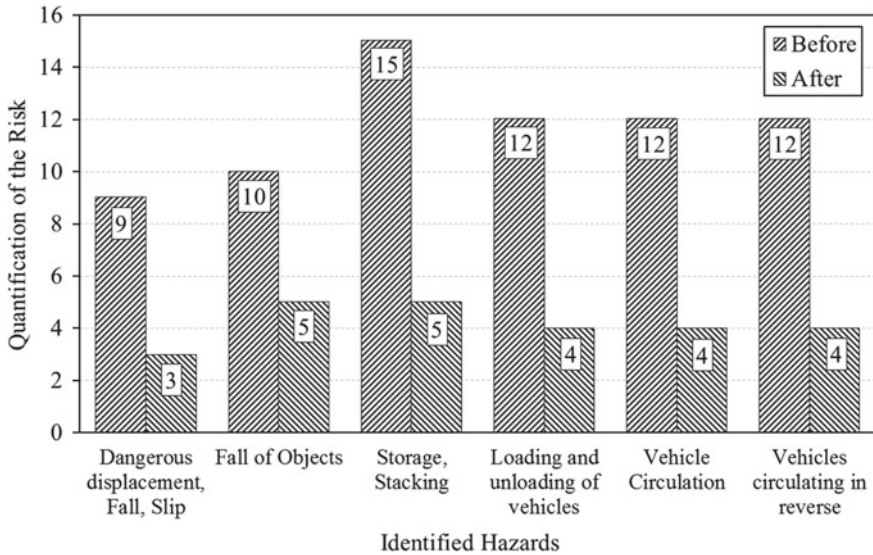


Fig. 3 Risk assessment before and after 5S

## 4 Results

Several actions applied in this project were inspired by the application in [23], among them, the implementation of barriers between forklift and pedestrian, the improvement of warnings and implementation of traffic rules where forklift trucks and pedestrians cross paths. Thus, this action managed to drastically reduce the contact between truck and operator, thus allowing a transition from a scenario in which this contact was excessive to practically nonexistent.

In the initial phase of this project, a risk assessment was performed using a matrix defined by the industrial unit in order to quantify and obtain risk quantification for each hazard. With this risk assessment, it is possible to make a comparison, quantitatively, of the scenario before and after implementation of *the* 5S. Thus, after the implementation of 5S, a new risk assessment was carried out in order to understand whether these actions had any type of impact on the safety of the screening area.

The results show that by applying 5S on the defined location it was possible to reduce the total risk by 64% using the risk assessment, as it can be observed in Fig. 3.

The results also show that the application of 2S (*Seiton* or Set in Order) was the one that brought the most significant impact in terms of safety. The fact that the areas of the screening room have been delimited by the installation of safety barriers has created an area where it became much harder to have any type of contact between man and machine. The evolution of the screening area can be seen in Figs. 4 and 5.



**Fig. 4** Evolution of the screening area before and after the implementation of 5S



**Fig. 5** Evolution of the area before and after the implementation of 5S—Security barriers

## 5 Conclusion

In this paper, a case of study in one of the plants of one of the European largest car producers was tested on how the implementation of lean tools, more specifically 5S, could contribute to the occupational safety conditions. The present work demonstrated another of the foremost advantages that is obtained from the use of 5S. Apart from being a powerful tool for organizing and optimizing the workplace environment this study also demonstrated that it is also essential to ensure occupational safety. The results showed that by applying 5S + 1S, that is, 6S on the defined location it was possible to reduce the total risk by as much as 64% by using the employed risk assessment tool. The results also showed that the application of 2S (*Seiton* or Set in Order) was the “S” that conveyed the most significant impact on the overall safety. Since these areas were demarcated by setting up safety barriers, it has created an area where it was much harder to have any type of contact between employees and forklift trucks. Even though all the actions carried out at the screening site have brought significant results and several safety benefits, there is still much potential for improvement.

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# Improving the Availability of a Production Line Through TPM in an Automotive Gearbox Industrial Unit



Inês M. Ribeiro, Radu Godina and João C. O. Matias

## 1 Introduction

For many years the maintenance function was considered a necessary evil of the productive function. However, the maintenance activities that ensure the efficiency, availability, and reliability of the equipment have become essential for organizations since they have a direct impact with quality, cost, and delivery of the products or service [1]. One of the most used approaches to improve the performance of maintenance activities is the implementation of Total Productive Maintenance (TPM) [2–4]. TPM is a maintenance methodology defined by Nakajima in Japan, which covers the entire life of equipment in every division including planning, manufacturing, and maintenance [5]. TPM has eight pillars that are aimed at proactively supporting this methodology. TPM starts with 5S that are the base of TPM because problems cannot be clearly seen and resolved when the workplace is unorganized [6]. One of the pillars of TPM is the Focused Improvement or, in Japanese, *kobetsu kaizen*, which the objective is to eliminate the greatest losses in order to improve the efficiency of the equipment [7]. Visual Management and 5-why are lean thinking tools that can be used in order to contribute to the success of this pillar [8]. The first one is

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used to simplify and facilitate the maintenance activities by using visual signals and the second one is used to identify the root cause of a problem or waste [9]. To be able to tell if the TPM program is working as intended as well as the effect of any improvement activities an OEE metric is normally utilized [10–13].

## 2 Methods

This work aims to reduce the number of failures in the equipment of a production line and the consequent increase in the availability of such equipment. In a first phase, the most penalizing equipment was identified as soon as their different parts most penalizing. Then, the “5 whys” tool was used to find out the root cause of the high number of failure in a certain location of the equipment. With the use of this tool, it was possible to elaborate a plan of actions that eradicated or diminished the high number of failures. Since the moment that it was discovered the local of the machine that had more failures until the moment that it was created the action plan, it spent a lot of time and effort because although this tool it is easy to understand, filling it was quite complicated. In a second phase and after some observations in the production line, it was identified that the oil cabinet where operators go in their autonomous maintenance activities had almost no labels, no colors or another form of identification. There is another cabinet where there are replacement parts that had no organization: same material in different locals, material without identification and mixed material. In a third phase, it was implemented 5S and visual management to facilitate the work in the maintenance activities. To monitor the evolution and impact of the implementation of the actions, OEE, MTBF and MTTR indicators were used.

## 3 Analysis and Optimization of the Crankcase Production Line

The studied production line was chosen due to the fact that its equipment represents a high percentage of failures. The selected assembly line produces metallic crankcases for automotive assembly industrial units. This particular element surrounds the lower part of the engine by housing the crankshaft and protecting the moving parts from foreign objects. The production line is divided into three areas: pre-machining, machining, and assembly. The equipment which suffers the most failures is located in the machining area. Thus, this study was focused on this specific area.

The machining area comprises a total of 15 machines in which 12 of them have the same technology and the other three are different. A total of six out of the 12 machines are responsible for machining the piece horizontally and the other six for machining the piece vertically. The aforementioned three distinct machines display

**Table 1** Maintenance indicators for the line in study in 2017

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MTBF (h)	153	132	134	157	263	161	108	105	161
MTTR (h)	1.7	3.6	3.4	3.1	3.9	5.2	5.9	3.8	6.1
Maintenance availability (%)	98.9	97.4	97.5	98.0	98.5	96.9	94.8	96.5	96.3
OEE (%)	86.0	79.1	81.9	84.2	73.0	80.4	78.3	78.6	81.6

a modern technology, and due to this reason, they have the capacity to machine the piece both ways, vertically, and horizontally.

### 3.1 Problems Identification

In order to identify the problems, an initial analysis of the state of the production line was made. A few maintenance indicators were analyzed which are represented in Table 1. The line had as objective to obtain an OEE equal or higher than 88%. However, none of the months reached the objective. In addition, a lower than 80% OEE was obtained for the four out of the nine months, which are represented in Table 1 as well.

Regarding the availability, the engineers at the production line had as an objective to obtain values equal or higher than 98%. Only in April, July, and August, this objective was reached. MTTR and MTBF are directly related with maintenance availability so it is fundamental to develop an action plan which would contribute to the reduction of the number of failures and the reduction of the time of the failure resolution.

After this analysis was performed, the equipment that contributed the most to the high number of faults was identified. It was verified that the equipment represented by the code “2100” was stopped for 480 h due to a malfunction between August and December of 2017, representing a percentage of 28.4% of the malfunctions occurred in the machining of this production line. The maintenance intervention registers associated with this equipment were analyzed in order to identify exactly where the failures were located and then to be able to act on them. With that analysis, it was verified that the subsets with more failures were the tool warehouse and the electro-tree. In order to identify the main problems, several observations in the production line were made. Also, the behavior of the operators and maintenance technicians working were also analyzed to with the purpose to identify their difficulties and obstacles. In Table 2 the identified problems can be observed.

**Table 2** Description of each identified problem

Problem	Description
Outdated autonomous maintenance plan (AMP)	AMP with excessive tasks, some of them were not realized, some of tasks were not correct since the equipment was updated yet the workers did not refresh the tasks in the plan
Disorganized oils cabinet	Oils without identification or with incorrect identification; dirty cabinet
Disorganized spare parts cabinet	Mixed components; several different components without identification; material no longer used
Lack of communication between different departments	No daily or weekly meetings existed where each person of maintenance or production could discuss the problems
Operators with few skills	It was found that usually, maintenance technicians did not have time for preventive maintenance because of corrective maintenance and sometimes corrective maintenance could be easily done by operators with some preparation
High numbers of failures in tool warehouse and the electro-tree	These are the two locations where many failures occur for the “2100” equipment

### 3.2 *Improvement Solutions*

Once the problems and improvement opportunities were identified, it was necessary to develop an action plan to reverse the initial condition with the purpose of reducing the number of failures and, consequently, increase the availability. For each problem, a solution is developed and presented in Table 3.

### 3.3 *Results*

After implementing the improvement actions, it is necessary to study the changes that these have brought to the production line. Table 4 shows the implemented solutions and the respective obtained results.

It is fundamental to analyze the performance of maintenance through the indicators MTTR, MTBF, OEE, and availability. These indicators will show if the implemented solutions are contributing to the reduction of the number of disruptions and, consequently, increasing the availability. Table 5 shows the mean values of MTBF, MTTR, and availability for the last quarter of 2017 and for the first quarter of 2018.

It can be observed an increase in MTBF and availability. The average of the first quarter of 2018 for MTBF is 155 h. This means that the line in study had a disruption

**Table 3** Description of each proposal solution

Problem	Improvement proposal
Outdated autonomous maintenance plan (AMP)	Analyze all AMP's tasks and eliminate the tasks that are not important. Also update all the tasks, photographs and materials
Disorganized oils cabinet	Reorganization of the oil and machine parts cabinets with 5S and visual management techniques
Disorganized spare parts cabinet	The use of visual management techniques, 5S and Kanban to improve this cabinet
Lack of communication between different departments	Create a maintenance support dashboard to facilitate the communication between maintenance and production department. The idea is to have weekly meetings with all people involved and then analyze the indicators, failures and all problems that occurred concerning the line
Operators with few skills	Develop a training program to increase operator skills
High numbers of failures in tool warehouse and the electro-tree	Use five why's technique to determine the root causes of the high number of failures

of 155 h in hours, on average. The value increased 31 h. This means that the number of disruptions decreased. Also, the availability increased 1.2% (from 95.9 to 97.1%) from last quarter of 2017 to first quarter of 2018. It is also observed that MTTR decreased from 5.26 to 4.56 h. This result shows that maintenance technicians took less time to solve the disruption. All these positive results are a consequence of the implemented solutions.

Another important indicator is OEE and it had a decrease of 0.4%. In Fig. 1, we can observe the different losses associated with OEE. Each color is associated with a different loss.

The color yellow (identified as AM) represents machine breakdowns, green represents induced stops (for example, lack of electricity), the color cream (identified as FE) represents external faults (for example, when there are not raw materials) and the color gray (MF) represents stops due to a tool change. This graph shows that the equipment disruption, identified in Fig. 1 as AM, had a decrease in the first months of 2018.

Also, these values are lower than the average obtained in the last three months of 2017. On the other hand, in the first quarter of 2018, other losses had increased leading to a decrease in OEE.

**Table 4** Obtained results for each implemented solution

Solution	Results
AMP revision	With the revision of AMP, some tasks were eliminated since they made no sense to be performed by operators and they were incorrect since the equipment has been changed. The time associated with each task was also changed since it was verified through field observations that some of the times were incorrect. With these modifications, it was possible to reduce the annual charge of the AMP by more than 200 h
Reorganization of the oil cabinet and spare parts cabinet	With the use of 5S and visual management techniques, the two cabinets were organized, facilitating the work of the operators and maintenance technicians. These contributed to decrease MTTR since the operators did not need so much time to find a specific part or oil
Create a maintenance support dashboard	With this dashboard, it was possible to schedule weekly meetings and analyze every problem that occurred in this line. Also, employees could discuss and find solutions together with the participation of everybody
Develop a training program to increase operator skills	The objective is that in each training group there is at least one operator of this line. With this, some operators will be able to resolve some disruptions of the line and maintenance technicians will be available for the most serious malfunctions
Use of five why's (5W) technique to decrease the number of disruptions	With the use of this lean tool it was found the root causes for the number of disruptions in the tool warehouse and the electro-tree. A lot of root causes were found, and an action plan was developed for each root cause

**Table 5** MTBF, MTTR, availability, and OEE in the last quarter of 2017 and in the first quarter of 2018

	Average of the last quarter of 2017	Average of the first quarter of 2018
MTBF (h)	124	155
MTTR (h)	5.26	4.56
Maintenance availability (%)	95.9	97.1
OEE	79.5	79.1

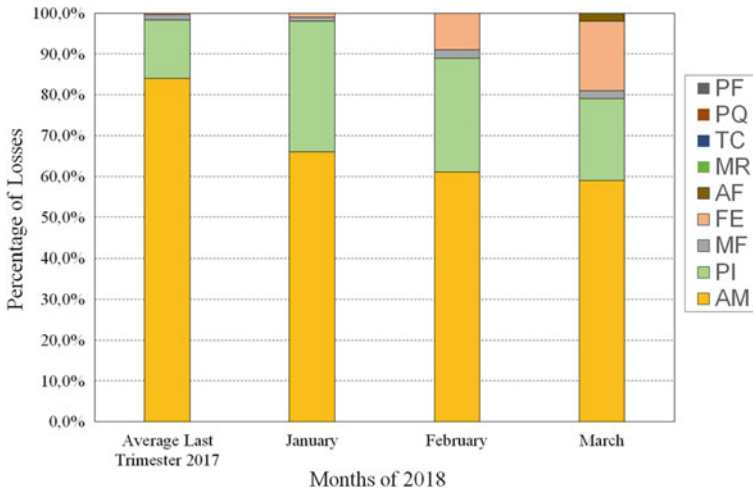


Fig. 1 The evolution of the losses

## 4 Conclusion

This paper focused on the use of the TPM methodology combined with a few lean thinking tools to optimize the availability of a critical production line in a company which produces mechanical components and gearboxes for the automotive industry. To measure the success of the implemented actions and to compare the results with the initial situation, several indicators were used: OEE, MTBF, and MTTR.

One of the main objectives of TPM is the search for the maximization of the overall efficiency of the equipment. To achieve this objective, it is essential for the equipment to have the highest availability possible. As such, it is necessary for the equipment to have none or a few disruptions. And if the equipment has them, the disruptions should be resolved quickly.

After analyzing the initial state of the line, several improvement actions were developed and implemented. The results showed that these actions contributed for a decrease in MTTR, for an increase of MTBF and, consequently, for an increase of availability. Despite this increase, it was not possible to reach 98% in availability in the average of the first three months of 2018, which can be justified by the definition of a goal that is too ambitious for the initial state of this production line. Although the main objective has not been yet achieved, this reason is not the only one responsible for the evaluation of the performance and success of this project. Despite not achieving the initial objective, the implemented solutions had positive results.

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# Environmental, Economic, and Social Impact of Industrial Symbiosis: Methods and Indicators Review



Angela Neves, Radu Godina, Susana G. Azevedo and João C. O. Matias

## 1 Introduction

In the last years, the intensive use of resources and the resulting increase in greenhouse gas emissions have led the world to climate change with serious and irreversible impacts for people and ecosystems [1]. Thus, it is essential to develop solutions that lead to an increase in sustainability with improvements not only in the environmental but also in economic and social dimensions. The industrial symbiosis (IS) whose central idea is that the waste of one company becomes the raw material for another [2], has contributed to this increased sustainability bringing benefits for the companies involved and for communities [3]. The reduction of the natural resource

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consumption, waste disposal, and emissions, economic gains for companies due to cost reduction with landfills and the sale and/or purchase of waste products [4], are some examples of the numerous advantages obtained due to the IS. So, in order to increase synergies between companies and to enlarge incentive policies, which application has a strong impact on the development of IS [5], it is imperative to continue the efforts of the development of the IS and contribute to its wide application. One of the ways to boost this increase is to make the results obtained from the various cases of successful implementation of industrial symbiosis visible. For this, numerous methods and indicators have been developed with the aim of quantifying the environmental, economic, and social impact that the industrial symbiosis has triggered in the companies and surrounding communities.

The main objective of this article is to provide a comprehensive review of previous studies concerning the methods and indicators used to assess the impact of IS in the economic, environmental, and social scopes. The advantages and limitations of each one are also listed.

## **2 Methods and Indicators to Assess the Impact of Industrial Symbiosis**

### ***2.1 Methodology***

With the aim of surveying the most cited methods and indicators used for quantifying the impacts of IS and their advantages and limitations, titles and abstracts of numerous publications were analysed and subsequently selected in accordance with the purpose of this review.

This study has been developed in several stages. The first one was to define the scope of the literature review, followed by the research of articles in several publishers, such as Elsevier, Springer, Emerald, Taylor & Francis, Wiley among others. For this search, combinations of “industrial symbiosis” or “eco-industrial park” and “method” or “quantitative assessment” were used in order to find publications that fit the objective of this literature review. After a careful analysis of the articles, through the reading of the titles, keywords, and abstracts, only those that aimed to quantify the contribution of industrial symbiosis to the achievement of sustainability in its environmental, economic, and social dimensions were selected. From the literature review was possible to understand the growth of the number of articles related to IS and the increase of studies that allow understanding the real impact of this approach.

## ***2.2 A Comprehensive Review on Evaluation Methods and Indicators***

Numerous methods, analyses and indicators have been used to evaluate the industrial symbiosis with respect to sustainability, development, performance, relations between companies, among others. Although several of them have a comprehensive application [6–8], others have been created specifically for industrial symbiosis [9–11]. Input–output analysis [12], ecological network analysis [13], lifecycle assessment [14], environmental impact assessment [15], carbon footprint analysis [7], material flow analysis [16], exergy analysis [17], emergy analysis [6], econometric analysis [18], social network analysis [19], ecological footprint analysis [20], cost-benefit analysis [21], and substance flow analysis [22] are some of the examples of methods and analyses used.

Several of these methods are used to assess the sustainability and many indicators of different dimensions are used to create a solid basis for decision-making. Indicators are numbers or measures that allow the interpretation of information about certain phenomena to be simplified and easier to understand [23, 24]. They also allow the development of an integral approach, essential to decision-making, in which they allow the understanding of the environmental, economic, and social dimensions in an isolated way, but also of the relationships between them.

The methods addressed in this review are those directly related to the assessment of the sustainability of industrial symbiosis, with respect to the environmental, economic, and social dimension and the most widely referenced. The indicators used in the various methods are also set forth, as well as the various advantages and disadvantages.

### **Life Cycle Assessment**

Life cycle assessment (LCA) is a tool that “addresses the environmental aspects and potential environmental impacts throughout a product’s life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e., cradle-to-grave) [25]. With the increase of greenhouse gas emissions and global warming, sustainability has become an issue that has attracted more and more interest and since the LCA is a tool that evaluates the environmental impact, it is understandable the increase of the use of this tool in the most diverse areas and the exponential growth of the number of studies published since its appearance in the 1960s [26]. Industrial symbiosis is no exception and several environmental impact studies have emerged using the LCA, even if industrial symbiosis entails some limitations in the application of this tool, such as the definition of the functional unit since the waste of one company is considered a by-product in another and the difficulty in obtaining data on the consumption and emissions of each one of the enterprises [21].

This method has contributed to highlight the role of industrial symbiosis in the improvement of sustainability, materialized by the reduction of polluting emissions, by the substitution and reduction of the consumption of resources and by the reduction of waste [27–31], being able to be applied in the decision-making and to influence

companies and political decision-makers to opt for industrial symbiosis as a way to reduce environmental impacts [8, 14].

The LCA methodology is defined in two International Standards: ISO 14040 [25] and ISO 14044 [32] and its study, according to these, is developed in four phases: goal and scope definition, inventory analysis, impact assessment, and interpretation. With this analysis, it is possible to evaluate the impact categories that should be appropriate with the goal of the study. Primary energy consumption [27, 31, 33], greenhouse gas (GHG) emission [27, 31, 33], acidification potential [27, 30, 31, 33–35], eutrophication potential [27, 30, 31, 33–35], global warming potential (GWP) [34, 35], Human toxicity air (HTA) [30, 35], total environmental impact potential (TEIP) [35], and climate change [30] are some of the impact categories used to assess industrial symbiosis. However, the assessment of greenhouse gases is clearly the most widely used, and there are articles in the literature that only contemplate the evaluation of this impact category [28, 29, 36].

### **Material Flow Analysis**

Similar to the previous method, the Material flow analysis (MFA) is recognized as a decision support tool, and also allows quantifying the effects of industrial symbiosis [37]. It is used in waste and environment management and through a simple material balance of inputs, outputs, wastes, and stocks, it allows to know, in an expeditious way, what wastes exist and their origins [38].

The beginning of this method goes back more than 2000 years and was postulated by Greek philosophers [38], and since then, has been widely used, individually or in conjunction with other methods that increase the scope of the analysis [7, 16, 39–41].

Even though the MFA is a simpler method that considers flows of materials and waste, sometimes its application in an industrial environment is more limited. So, in addition to combining this method with others, it is also possible to associate it with indicators that allow evaluating the evolution of the process and detecting possible weaknesses. For the MFA analysis to be complete, these indicators reflect inputs and outputs. However, outputs are more difficult to account for than indicators for input flows because input depends on materials and outputs are accounted as environmental waste and complete information in terms of mass balance is rarely available [42].

An example was the study made by Sendra et al. [39] in which two input indicators related to materials were used: direct material input and total material requirement. On the basis of these, environmental indicators were also developed to assess the amount of wastes, efficiency water, and energy.

One of the examples of the use of MFA with another methods, is the study conducted by Ohnishi et al. [7] with the aim of quantifying the effects of industrial and urban symbiosis in Kawasaki Eco-town, in which the MFA served to identify the material and inventory flows of a system and later a more intensive analysis was done using the carbon footprint and energy method.

### **Emergy Method**

Emergy is “the available energy of one kind (usually solar emergy joules) used up directly and indirectly to generate a service or product” [43]. This analysis, in addition to considering the economic dimension and the resources, also takes into account the

contribution of the local ecosystem. Thus, parameters that are usually not considered in other methods, in this analysis parameters as the sunlight, wind, rain, indirect support incorporated in human productive activities are taken into account [44].

Since this method was proposed in the 1980s [43], many studies have been carried out with the aim of evaluating the economic and environmental component of a process. In industrial symbiosis, this method was used to evaluate each symbiotic flow, quantifying the respective energy and mass which are subsequently converted to the same unit, as previously mentioned [6, 41, 44–54]. For this purpose, some sustainability indicators can also be established in order to evaluate various energy and environmental performances. Examples of these indicators are: energy yield ratio that expresses the production capability of the system, energy loading ratio that reflects the pressure of the economic activity on local eco-environment, energy sustainability index that measures the contribution of a resource or process to the system per unit of environmental loading, energy-to-money ratio that indicates the energy consumed to generate per unit money and money saving due to implementing industrial symbiosis in the industrial park [49–51].

### **Integration of Different Methods**

Some of the methods used to evaluate the sustainability of industrial symbiosis have some limitations, so in order to overcome those, several methods can be conjugated in order to promote the best of each method and to obtain a more reliable result.

Some examples are related to the Material flow analysis because, as previously mentioned, represents a simpler method of assessing inputs and outputs of materials and wastes, and it is often necessary to include indicators or complements with other methods to make the analysis more complete. This method often appears associated with energy method. The energy method adds to the joint analysis the assessment of the contribution of natural ecosystems and has the particularity of transforming several elements that enter into the analysis that are of different nature, such as materials, energy, services, in the same unit to evaluate sustainability [7, 40].

Emergy analysis also appears often associated with lifecycle assessment [55–58]. These methods turn out to be complementary, because LCA, as seen above, aims to quantify impact categories, such as greenhouse gas emissions, acidification potential, primary energy consumption, etc. However, this analysis, in general, does not contemplate flows that are not associated in some way to the transport of matter and energy. And, if the objective is to assess sustainability, in some cases these values may be significant. The emergy analysis does not consider the pollutant emissions, but allows counting all the resources in the same value base and allows ease of comparability with the generated product and with more knowledge, it becomes possible to decide for a more sustainable option.

**Table 1** Comparison between different methods: advantages and disadvantages

Method	Advantages	Disadvantages
LCA	<ul style="list-style-type: none"> <li>• as a bottom-up method, can provide more specific information to decision-makers [57]</li> <li>• a feasible tool for the quantification of environmental performance of IS networks in order to capture all elements of the environmental performance [14, 59]</li> </ul>	<ul style="list-style-type: none"> <li>• consumes more time and labor, due to the requirement of a large amount of detailed data [57]</li> <li>• the impact factors of LCA reflect the national average and not the characteristic factors of specific enterprises [31]</li> <li>• uncertainty of an alternative system and the difficulty of making assumptions for by-products [31]</li> </ul>
MFA	<ul style="list-style-type: none"> <li>• enables planning and decision-making [37]</li> </ul>	<ul style="list-style-type: none"> <li>• MFA alone is not a sufficient tool to assess or support engineering or management measures [38]</li> </ul>
Energy	<ul style="list-style-type: none"> <li>• transform different kinds of inputs (materials, energy, services) in the same unit to evaluate sustainability [7]</li> <li>• considers the contributions of the natural ecosystem so that the IS is analyzed as a whole [7]</li> </ul>	<ul style="list-style-type: none"> <li>• gives insufficient consideration to the impacts of pollutant emission, especially for industrial systems [56]</li> </ul>

### 2.3 Advantages and Disadvantages of Different Methods

The methods outlined above have inherent advantages and disadvantages in the way they determine the dimensions of sustainability. Table 1 summarizes the main advantages and disadvantages.

## 3 Conclusion

The number of articles concerning the methods and indicators aiming to assess the impact of IS has been increasing in the last few years. Although in many research articles the environmental, economic and social advantages of the application of IS are mentioned, most of the articles address methods and indicators that allow the quantification of the environmental effects, followed by economic impacts. All the studies provided by the application of these methods and indicators add an important contribution to the overall understanding of the importance of IS and highlights the many advantages for organizations and communities. With the intention of stimulating IS it is necessary to disseminate the results obtained by the various methods and create platforms that could enable the involvement of organizations in creating new partnerships. It could also lead to the intervention of government in order to create new incentive policies and stimulate the communities to value IS and also demand the

companies to adopt new sustainable practices which could lead to several advantages for all the stakeholders.

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# Continuous Improvement in an Industrial Unit of the Wood Industry Through Kanban



Flávia C. S. Guia, Radu Godina and João C. O. Matias

## 1 Introduction

Faced against several factors that have disputed the change, such as globalization, technological advancement, increasing customer interest and the respective demand, the growing awareness of society on ethical issues has led companies to adopt strategies on continuous improvement processes, which are ensuring that processes become more adjusted and the waste can be reduced [1].

All the practices around continuous improvement will only have value if they are long-term organizational tactics, meaning that continuous improvement becomes a new way of managing a strategic factor. Therefore, it is important to have a culture defined by the attitudes and habits of their leaders. Ohno found that only a very strong leadership management can take the organization on another and better path [2–4].

The largest difficulty is the internalization of this culture. The problem crosses the fact that many teams are not willing to accept lean principles [5, 6]. According to [7] the daily improvement is an approach to carry out the metrics, but also a way to accelerate the implementation of continuous improvement throughout the organization.

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Although these techniques are currently well known and there are many documents and reports on the subject, it must have a strong adaptation on the shop floor to really work, since tools implemented directly from the literature are not a guarantee of success [8]. Companies must adapt tools to their needs and must include the whole organization in the improvement process.

The use of *Kanban* systems, such as visual stock management methodologies, capable of controlling the strategic production quantities in all the processes, enables organizations to maximize the stock capacity, minimizing the average production time and, with that, obtain significant saves on inventory costs [9–11].

The *Kanban* system has its origins in the Japanese industry as a simple solution developed to control the logistics chain from the point of view of the production through visual management. The best-known system was the one created by the Toyota Motor company in the early 1950s. The basic idea of this pull planning system is to use these cards to authorize the upstream delivery or production of a new lot to replenish the downstream stock [12–14]. The *Kanban* premise, according to [9] “the material will not be produced or moved until a customer sends the signal”.

Many are the practical studies developed on the different applications of the *Kanban* system, which show that it is simple to use and with many positive impacts. Authors in [15] describe an electronic *Kanban* system, in which they emphasize output, improve performance, productivity, and quality at work. On the other hand, this tool needs a very strong culture to be adapted.

In [16] is proposed a new empirical method to minimize problems of large quantities in processing, a lot of time spent in non-added activities, delays in deliveries and nonconformities. It allowed the authors to conclude that both the setup time and the takt time ratio may have negative or positive impacts. He also noted that in many cases reducing the *Kanban* capacity means increasing the amount under processing.

Many writers emphasize that company culture, employee attitude, and interest in improving operations are essential to a success system. In [9] is stated that senior management commitment, supplier participation, inventory management, and quality improvement are the keys for an implementation of this stock control system.

From the point of view of the production system, it is possible to find different contributions by the *Kanban* system. However, it is all based on the principle that it helps to improve the productivity of the company while minimizing the waste of production [17].

The objective of this project arises with the recent startup of a manufacturing plant producing samples derived from wood. The company lived a period of pressure, due to the need to satisfy the customer and, simultaneously, organize and manage the overloaded stock spaces. The unit currently has the largest gap to fill in failures during startup. The present study intends to demonstrate, in a working context, how two continuous improvement tools can, in an integrated way, contribute to the optimization of a recent unit in the wood industry.

The remainder of this paper is organized as follows. In Sect. 2, the methodology used in this research study is presented. In Sect. 3, the description of the plant is made. In Sect. 4, it is discussed the implementation of the basic principles of the Improving Our Work (IOW) indicator and the *Kanban* system. Finally, in Sect. 5, an

analysis of the results is obtained. The article is concluded in Sect. 6 with general conclusions and recommendations.

## 2 Methodology

The methodology, according to [18], is a strategy, plan of action or project behind the choice and use of specific methods and paradigms, linking the selection and use of methods to the results.

The qualitative research is based on descriptive techniques of data collection and detailed analysis. In this type of investigation, the physical context is privileged as a direct source of the data, and the researcher is the main collection element and it is both as an observer and a researcher [19]. Action research consists of a set of methodologies that simultaneously include action and research. This qualitative research basically seeks to analyze a specific reality and stimulate the decision-making of the agents [20].

The research methodology used in this study initially involves the definition and characterization of the problem, through a structured workshop. The second step focuses on a bibliographical research based on several scientific articles, resulting from the contribution of the research of several authors. The third and final stage involves the practical implementation of the methodologies under study, namely the implementation of lean tools for the creation of a culture of continuous improvement and the implementation of a *Kanban* system in order to ensure efficient stock management.

Given the defined objectives, a qualitative research methodology was used, namely, action research, with the aim of studying, through appropriate tools, the impact of two methodologies, such as the *Kanban* system and the daily used tools of continuous improvement.

## 3 The Industrial Unit

The case study comprises a company located in a small industrial complex, which comprises a sample center that has five employees who work daily to satisfy customers dispersed by 33 countries around the world.

The factory is characterized by producing different types of products: standard type samples, customized and prototypes. The standard ones are being made for the inventory. Therefore, they are not produced according to the customer's request. Hence the name Standard, since its characteristics and features are common for all the customers. On the other hand, Prototypes and Customized are being made by order, when there is a customer request, since they have a lower frequency and are made for different specific cases.

The objective of this project was born with the recent startup of a manufacturing plant producing samples derived from wood. The company lived a period of pressure, due to the need to satisfy the customer and simultaneously organize and manage the overloaded stock spaces. The unit currently has the largest gap to fill in failures during startup.

The selected warehouse was one of Melamine, which are products with greater strategic value in the organization.

## 4 Kanban System and Continuous Improvement

As mentioned previously, in view of the recent start of the unit, there were many opportunities for improvement and it was important to define priorities for actions given the time allocated to the project. In order to accomplish this, a structured problem-solving workshop was implemented, using Ishikawa's diagram and 5 whys, ending with an action plan.

Brainstorming principles were used in order to elaborate the Ishikawa diagram, which allowed identifying the causes that affect the delivery of orders within the established time, emphasizing:

- Stock routing;
- High approval time;
- Lack of organization in teamwork;
- Very long production processes.

The workshop triggered actions focused on solving the identified problems in a systematic, structured and creative way, as it can be observed in Table 1.

The manufacturing unit in question was in a very embryonic state with about 4% at the maturity of the IOW. The reasons that drove this value are briefly described as follows:

**Table 1** Countermeasures resulting from the structured problem-solving workshop

Countermeasures (Actions to validate/eliminate/reduce root causes)
Daily IOW implementation
Board time creation
Production register
Define KPI's and goals
Meetings with a focus on problem-solving
Definition of an implementation plan for 5S methodologies
Implementation of <i>Kanban</i> system
Creation of a space to report stock breach
Visual management in warehouse

- The team's activities were not focused on fulfilling the mission, just as their expectations in terms of performance were not defined;
- Lack of regular meetings without support for a visual picture and without a standardized agenda;
- The indicators were not defined;
- There was an absence of registry of production, so there were no defined goals or any types of trend analysis;
- The team did not use the appropriate tools to solve problems. They implemented corrective actions and not preventive actions;
- There was no proactive system aimed to identify situations of potential risk;
- There was no standardization process;
- The workplace did not follow the principles of visual management and organization.

As a result of the action plan, some steps have been taken to implement the basic principles of daily IOW. With regard to the definition of the mission, the team is expected to be able to clearly identify its clients and their expectations in terms of performance and that their activities focus on the fulfillment of the mission. In order to guarantee the principle of sharing and discussion of information, we resorted to the creation of a visual framework adapted to the needs of the team, in order to be used as a support in the meetings and to allow the alignment with the daily activities. The meeting was structured according to the needs, and as a goal to establish a communication bridge between the members of the team. As mentioned, the team had no indicators associated with its performance, so they were defined to reflect the purpose, problems, and concerns of the team. It is expected that the way of solving problems solved causes has no recurrences and the implemented actions lead to normalization, thus reducing the variability of the process. As the authors in [21, 22] affirm, if the organization's goal is set to have an impact on the workplace and productivity, the 5S methodology should be understood as a method to improve efficiency, performance, and quality. To this end, a 5S implementation plan was developed for the first four S of the methodology, those being "Sort", "Set In order", "Shine", and "Standardize" [23].

The impact of the improvements obtained can be analyzed in Fig. 1, in which the blue points indicate the level of this for each topic of the self-assessment tool, and the orange line the long-term goal (level = 4).

As expected with the implementation of the basic principles of the daily IOW, the team demonstrates:

- Involvement of all members in frequent continuous improvement activities;
- There are countermeasures to act on deviations from the indicators.

Faced with the lack of organization resulting from a hard start, the organizer prepared the space inefficiently and intuitively. Initially the products were organized according to the demand, however, after a period of time, it was verified that the products under study presented high variability of the demand which resulted

in significant wastes, such as the following: transport, overproduction and people movement.

Another problem that the unit felt in the case of the stock management was the impossibility to predict stock stoppages.

With a focus on addressing these challenges that affect both the organization of the shelves and the stock management of the warehouse, the team used the implementation of a *Kanban* system, to ensure the reduction of waste, forecast the stock break, organize the warehouse and facilitate the planning process.

With the implementation of the *Kanban* system, the space is more homogeneous, organized, and visual, and effectively facilitates not only the daily work of employees but also the whole process inherent in production: the planning. Table 2 summarizes the scenario before and after the implementation.

All the actions implemented began simultaneously. However, the actions related to the creation of a culture of continuous improvement only had a positive impact when the employees were involved in the implementation of the *Kanban* system.



**Fig. 1** Level of maturity in each tool

**Table 2** Representation of before and after the implementation of the *Kanban* system

Before	After
Product inquiry on shelves, different from product type	Product inquiry on the four shelves without restrictions
Organization according to demand	Organization in numerical order
3 types of waste: transport, rework, movements of people	Reduced average packaging time (120 s per operator to 70) Reduced rework
Transmission of stock information through the word	Transmission through the <i>Kanban</i> box
There was no visual and practical way of predicting stock	<i>Kanban</i> card with all useful information for the warehouse and planning
There was no identification	Identification labels
–	<i>Kanban</i> board

## 5 Results

The implementation of a *Kanban* system initially aimed at reducing stock turnover and making the warehouse more visual, which led the company and its employees to try to improve the company’s remaining processes.

Daily meetings were with a focus on indicators and problem-solving as a team, with routines to identify the safety and waste problems. With the implementation of the *Kanban* system, the team realized how important is to have an organized work space and with visual management. The team started with the implementation of 5S methodologies in all parts of the factory beyond the warehouse.

The structured problem-solving workshop was carried out with the purpose of defining priorities to optimize the manufacturing unit, allowing the team to define their problems and their resolution needs and the indicator selected to validate the effectiveness of this was the number of standard orders with lead more than 3 days. By correctly implementing *Kanban*, it was possible to visually observe a palpable improvement in the percentage of orders known as *Standard* with a lead time higher than 3 days, as it can be observed in Fig. 2. The implementation of the *Kanban* system occurred during the Month 2 and the immediate impact can be verified in Month 3 and onwards. By analyzing Fig. 2, it can be highlighted that this indicator was improved in as much as experiencing a 45% steep drop. The subsequent oscillation of the following months signifies that there is still a lot of work yet to be done.

The application of the defined methodologies and tools were carried out based on the involvement of all collaborators. Effectively, it was verified that through simple

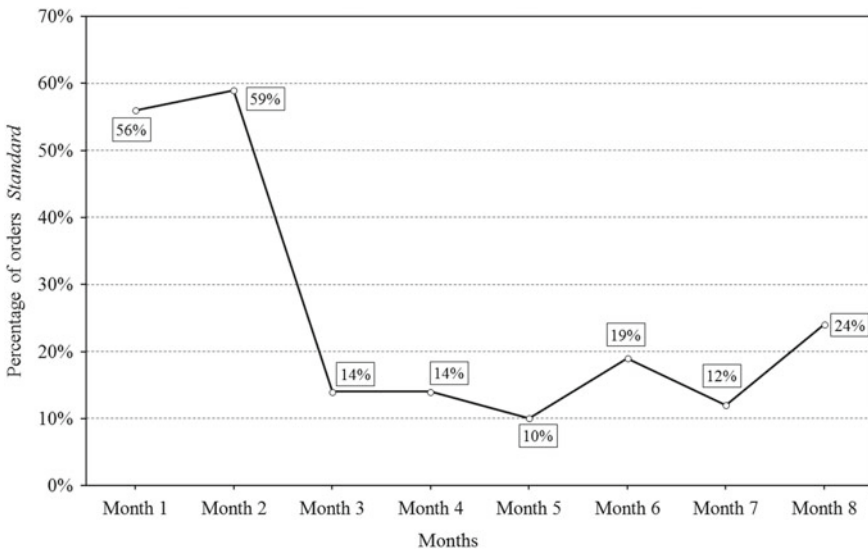
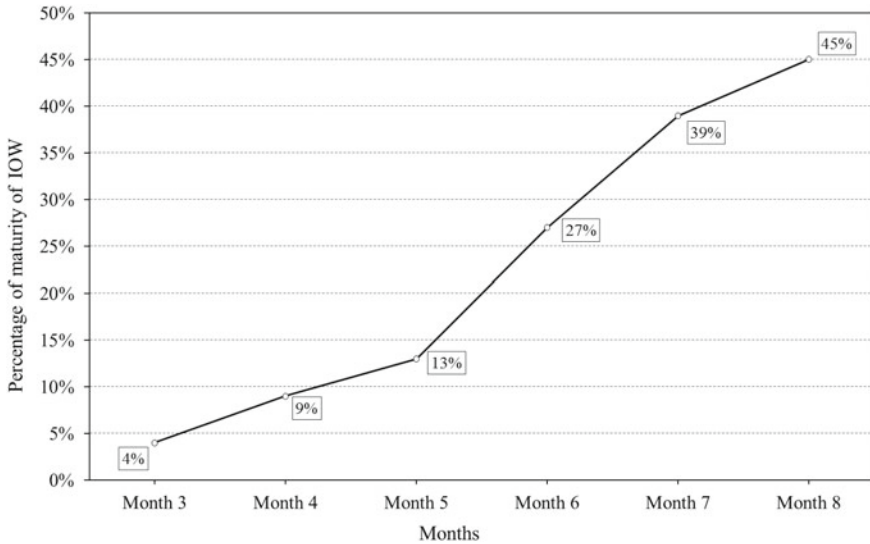


Fig. 2 Percentage of orders known as *Standard* with a lead time higher than 3 days



**Fig. 3** The IOW indicator presented as the percentage of maturity

methodologies of continuous improvement, as team framework, meetings, causes analysis, indicators definition, mission, that the indicator of the IOW maturity of the team can considerably evolve. In the Fig. 3 it is possible to verify the evolution of the maturity of the IOW during the months destined to the project. It can be observed in this figure that the implementation of the *Kanban* had also a significant impact on the IOW maturity of the team. This indicator increased from a meagre 4% to an acceptable 45%. Yet, as indicated in the previous indicator, there is still a rough road ahead.

As mentioned previously, the impact of this visual management was quite substantial, from all the means of identification that originated in the implementation of the *Kanban* system, visual management is facilitating medium for the daily work of employees. The used *Kanban* cards as well as the framework for production planning were very useful in the organization of the team. The idea of clarity and objectivity of information was one of the principles used and reflected in the positive impact.

## 6 Conclusion

In this study, a case of a Portuguese factory in the wood industry was analyzed where the *Kanban* tool and other lean methodologies were implemented. The initial goal of using the *Kanban* system was just to optimize the stock management. However, while the team was changing the warehouse to make it more visual and organized, the process was motivating the use of other Lean tools. This case shows that creating



a culture of continuous improvement should be a gradual process and it is a need for a team to see to believe that it is possible, the rest comes by increment. By properly implementing *Kanban* it was possible to visually observe a tangible improvement in the percentage of orders known as Standard with a lead time higher than 3 days. Several others indicators were also improved, such as the IOW maturity, and with the implementation of the *Kanban* system, the team realized how important it is to have an organized work space and with visual management.

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# Quality Control in the Context of Industry 4.0



Radu Godina and João C. O. Matias

## 1 Introduction

Industry 4.0 is an industry concept that recently appeared that encompasses the main technological innovations in the fields of automation, control, and information technology applied to manufacturing processes. It includes concepts beginning from Cyber-Physical Systems, Internet of Things (IoT) and Internet Services, production processes tend to become increasingly efficient, autonomous, and customizable [1].

This means a new period in the context of the great industrial revolutions, naming this the fourth revolution. With smart factories, a number of changes will take place in the way the products will be manufactured, impacting several market sectors [2].

The quality control could highly benefit from this paradigm shift on account of the gradually significant spread of sensor technology on shop floors, where the quality engineers will be able to gather as much measurement data as possible, opening the possibility to detect defects that otherwise would be undetected. This paradigm shift could also open the doors to the possibility to record 100% of measured data, therefore, signifying that the recorded data for the quality control no longer will need certain statistical tools since a 100% control could be a reality. This change is rather fundamental since every single defective piece could be identified and thus segregated [3].

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Sensors could be integrated into machines since measuring capabilities could be added to every machine tool. However, many challenges arise from this possibility, such as significant costs due to the sensor integration and interferences from the manufacturing process such as humidity, dust, and temperature. The machine tool must then be capable to obtain much more data with the assistance of WSNs in very short periods of time. This means that the current sensors must be substituted by WSNs, since a connected infrastructure is a vital requirement to utilize the possibilities of instantaneous measurements with the highest efficiency [4].

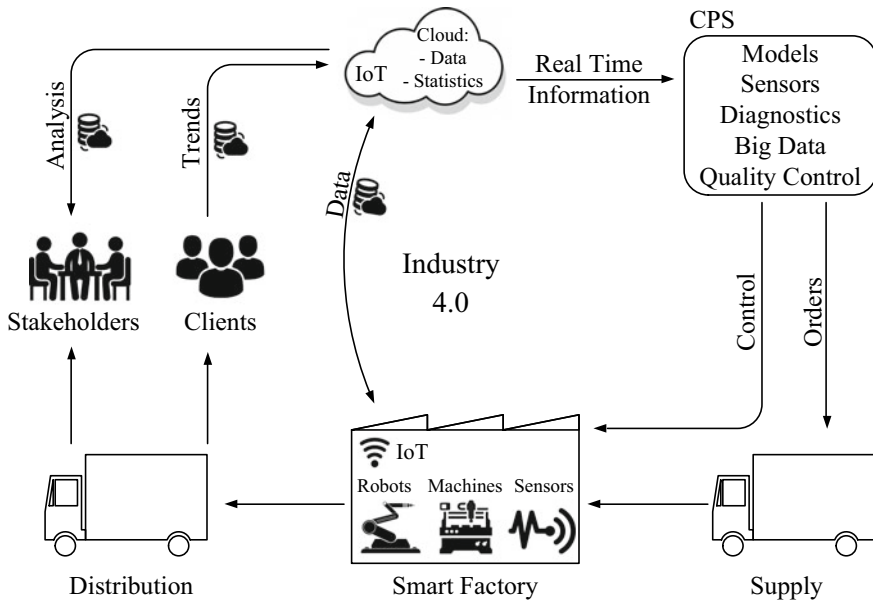
Engineers and decision-makers will require a clear and interactive evaluation of the data. The fusion of data must be possible in order for this to function and it should be obtained from distinct sensors thus leading to a combined result from different measurements. With the purpose of coping with the intricate networks of a certain process, data mining algorithms such adaptive neuro-fuzzy inference system or neural networks could be used to achieve the combined result from different measurements [5].

## 2 Industry 4.0

The term Industry 4.0 originated from a project of the German government that aimed to stimulate new technological strategies [6]. The drastic paradigm shift currently occurring in industrial activity requires strong assimilation of digital communication systems with the industrial process. This means a new period in the context of an industrial revolution. With intelligent factories, a number of changes will take place in the way the products will be manufactured which has the potential to impact several markets. Thus, with this blend, the aim is to reinvent services, products, and methods of production. It can be perceived as a technological revolution defined by the merger of a physical domain—the industrial units and the virtual domain—digital communication systems. This integration could lead to a universal integration of information, products, processes, machines, sites, and people [7, 8].

The concept of Industry 4.0 foments the connectivity between physical objects such as machines and devices, sensors, and company's assets, and to the cloud [6]. This allows the stakeholders to access any required information in real time. The rapid evolution witnessed in image and pattern recognition and sensor technologies allow for innovative forms of solutions [9]. As can be observed in Fig. 1, adapted from [10], a wide range of technologies and elements that are integral to Industry 4.0 are represented. Some of these elements are the cyber-physical systems (CPS), Internet of Things (IoT), Smart Factory and Big Data.

The crucial aim of the Industry 4.0 concept is to further fulfill the customer requirements, thus affecting the most distinct areas of manufacturing, beginning with the research and development (R&D), management, commissioning, logistics up to the use of products and recycling [11]. It is worth mentioning that an important advantage of Industry 4.0 in detriment of Computer Integrated Manufacturing (CIM)



**Fig. 1** A figure illustrating the main elements of Industry 4.0

is the regard for the human role in the entire production process since, in the case of CIM, the employees influence in manufacturing is limited [12].

### 2.1 The Cyber-Physical Systems (CPS)

The cyber-physical systems (CPS) are a concept of the merger between the physical and digital worlds with the analytic instruments, aiming to improve the industry’s efficiency [10]. The CPS’s broad adoption is closely related to Industry 4.0. Strategic technological concepts part of the CPS comprise trends such as cloud computing, Internet of Things (IoT), smart technologies and Big Data. The CPS is the foundation of the several new technological areas: smart medicine, smart manufacturing, smart city, smart buildings, smart electric vehicles, mobile systems, wearable devices, novel defense systems, among others [13].

### 2.2 Smart Factory

It is somewhat hard to pinpoint the exact definition of the smart factory. According to [14] a *Smart Factory* is defined as a manufacturing solution that conveys an adaptive

and flexible manufacture process which has the potential to overcome arising challenges within a fast-changing reality with growing complexity. Such type of a unique solution may well be related to an increasing automation, perceived as a merger of hardware, software, and/or mechanics, leading to optimization at the industrial unit. This solution could cause a decrease in needless labor and a reduction of waste. In contrast, it may well be perceived in a viewpoint of a partnership among distinct industrial and nonindustrial partners, in which the “*Smart*” element contributes to establishing a dynamic organization [14].

### 2.3 *Big Data*

In the last decade, massive volumes of data are generated daily at unparalleled levels and with distinct origins. Thus, it is necessary to process, read and efficiently manage enormous data sets [15]. Big Data is a term that defines the vast quantity of data that is generated and processed by systems with a strong processing capacity. The distributed applications support these types of multiple connection systems [16]. What distinguishes such types of data is the lack of capability to analyze it by employing common database, processing, and management tools [17]. The implementation of Big Data could affect several fields of application such as entertainment, financial, healthcare, communication, security, agriculture, and, naturally, manufacturing [18]. The concept of Big Data generates opportunities for the industry to generate products with a higher added-value [19]. The idea is to obtain added value from the variety and quantity of data by being capable to analyze and process it in real time.

### 2.4 *Internet of Things*

IoT has many definitions, one of them is given in [20] in which is proposed to merge entirely user-centered and technical definitions by describing IoT as a network of networks. This network could, through wireless mobile devices and unified/standardized electronic identification systems, identify unequivocally physical objects and digital entities. This will allow the user to be capable of recovering, storing, transferring and processing, and always keeping the connection between the virtual and physical worlds [21]. However, if defined by a more practical perspective, the IoT entails the standardized and direct digital identification of a physical object (for instance, with SMTP protocols, IP address, http, among others) through the use of a wireless network [22].

### 3 The Importance of Quality Control

The formal definition of quality defined by ISO 9001 is: “Degree in which a set of inherent characteristics satisfies the requirements” [23]. In other words, ensuring the quality of a product or service is to ensure that its values are satisfactorily met by the final customer. To ensure the overall quality—processes, products, machinery, equipment, and systems must meet the statutory and contractual quality requirements. A quality management system includes all the activities of the global management that determine the quality policy, objectives, and responsibilities, as well as their implementation. As ISO 9000 explains, a management system provides the means to establish a policy and objectives and the means to achieve them [24].

Quality, independent of the branch in which it operates, should not be viewed by organizations as a mere monitoring tool, but rather as a mechanism to anticipate problems, preventing them from occurring, and, ultimately, if they occur, solving them. Faced with an ever-changing reality full of new developments, new products, brands and competitors, the tools provided by a robust quality control system reinforce the structure of the key strategies for maintaining and strengthening the link with the final customer. Consequently, among the several advantages of quality control, there is an increase in sales and competitiveness, image consolidation, customer loyalty, among others. Overall, a well-implemented quality management system improves the organization, providing a competitive advantage [25].

The production systems are becoming increasingly flexible due to a higher customer heterogeneity, an overall more demanding customer, fiercer competition, and faster-evolving technology [26]. The tendency of the production is to be made in small batches, the quantity of pieces per batch is reduced, the variety is high, the product size is unequal, the tool change and setup is constant [27], the level of precision is distinct. Therefore, it becomes challenging to utilize classical tools such as the statistical process control (SPC) in order to create control charts with the aim of overseeing the overall production process [28]. Thus, many challenges arise regarding the quality control under the uncertainty of and the rapid evolution of the industrial sector and Industry 4.0 could be a potential solution.

### 4 The Link Between Quality Control and Industry 4.0

Industry 4.0 covers a wide range of technologies that allow the progress of the value chain and through this concept will be possible to diminish manufacturing lead times and to improve the quality of the overall organizational performance and the final product [29]. The combined structures of data could enable the capacity to locate any specific product and/or equipment or any associated information [30]. The estimated value of the combined structures of data for the industrial sector is, as stated by Gifford et al. [31], to convey operating efficiency through a tighter control, in real time, of the equipment, energy, quality, and reliability.

The main purpose is the possible profits of a given organization by reducing the total costs of the produced piece [32]. In order to achieve such a goal, and to comply with ever-growing demands of the client, it is necessary to increase the flexibility of the production systems [33]. The consequence of such a production model is the production in small batch sizes in shorter periods of time and with an increased complexity. Decentralizing the structures of the production is an additional aim of employing Industry 4.0 and is a way to reduce the complexity [29]. Since a high level of productivity has to be achieved to stay competitive and in order to provide more and more customized products, which is a competitive advantage, Industry 4.0 centers on the improvement of the competitiveness through cost reduction and flexibility increase in a decentralized production system [32]. However, quality suffers when customized products are manufactured in small batch sizes since it is increasingly challenging to utilize common methods to control quality [34] and to inspect the production process when the production is made in small batches [28]. This means that it is more likely to obtain flawed assessments and give false alarms due to a lack of sample data and erroneous measurements. This is why it is particularly important to integrate and apply the tools of Industry 4.0 to the quality control in order to decidedly increase the precision of the measurements.

With the aim of researching this impact as well as the utilized methods, a comprehensive analysis of the effect of Industry 4.0 on quality control is imperative. The integration of WSNs and IoT is a substantial challenge and it should be implemented to guide engineers to make the correct decisions. As a consequence, by utilizing machine learning and smart sensors, irregularities could be automatically accommodated by the process in order to guarantee the best possible quality of the final product [35]. As it can be assessed from Fig. 1, the quality control could play an important role in Industry 4.0 and several advantages can be gained from this paradigm shift on account of the increasingly significant dissemination of sensor technologies on shop floors, where the quality engineers will be allowed to harvest as much measurement data as possible, thus opening the possibility to detect defects that otherwise would be dispatched undetected. This paradigm shift could also open the doors to the possibility to document 100% of the measured data. As a result, this means that the recorded data for the quality control no longer will need certain statistical tools since a 100% quality control in real time could be a reality. This change is rather fundamental since every single defective piece could be instantly identified and thus segregated [3].

However, improving the precision of the piece measurements in order to boost the quality of the finished product might not be the only contribution of Industry 4.0 to the overall quality. The tools of Industry 4.0 could contribute to increase the quality in other stages of the entire process of production, such as the quality of information required for optimization, planning, and operation, the quality of forecasting, simulations and prototyping and could even contribute to a better worker participation and engagement.



### ***4.1 The Quality of Information***

The strength of the connection of the digital, the service, and the physical domains will ultimately define the quality of information necessary for planning, operation, and optimization of the process [36]. The reason is that when data is transmitted in real-time the transparency and the quality of the information increases [35]. By acquiring and processing, the information of the product [37] with high quality and precision will allow automatic monitoring and awareness which will result in a growth in efficiency of all the elements of Industry 4.0 concept [38]. The production process and the quality management system will gather and utilize such types of novel information/data for a finer and more precise decision-making and processes evaluation. Such strength will improve the modern quality management, since it not only tries to prevent the production and delivery of defected products but also tries to guarantee the highest possible performance with the best possible efficiency for every process of an enterprise [3].

### ***4.2 Improving the Quality of the Forecast***

A few of Industry 4.0 tools could support the improvement of the production leveling (*heijunka*). For example, the quality of the forecast could be improved by data analytics. The planning becomes easier if data history is utilized at the same time as the data related to a superior understanding of the customer's requirements by making a detailed market analysis [29]. Here, Big Data can be utilized for a thorough analysis of data recorded beforehand and utilized to detect problems which might occur in distinct production processes and could also be used to forecast the occurrence of future problems. Big Data could also be used to find several solutions that could prevent the aforementioned problems of occurring once more [39].

### ***4.3 Simulations and Prototyping***

Simulations and prototyping could allow the use of real-time data to emulate the physical production process in a computer-generated model. The model could comprise products, machines, and operators. This will allow testing and optimizing the machine characteristics, in the simulation, for the succeeding product previous to any real-life fabrication, therefore, reducing setup times and increasing the overall quality [29]. By employing simulations of a production process will not only help diminish the downtimes and setup times but it will also help to decrease the number of production failures in the start-up phase [40]. The quality of the decision-making could also be enhanced if simulations are used for this purpose. Products could also be constantly improved by using simulations. This signifies that when a product is

developed, its production could be simulated at the same time, which would allow to identify obstacles and quality problems and create the possibility to eliminate them before the first piece is ever produced [41].

#### ***4.4 Worker Participation and Engagement***

The topic of the participation of operators in the production processes is another element of Industry 4.0. This is a paradigm with connections to digital culture, digital society, and Industry 4.0 [7]. When human labor in the context of Industry 4.0 and smart factory is addressed, these terms are frequently recurring: passion, flexibility, responsibility, participation, integration motivation, and teamwork [7]. The participating routines of the operators largely depend on the tool change utilized in the workshop and on the habits that stem from such tools [7]. The desired type of the future factory operator is to be proactive and participative, contrasting with a reactive or resistant type of operator. In the Industry 4.0 concept, the emphasis of the enterprise should be the operator participation and the integration of the worker into the decision-making process, similar to the digital networks [7].

### **5 Current Challenges**

Several challenges still persist for the implementation of Industry 4.0 and specifically, the blending of quality control with this new paradigm. Some of the challenges concerning quality are listed as follows:

- Lack of processing capacity—The fast spread of IoT has cemented the basis of Industry 4.0 by digitally connecting objects and devices. However, such types of changes create also challenges concerning several factors. For instance, some of the challenges are the effective management of the huge quantities of data, the process of such types of data, their storage, and their conversion into useful information and thus improving the decision-making [42].
- Absence of feedback for the required information on quality—According to a study made in [43] in the vehicle assembly industry, the feedback concerning data on quality as fed to quality engineers and systems is only found to a limited degree. The real-time feeding of data was also lacking and is communicated with a time delay. The feedback on quality to different areas of the process occurred only in dispersed intervals of time and only in situations of a worrying quality irregularity or defect, usually in which the ones where the identification feedback took several working hours [43].
- The absence of a connection between the system and the operator in the quality context is another negative challenge that needs to be overcome. A “*smart*” method needs to be put in place for the quality control concerning the link between system

and human. In this case, what is necessary is ample, real-time feedback of data concerning quality with a user-friendly visualization of the condition of the quality [30].

- Complete information preparation for a proper visualization—The state of the quality needs to be properly visualized by the operator or the engineer. In the study made in made in [43], the way the quality information was visualized was restricted to only a few elementary important data. In order to overcome this challenge the applied technologies should be more complete and crafted in a user-friendly manner in order to properly visualize the state of the quality [43].
- A poor application of technologies oriented for the process—The workspace technologies such as the visual information that assists the operator might not be correctly integrated into the production process which could also occur with the process control and quality feedback. The physical machines and devices need to be correctly connected to the implemented quality systems [43].

## 6 Conclusion

Industry 4.0 is a concept that is already a reality and begins to have an effect on the operational indicators of enterprises. At the basis of this revolution are the WSN since they consist of spatially dispersed and independent sensors capable to monitor physical or environmental characteristics. Products, machines, and people will be connected, increasingly in number through WSN and IoT. With these tools in smart factories, a number of changes will take place in the way the products will be manufactured, impacting several market sectors. The measurement for the quality control no longer will be made in a distinct metrology section, but instantaneously on the production line. The WSN will open the door to register and transmit the collected data for quality control thus opening a full range of possibilities in this field.

In this paper, a broad analysis of the link between quality control and Industry 4.0 was made. Several benefits and challenges are addressed. Besides the direct improvement of the quality control, the set of tools of Industry 4.0 could strengthen the quality in all stages of the entire process of production, such as the quality of information required for optimization, planning and operation, the quality of forecasting, simulations and prototyping and could even the lead to a better employee participation and engagement.

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# Aligning e-service Attributes for Hedonic and Utilitarian Consumption: An Exploratory Study in the Context of Consumer Electronics



Larissa Schulz, Nuno Fouto, Marlene Amorim and Mário Rodrigues

## 1 Introduction

In recent years, e-services have expanded in both volume and sophistication. A growing number of company websites, across different business sectors, have evolved from having a barely supporting role to become effective new sales channels, allowing customers to engage in interactions and to place requests that used to be only available in physical stores. These developments, notably for online commerce, have led to the proliferation of studies investigating the characteristics, motivations and preferences of the e-consumer, enabling the definition of e-consumption typologies and contributing to the understanding of customer behaviour throughout their e-purchasing journeys, notably in what concerns their requirements and habits for information search and order placement via virtual channels. The effective setup of e-delivery systems, including website design decisions, builds on knowledge about consumers much in the same way physical stores adjust to the profiles of its target audience. Retailers are expected to adopt different online strategies across distinct product categories in order to adequately meet their e-consumers' needs [1]. Addend

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to customer personal profiles, it is likely that other elements, including the nature of each consumption episode, i.e. utilitarian vs. hedonic consumption, will play a role in determining the customer requirements regarding the characteristics and functions from company websites. The former refers to a practical or functional purchase intention, whereas the latter is more driven by emotional and experiential elements, often linked to self-expression desires. In order to meet hedonic consumption expectations, for example, the content of retail websites could include elements such as figurative language, and be richer in pictures' colour range [2]. In order to fit utilitarian consumption circumstances, retail websites should be able to meet consumer searches for information regarding material benefits, and other more rational elements that influence purchase decisions (e.g. price and items comparison). Website design decisions should take into account the need to meet requirements like accessibility, literal language and clarification of information and payment options [3].

The purpose of this study is to investigate whether the website attributes that are offered to e-shoppers differ for utilitarian and hedonic products. The study builds on a preliminary literature review on website attributes to put together a characterization for the array of elements that retail websites commonly include to support customer information search and order placement activities. The study then draws on knowledge about utilitarian and hedonic consumption to develop a framework concerning the distinctive characteristics that should be expected from retail websites, according to the portfolio of consumer goods that they offer. The framework is then applied to frame the analysis of the characteristics of major websites for consumer electronics, offering a discussion on the nature of the information provided for utilitarian and hedonic products in this particular retail context.

## 2 Literature Review

Early online service channels were, to a great extent, driven by the purpose of complementing the service of physical stores, notably by providing information and details about the provider and the products available in stores, which allowed customers to save time in the pre-purchase decision phase. In the present, online channels have evolved far beyond such informational role to become transactional systems, enabling customers to complete their purchase journeys without the need to resort to physical stores. Service providers have realized that Evidence e-shoppers, much alike physical store visitors, can have very different profiles and purchasing requirements, that, naturally, must be taken into account in the design on e-commerce systems. Online consumers make decisions building on service quality judgements and expectations that are greatly influenced by the contents and functionalities available in the providers' online presence [3, 4].

## 2.1 *Aligning e-service Systems and e-shoppers Requirements*

The introduction of an online service channel can have diverse effects for the performance of a retailer. Whereas often customers will use the online channel and the physical stores in a complementary manner, in other cases consumers can completely transfer their purchases to the online context. Setting up a website with the adequate constellation of attributes valued by consumers is very important for providers to capture the attention and promote repeated visits of e-shoppers [5]. Research results have suggested that users can take less than 50 s to formulate their first impressions about the usefulness of a website [6].

The intangible nature of the interactions that are involved in online shopping experiences can contribute to customers' uncertainty since customers are used to relying on information derived from the physical sensorial inspection of goods (e.g. touch, smell) that is not possible in the online setting [1]. The purchase of other (non-sensorial) items can more easily be supported by objective online information. One of the key challenges of online commerce, therefore, is the ability to enable customers to experience similar sensations like the ones enabled by the physical contact with items or at least have a perception of them. To this end, the design, functionalities, and nature of the information made available in the providers' websites assume critical importance in influencing customers' intentions to effectively place an online order. The performance of online retailing systems depends largely on the ability to communicate effectively and enable customers to access relevant information to support their decisions and judgements [7]. Online purchase decisions are very much influenced by the appearance and design of the various website elements (e.g. pictures, colours, payment options, etc.) [8].

There has been extensive research addressing the nature and the relative importance of various e-store attributes for distinct consumer groups and consumption circumstances. A recent study identified six categories of attributes for characterizing online retail [9]: 'e-Store Essentials', including interaction and delivery elements related to safety, trust, order confirmation, delivery costs, payment, and return options; 'Offline Presence', relating to the possibility of picking up merchandise in physical stores; 'Price Orientation', relating to the availability of special offers and promotions; 'Website Attractiveness', linked to the appearance and general design of the website; 'Merchandise Variety', concerning quantity, quality, and novelty of the product assortment offered by the online retailer; and 'Web Security/Certification' relating to the safety mechanisms and guarantees of the website. Other approaches have relied on a distinction between the 'General (operational) Elements' of websites and 'Marketing Mix' elements. Generic elements concern website appearance, ease of navigation, compatibility with consumer technology, level of performance of search functions, availability and relevance of links, accuracy, and reliability of information, and also customization possibilities. Marketing elements involve elements related to the products (e.g. assortment, completeness of product description, etc.); the prices (e.g. competitiveness, flexibility, payment options); location (e.g. delivery time, geographic coverage, etc.); promotion (e.g. communication, special



offers and/or benefits to users, etc.); processes (e.g. customization possibilities, ease of use, etc.); people (e.g. online support, possibilities of interaction with sales members or other peer or referral groups) and physical evidence (information and clues that help customer in assessing the quality and functionality of items, such as brand elements, pictures, etc.) [10].

When putting into perspective traditional and online shopping, research results have supported that some characteristics and drivers of consumption are specific to online shoppers [9]. For online settings authors have highlighted the existence of: ‘*e-window shoppers*’, as that are mostly attired by website uniqueness’s and the possibility of browsing across interesting pages; ‘*interactive shoppers*’, as those that search for particularly customized online services and possibilities for discounts; and ‘*risk-averse shoppers*’ that are more prone for shopping in physical stores, and exhibit very demanding requirements in what concerns website safety and guarantees. Other identified online behaviours include ‘*apathetic shoppers*’ that have relatively weak motivation for online purchase and pay very modest attention to online attributes; ‘*shopping enthusiasts*’ that, on the contrary, are highly motivated for online shopping and pay attention to a wide range of website attributes; ‘*destination shoppers*’ as consumers concerned with following the latest trends, whom appreciate variety and novelty, and are very attentive for website design and attractiveness; ‘*basic shoppers*’ that are essentially driven by shopping convenience elements, and ‘*bargain seekers*’ as those who are more practice in online information browsing about products and price opportunities. The variety of elements affecting customers’ engagement and motivation for online shopping include also: customer personal characteristics, such as level of education and degree of experience and familiarity with online systems [11], customers’ economic and purchasing power [12], customers’ orientation towards novelty and experimentation [13, 14] and customer’s attentiveness to price and quality of service delivery [15]. Some interesting insights have also emerged from empirical evidence suggesting that online shoppers are less price and brand conscious and more prone to be influenced by promotions and direct marketing actions [12].

## ***2.2 Understanding Utilitarian Versus Hedonic Consumption***

Regardless of the differences between online and offline purchase determinants that research has been unveiling, there is extensive knowledge about customer behaviour that must be acknowledged regardless of the type of service channels. This is the case of what we know about two fundamentally distinct types of purchasing behaviour: hedonic consumption, related to a demand for multisensorial, fantasy dimensions, and to the emotional elements in a purchasing experience; and utilitarian consumption, more associated with a rational pursuit for a concrete objective [16, 17]. The motivations for hedonic consumption include the search for sensations, and the escape from reality [17], for which it is more linked to products and services with more subjective purposes, oriented towards the search of emotions, like in the case

of music, theatre and sports [18]. Nevertheless, some common goods can also be purchased with hedonic motivations, such as the case of wine consumption that can involve fantasy and multisensorial elements, beyond taste and appearance [19]. Utilitarian consumption is usually associate to a more rational consumer attitude, translating into more efficient purchase practices, like the need to save time and resources, the preferences for fast and non-lengthy purchasing processes [20].

Hedonic consumption is, generally, very tightly linked with brand or store communication, and for this reason, in online setting elements related to the visual and sensorial virtual shopping environment will be more important to motivate this type of purchase. In the case of utilitarian purposes, relevant shopping determinants will be related to rational elements such as price information and amount of shopping and delivery alternatives.

### 3 Methodology

This study was driven by the purpose of investigating whether online retailers are aligning distinct website elements (e.g. information) with specific consumption characteristics across product categories. Notably, we aimed to explore if there were differences in the nature of online attributes displayed for hedonic and utilitarian goods. To this end, the study built on the literature to identify the array of website elements and attributes that would be relevant to analyse empirically across online retailers. Subscribing to some of the aforementioned research results [10], the study identified a list of attributes to be analysed in the websites of selected online retailers distinguishing among ‘General Elements’—Webpage appearance, Written Content and Ease of Navigation—and ‘Marketing Mix’ elements—those related to Product, Price, Location, Promotion, People and Processes (Table 1).

The study addressed a sample of the largest international online retailers, selected from the ranking ‘E-commerce Retail List 2016’—Amazon, Walmart and Best Buy. By focusing on large established retailers, the study aimed at being able to access a homogeneous sample of e-retailers whose practices were likely to be relevant, up-to-date and competitive. Given the extensive array of items carried by the selected retailers, and given the exploratory nature of the study, the empirical investigation was then further focused on the analysis of a subset of products, i.e. consumer electronics, that was considered to be relevant to a large volume of demanding consumers, and whose acknowledged competitiveness offered a reliable base for the researchers to get in contact with up-to-date and practices of online communication and service. Aligned with the purpose of the study, the sample specifically included a category of utilitarian products, whose purchases are often motivated for professional utilization—i.e. laptop computers—and a category of hedonic products—i.e. game consoles—that are to a large extent purchased for utilization in leisure contexts. For each product category, the selected sample of items was driven by criteria related to the volume, variety and product age in the market. To this end, the researchers firstly collected information from the online retailers about the number of models available for each brand from

**Table 1** List of attributes for data collection and analysis in online retailers' product pages

General elements	<b>Page appearance</b>
	Number of available product pictures
	Style of product pictures
	Presence of videos about the product (Y/N)
	Title/designation of product page
	<b>Written content</b>
	Language style (subjective/with adjectives; objective/rational; mixed)
	Navigation elements
	Internal links
	Social presence (Y/N)
Marketing mix elements	<b>Product</b>
	Product customization (Y/N)
	Product availability information (Y/N)
	Additional guarantees (Y/N)
	Product comparison (Y/N)
	<b>Price</b>
	Discounts (Y/N)
	Payment alternatives (Y/N)
	<b>Placement</b>
	Delivery options (Y/N)
	Delivery package options (Y/N)
	<b>Promotion</b>
	Special offers (Y/N)
	Online promotions (Y/N)
	Benefits to users (Y/N)
	<b>People and Processes</b>
	User support (Y/N)
Online assistance (Y/N)	
Products reviews (Y/N)	
Website feedback (Y/N)	

the variable array of laptops and console brands, in order to select the most representative international sales leaders. Next, the researchers resorted to the websites of the specifics selected brands (e.g. Apple, Intel, etc.) to include in the sample of the most recent products launched in the market. This procedure resulted in a sample of 78 distinct products whose online retailers' pages where than accessed to collecting formation about the nature and the characteristics of the present e-shopping attributes.

### 4 Discussion and Overview of Study Findings

The empirical study addressed the analysis of a sample of 78 items from two distinct categories of consumer electronics products—computer laptops and game consoles—collected from the online product pages of three of the largest online retailers (Table 2).

The analysis of differences in the volume and nature of the website information and attributes (as listed in Table 1) in the products' webpages supported the existence of remarkable differences across their two distinct categories of hedonic and utilitarian products. Among the most salient differences, one can cite the consistent superiority in the number of words used to describe utilitarian products, as compared to hedonic items (mean difference of 12.328 (Sig 0.000)). A typical page description for a laptop product would include upfront detailed information about the product specifications (e.g. '2016 Newest Toshiba Satellite Radius 2-in-1 15.6' 4 K Ultra HD Touchscreen Flagship Laptop, Intel Core i7-6500U Mobile Processor, 12 GB Memory, 1 TB Hard Drive, Webcam, WIFI, Bluetooth, Windows 10), whereas the title of Game Consoles pages where consistently succinct and evidencing distinctive performance qualities and adjectives (e.g. Wii U Mario Kart 8 and Nintendoland 32 GB Deluxe bundle). These results were consistent across the tree retailers considered in the sample (see Table 3).

**Table 2** Summary of data sample

R-retailer	No. of product pages
Amazon	31
Best buy	21
Walmart	26

**Table 3** Average number of word in product page titles/descriptions for hedonic versus utilitarian products

R-retailer	Average number of words in title/page description	
	Game consoles	Computer laptops
Amazon	7	21
Best buy	8	21
Walmart	9	18

**Table 4** Difference (avg. nr.) in the type of pictures displayed to illustrate hedonic versus utilitarian products

	Hedonic	Utilitarian
Product photos	5	55
Product utilization photos	17	1

Likewise, differences were found for the number and style of the pictures provided for each category of products. A superior number of photos were, in general, present for utilitarian products, together with a stronger dispersion in the distribution of the observed number of photos for this category of products. These results can, to some extent, be explained by the fact that some of the considered utilitarian products can have in some circumstances be subject to hedonic purchase behaviour, in line with what was also remarked in the literature [19]. Differences were also present in the style of the pictures offered for the two types of products. Whereas the average number of photos was superior for utilitarian items, as aforementioned, the style of the photos evidenced differences of other nature: hedonic products were accompanied by a superior number of photos suggesting scenarios related to the product utilization (e.g. presenting consumers engaged in fun and enjoyment of the consoles), while utilitarian photos, although abundant were typically devoted to display the products or product technical and functional details (see Table 4).

Overall, the exploratory findings suggest that e-retailers are aligning their online attributes with prevalent knowledge about customer behaviour, suggesting that regardless of e-shoppers specificities, some of what we have learned about determinants of purchasing behaviour, can be applied to systematically design online service systems.

## 5 Conclusions

The expansion of online consumption has allowed for unprecedented opportunities for companies to expand the reach of their services, as well as to achieve superior levels of quality building on increased opportunities to improve consumer convenience, and richness of service information among other benefits. Nevertheless, and despite the continuous growth in the adoption of online services, multiple empirical and research results have been showing that the performance of the online channels can be very heterogeneous depending on the characteristics of the products and services to be delivered [21]. Therefore, the managerial implications of such research results have been indicating that specification of online services and in particular the setup of the characteristics and functionalities of online service and shopping interfaces needs to take into account the specific characteristics, and differences of the various products. This study adds to this body of knowledge by exploring how the nature of consumption behaviours also needs to be taken into account when setting up service sales and delivery channels. This study explores the nature of utilitarian versus hedonic consumption processes in online settings, and discusses the differentiation

that is needed to setup corresponding services processes and outcomes. The study offers evidence on the need to deploy adequate differentiated information and online service process attributes to meet customer requirements for utilitarian and hedonic shopping motivations.

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# Extracting Relevant Quality Dimensions from Online Customer Reviews in Accommodation Services



Marlene Amorim, Mário Rodrigues and Carina Fidalgo

## 1 Introduction

Consumers are increasingly resorting to online means to share opinions about quality of service experiences, releasing, every day overwhelming volumes of information that exert a pervasive influence on purchase decisions. This context is facilitated by the dissemination of technologies that encourage the production and sharing of user created content. The growing familiarity of customers with Internet technologies has led many service providers to implement online tools that offer efficient ways for users to make their ideas available to vast audiences in a fast manner [1]. The importance of such form of communication, known as electronic word-of-mouth (eWOM) or word-of-mouse, has been extensively acknowledged in the literature, often being referred as a more effective means to influence customers' consumption decisions than other tools, such as personal sales or advertising, because it can be perceived by costumers as a rather reliable source of information. Whereas customer reviews are now a common feature in many company websites, research is still necessary to gain knowledge about how to effectively use eWOM data as a valued adding tool to inform customer decision making, as well as to guide managerial actions towards service improvement and innovation. This study proposes a contribution in this direction.

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The study offers an exploratory analysis of eWOM, in the context of hotel industry in Portugal, building on a sample of customer reviews extracted from a prevalent online service for hotel bookings. The hotel industry offers an adequate and rich context for the nature of this study for the fact that the travel and tourism industry is known for being a pioneer for the growing trends of promotion and distribution of services over the Internet [2]. The analysis aimed at developing an approach for making sense of customer reviews, by identifying relevant service quality dimensions embedded in the voices of hotel customers, while offering a concise tool for the visualization of the results. To this end, the study employed the principles of importance-performance analysis (IPA), a marketing research technique acknowledged for offering a concise graphical representation of results, to develop a framework for identifying salient hotel service attributes from the available and uncategorized information provided by customer reviews. The study offers a timely approach for assisting managers in the task of sense-making from growing volumes of user-generated information from a key source of information for the identification of priorities for service improvement and innovation.

## 2 Assessing Service Quality: Principles and Challenges

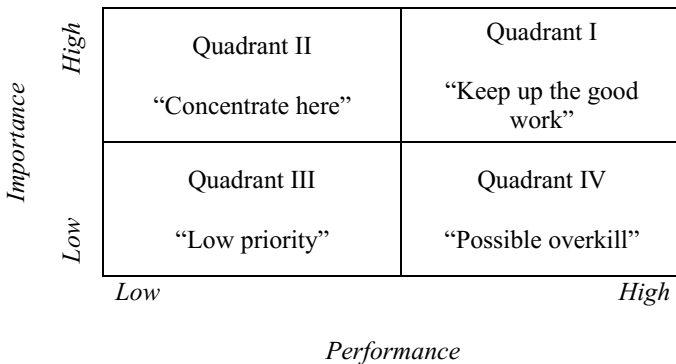
The development of models and measurements for capturing customers' quality assessments has dominated the agendas of service management scholars and practitioners, given the generalized consensus about its association with customer satisfaction, loyalty, and service providers' profitability [3–5]. Moreover, quality is also recognized as a strategic tool for attaining operational efficiency and overall business performance [6]. However, the task of measuring service quality has proven to be hard to operationalize for several reasons, in particular, due to the relative paucity of tangible cues to assess service results. For this reason, service quality largely relies on parameters derived from customers' "perceived" experience [7–9]. Most of these approaches rely on customer survey data employing multi-item scales that try to capture the acknowledged multidimensionality of service experiences, and allow discriminated information about different attributed and dimensions that affect customer value (e.g. generic scales such as SERVQUAL, SERVPREF, along with other sector-specific scales where items are adapted to particularities, such as in retail, health or hospitality and tourism services). Prevalent models account for the recognized dual nature of service quality determinants, i.e. the quality of service outputs as well as the quality of the experience with the delivery processes (e.g. responsiveness, employee empathy, etc.) [5].

Importance-performance analysis is a popular approach for interpreting customer satisfaction and for setting up priorities for upgrading service quality proposed by Martilla and James [10]. IPA builds on customers' assessments concerning the importance and the performance of quality attributes in order to diagnose areas for improvement—typically using data collected by means of questionnaires employing service scales. IPA offers a plot representation for the measurements for importance-

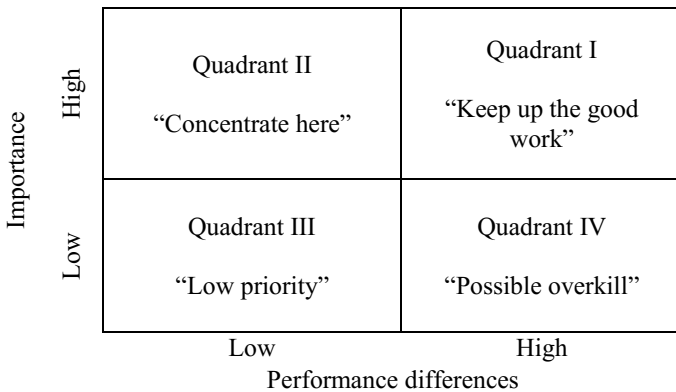
performance, declared by customers, consisting of a four quadrants matrix. The IPA matrix plots these values against two axis: a vertical axis—for the values of performance of service attributes; and an horizontal axis—for the values of attribute importance (see Fig. 1).

Such concise display enables the quick visual identification of what elements demand for managerial improvement actions (i.e. attributes ranked in the quadrant for high importance vs. low performance) as well as others where the providers efforts are potentially misplaced (i.e. attributes ranked in the quadrant for low (customer) importance vs. high (provider) performance).

Subsequent studies have proposed modified approaches building on the principles of the IPA framework, extending its scope of application. For example, CIPA, i.e. competitive importance-performance analysis, is focused on the gaps of the performance of a given service company and that of its competitors, offering a tool to diagnose which competitive attributes demand improvement (see Fig. 2).



**Fig. 1** Traditional IPA approach



**Fig. 2** Competitive importance-performance analysis

Other formulations of IPA aim to address criticisms about its assumptions, namely, the independence between the importance and performance measures and the linear relationship between the attributes and the performance. The so-called IPA with the three-factor theory employs also a matrix representation for the measurements but takes into account the fact that not all service attributes are equally important for customer satisfaction [11–13]. This approach distinguishes three types of factors: (i) basic factors, i.e. minimum requirements that cause dissatisfaction if not fulfilled while not leading to customer satisfaction if fulfilled; (ii) performance factors, i.e. elements that cause satisfaction or dissatisfaction, depending on their performance level and (iii) excitement factors that can increase customer satisfaction if delivered but do not cause dissatisfaction if not delivered [14]. The modified IPA approach employs this three-factor theory [15] and uses estimations of the relative importance of the quality attributes, instead of using customer declared information. The importance-performance lens of analysis, therefore, offers a versatile methodology for approaching the prioritization of service attributes.

This study builds on prevalent approaches of extending the applications of IPA by developing a modified version of IPA for identifying areas for service improvement building on qualitative data in the context of hotel experiences.

### 3 Methodology and Data Considerations

The main objective of the study was to develop a flexible and concise methodology to make sense for the ever-growing online customer reviews that are available for a wide diversity of service business, in an abundant and unstructured manner. Despite the volume and richness of data available, the ability of both customers and providers to summarize and interpret customer generated content is still very limited and often done ad hoc by managers, therefore hurting its utility and value for customer decision and company improvements. Yet recent research results confirm that such sources of information are increasingly accessed by customers to support purchase decisions [16]. To this end, the study focused on customer online reviews in the context of the hotel industry for several reasons. Tourism and hospitality services are experiential in nature which makes pre-purchase quality assessments rather difficult, leading customers to search for various clues and information to support their choices. In this context, the opinions of other customers assume a critical role. In addition, this service industry has a pioneering record in the utilization of online means for customer service interactions (e.g. travel reservations), and for the abundance of eWOM behaviour.

The study addressed a sample of customer reviews for a selected number of hotels in a medium sized tourist destination city in Portugal available in the online reservation website [Booking.com](https://www.booking.com). The choice of using [Booking.com](https://www.booking.com) as a source was justified for being the website offering the largest volume of reviews and diversity of customer profiles, and for offering a significant volume of data for all the units in the

**Table 1** Characterization of the hotel sample

Hotel	Star rating	Rooms	Location <sup>a</sup>	Available services	Average price <sup>b</sup>
Moliceiro	4	49	0	16	€99
Aveiro P.lce	4	49	0	13	€62
Melia Ria	4	128	10 min	22	€94
Américas	4	70	5	16	€79
Imperial	3	107	0	8	€63
J.Ardim	3	48	0	11	€56
Afonso V	3	78	5	6	€49
Veneza	3	49	0	7	€68
Aveiro C.ter	2	24	0	8	€58
J. Estevão	2	12	1	6	€57
Salinas	2	18	0	7	€58

<sup>a</sup>Walking time to the city center (minutes)

<sup>b</sup>Standard double room, average

selected sample of hotels Data extraction returned a volume of over 5600 customer reviews, for a set of 11 hotel units (described in Table 1), for a period of one year.

The chosen hotel reservation Website exhibits written online customer reviews, organized into groups—positive and negative reviews—as well as a rating obtained from customer scoring. In order to guarantee reliability, i.e. that the reviews resort from individual experiences, the Website only allows for reviews from customer who have effectively made a reservation.

## 4 Findings and Discussion

The IPA addressed the data from the sample of extracted customer reviews. The first step in the analysis involved the identification of the most frequent terms and expressions about the hotel experience as stated by customers, for which text mining tools were employed, including a preliminary cleaning of symbols and words with no relevant meaning, and the standardization of terms, whenever synonyms are used to refer to the same hotel service element. The terms and expressions with higher frequency were retained for inclusion in the IPA analysis. A second step involved the identification of dimensions of affinity for the service quality attributes present in customers' statements. This process led to the identification of three dominant service quality elements, motivating the expression of (positive or negative) customer opinions: room, location, and staff. Whereas a more detailed list of attributes could be retained the choice was for the use of a more aggregated level of analysis given the exploratory nature of the study.

The IPA matrix for the 11 hotels is displayed in Fig. 3, where the data points for importance-performance for the three salient attributes, room, location, and staff are, respectively, ●, ▲ and \*. In the traditional IPA, the horizontal and vertical axis represent the coordinates for the values of importance, and the performance as perceived by the customers, usually resulting from structured questionnaire answers, using ordinal scales (e.g. 1 to 7), where customers state their expectations (i.e. interpreted as importance) and service perceptions (i.e. experienced performance). In the current study, and given the qualitative nature of the available data—the reviews—the values for the matrix coordinates were obtained as follows. For each service attribute (room, location and staff) the total frequency (considering all the terms and expressions associated to a given service attribute) was employed as a proxy for the importance of the attribute, therefore assuming, that customers express more opinions for items that are more relevant for their experience. As for performance, the analysis employed the ratio of the number of positive reviews towards the sum of positive and negative comments, for a given service attribute. According to this logic, a hotel for which the proportion of positive comments is higher than the negatives corresponds to a positive performance. This proxy measurement for performance therefore varies between 0 (when all comments are negative) and 1 (when all comments are positive).

Also, the traditional IPA usually employs a central tendency measure (e.g. mean, median) to split each axis and identify the four quadrants. In the current study, the value of the mean was employed to split the plot area.

The interpretation of the IPA graph offers a number of interesting insights. Overall, for each hotel unit, the three service attributes considered in the analysis are closely positioned next to each other. This suggests that when hotel customers are pleased with a hotel, or with the particular performance of one service attribute and they engage in offering positive comments, they tend to be positive about the remaining attributes. Whereas there is some natural dispersion in the points exhibited in Fig. 3 most service attributes, for the diverse hotels, is positioned in the quadrants II and IV pointing towards urgent action and resource underutilization, respectively.

Overall the service attributes for the various hotel units are positioned very closely in the IPA map. A look at the positioning of the service attributes (room, location and staff) the one with stronger consistency in customers' opinions is staff, as in 90% of cases appears as the most important attribute. An opposed pattern is shown for the attribute room, for which customers seem to hold more heterogeneous opinions about its importance. Overall the data suggests some inconsistency in customers' perceptions about the importance of the service attributes. Of particular interest is the observation that there is a great variability in what regards the number of positive or negative comments. Most of the hotels exhibit a value for the performance measure (i.e. positive comments divided by the sum of positive and negative comments) not very distant from 0.5, therefore suggesting the existence of some level of service inconsistency across customers, a characteristic that is rather undesirable in service settings.

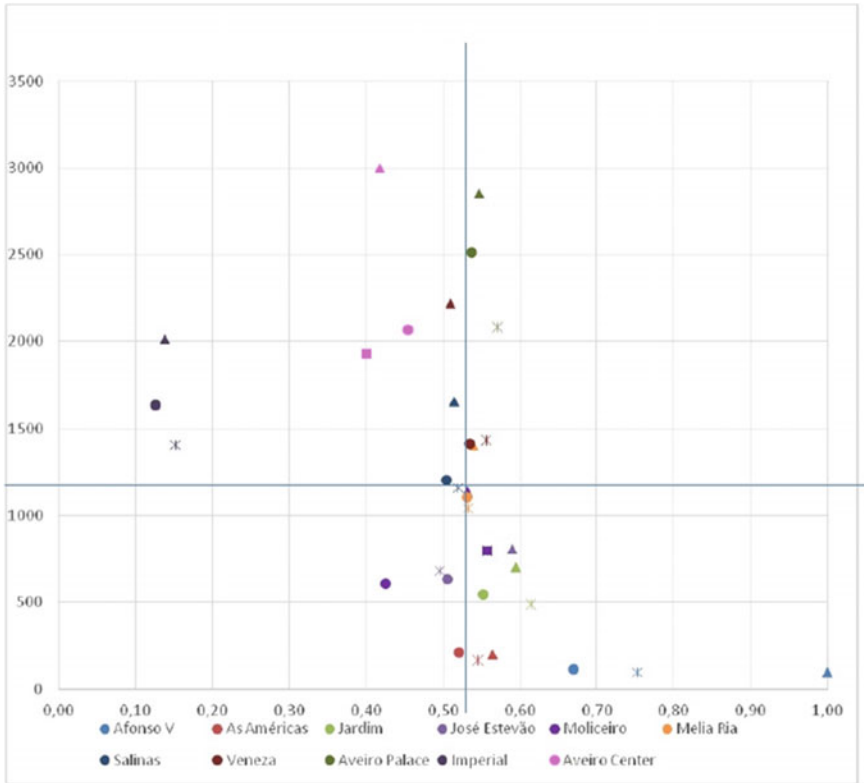
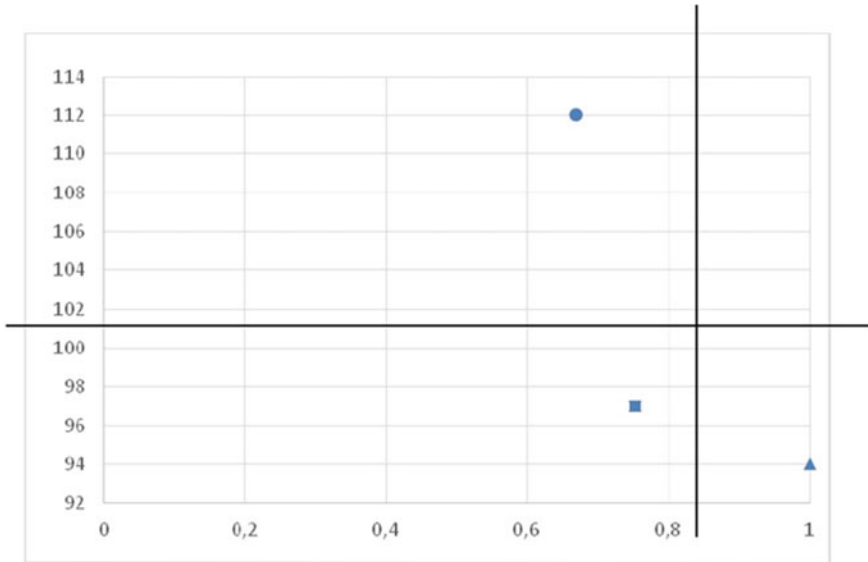


Fig. 3 Modified IPA for hotel sample

The proposed analysis is susceptible to being conducted at a more fine-grained level, i.e. in this case, for each hotel (see, for example, Fig. 4)

This study, although exploratory and restricted to a small sample of service providers, from a specific service context—hotels—offers an illustrative insight of how existing managerial analytical tools can be adapted to help making sense of large volume of customer-generated content. Whereas the study was applied in the context of hotel services, it is clear that the principles of the tool are applicable to any service industry, given that there is some kind of customer content to work with. The study shows that is possible to apply tools to offer a concise and structured view of the content generated by customers in their service reviews, and therefore to extract value from this abundant source of information. The extracted service attributes (room, location and staff) are particular to this study, its context and the limitations of sample selection, not meaning that they are the overall more important in the hotel industry. In order to do so, the study would have to be extended to a wider sample and account for any conditioning variables (e.g. seasonality, weather,



**Fig. 4** Modified IPA for one hotel unit (Hotel Afonso V)

customer experience, etc.). As such this work suggested that there is a vast array of models and tools for assessing service quality that can be called to help make sense of the overwhelming h volume of eWOM.

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# Insertion of Risk Management in Quality Management Systems with the Advent of ISO 9001:2015: Descriptive and Content Analyzes



Gabriel Henrique Silva Rampini , Fernando Tobal Berssaneti   
and Ana Maria Saut 

## 1 Introduction

Since the 1950s, quality management practices started to be widely adopted by companies as part of an effort to increase their production and behavioural factors, such as executive commitment and employee empowerment [1]. In the meantime, academic research on the subject grew in importance [2] leading to the introduction of quality management as a discipline in many business and engineering schools, being a significant object of study and application [3]. Later, quality management became more mature as a discipline and quality awards were developed, helping the adoption of common best practices by organizations around the world [4].

Quality management best practices evolved over time leading to the development of specific norms, standards, and certifications based on accumulated research and experiences [5]. One of the most important and recognized standards is the ‘9000 series—Quality Management System’ from the International Organization for Standardization (ISO), which is composed by four main standards periodically reviewed and already implemented in more than one million certified companies throughout the world [6]. The 2015 review of the ISO 9001 standard made an important change incorporating risk management as part of the quality management system [7]. However, which risk management processes must be carried out under the quality management system is still a topic under debate in the literature [8].

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The current debate on academia follows two divergent arguments. On one hand, some authors argue that the changes introduced by ISO 9001:2015 may effectively improve quality management processes if companies apply the norms as it is [9]. On the other hand, another stream of authors argues that companies pursuing certification will not necessarily experience a significant improvement in their quality management processes, mainly because of the lack of commitment from the top administration [10]. Therefore, there is an important gap not addressed in the literature regarding the interdisciplinary aspects of quality and risk management, and both academia and industry may benefit from this debate. In order to address such research gap, we reviewed, analyzed and outlined a profile of the existing academic research regarding the risk management practices introduced by ISO 9001:2015 which would be incorporated into the organization's quality management system.

The present article was structured in four further sections to better address the current research goal. In the following section, a theoretical framework is presented to introduce the main definitions and outline the current debate regarding the researched topic. Section 3 describes the methods used to search, collect, analyze and synthesize the data collected. Section 4 presents the results of the bibliometric analysis conducted and discusses the main findings uncovered by it during the analysis. Finally, Sect. 5 presents some conclusions, implications, limitations of this article and some suggestions for further research.

## 2 Theoretical Framework

### 2.1 *Quality Management*

Quality is a degree to which a set of inherent characteristics fulfills requirement [11]. The quality of services and products is dependent upon the way organizations perform their activities through the production chain [5] and, given its impact in the company's business, it should be considered strategic by organization [12]. In other words, managing quality enables organizations to compete and sustain long-term competitive advantage in the market [13].

In this context, quality management is a group of processes focused on the quality of activities carried out by an organization, encompassing aspects such as planning, control, assurance and improvement of processes [5]. Some common principles, practices and techniques guide such managerial activities in organizations in general, although it may be adapted according to the particularities and cultures of each company [14].

The ISO 9001:2015 presents some quality management principles that are essential for the elaboration and interpretation of quality management guidelines, namely: customer focus, leadership, people engagement, process approach, improvement, evidence-based decision-making and relationship management. The purpose of such quality management principles, practices and guidelines are to continuously

improve organizational processes in order to achieve the quality goal defined by the organization [15]. Basically, this goal is achieved through continuous improvement techniques such as Deming's PDCA (Plan—Do—Act—Check) cycle, which consists in the systematic and continuous application of a cyclical system applied to organizational processes, including the quality management system [16].

## **2.2 ISO 9001:2015**

ISO 9001:2015 is part of the family of standards referred to as 9000 series—Quality Management Systems. It is a standard that presents the requirements to develop a quality management system, intended to organizational procedures, certification and contractual purposes [5]. Organizations pursuing certification must adapt their processes to comply with requirements established by the standard and later be assessed by a group of examiners. If successful, the organization receives a certificate of national and international recognition because of its compliance with the quality standard [17]. A quality certification was once a way to differentiate and set itself apart from the competition, although, nowadays, due to its popularization and acceptance in the corporate world, it is practically a necessary certification for the survival of companies in the market [18].

ISO standards are continuously reviewed and improved to incorporate and adapt concepts and business management practices to today's challenges [17]. For instance, the 2008 review focused on business process management, highlighting the importance of organizations defining processes driven by a comprehensive and systemic understanding of what quality management is, covering aspects such as identification, implementation, management and continuous improvement of the quality management system [19]. In addition to that, the 2015 review, besides its use of the PDCA cycle at all levels of the organization, the main emphasis shifts to developing a risk mentality as an essential strategy to develop an effective quality management system [11]. All those changes had the purpose of enabling companies to adapt and navigate themselves into the dynamic business environment in which they compete, allowing them to sustain growth and improve success rates. Given this dynamic nature, organizations certified by previously standards, such as ISO 9001:2008, need to adapt their practices to the current standard in order to maintain their certification.

The underlining assumption embedded into the ISO 9001:2015 is that developing incentives to towards an enterprise risk mentality would make organizations to think about threats and opportunities existing during the decision-making process [8]. By critically thinking and acting in a timely manner, organizations would ensure the quality of their products and services, ultimately leading to the achievement of their strategic goals [14].

### **2.3 Risk Management**

Organizations are constantly under the influence of internal and external factors that make uncertain whether and when planned goals will be achieved. The effects of such factors on the organization's goals are called risk [20]. In other words, risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope, schedule, cost or quality [21].

Risk management is a group of processes designed to increase the rate of success of complex, multidisciplinary and challenging activities such as managing projects and developing products [22]. In addition to that, it is an essential practice in any business environment because risks affect organizations in many ways, including main processes responsible to sustain and guarantee the achievement of strategic objectives [23]. Therefore, risk management should be incorporated into strategic plan that managers actually execute [24], taking into account specific characteristics of the internal and external organizational environments and enforcing procedures to monitor and control it.

In the context of quality management systems, risk management is a requirement that must be implemented in all organizational processes [25]. Moreover, the risk mentality created by such procedures should allow organizations to determine the factors that may cause deviations from the intended outcomes of their processes and quality management system, allowing them to adopt preventive controls measures to minimize threats and maximize opportunities [16].

## **3 Methods**

Given the aim of this article, a bibliometric analysis was conducted to address the research gap identified, which is a technique used to better identify standards in a given theme [26]. A bibliometric analysis usually starts with a bibliographic review, which is composed of three distinct steps, namely planning, review and findings, and then a descriptive and content analysis stage aiming to discuss the results [27].

The planning phase consisted of developing the bibliographic portfolio to identify how ISO 9001 was discussed in academia in the context of quality and risk management, allowing to outline the relationship between these two themes. Following that, a content analysis was designed to identify the main topics discussed after the insertion of risk management in quality management systems by ISO 9001:2015.

The bibliographic portfolio was based on data from the Web of Science Core Collection and Scopus databases, which combined cover the most relevant journals and publications in the field. Moreover, they allow the complete extraction of bibliometric data in a way data allows later analysis.

The following criteria were used as inclusion parameters: proceedings (in the case of the Web of Science Core Collection), conference papers (in the case of Scopus) and finally, articles in both of them. The timespan used was from January 2015 to

February 2018, since the latest ISO 9001 review was presented in 2015. Therefore, given the focus on recent developments, conference papers were included as a search parameter in order to capture the novelty of the subject addressed. Finally, the search strings used three main identifiers: the first for quality management, another for risk management and one more for ISO 9001:2015. Thus, in order to extract the most appropriate publications, the following search strings were applied to the titles, abstracts and authors keywords fields: 'quality' AND 'management' AND 'risk\*' AND 'ISO' AND '9001' (Table 1).

After the planning stage, the bibliographic portfolio review began with the analysis of the raw data extracted from the databases. Initially, the Web of Science Core Collection hit 46 documents and Scopus 58 documents. The documents were then imported to Mendeley<sup>®</sup>, revealing 27 duplicated documents that were excluded. Finally, after this initial filter, 77 documents remained in the dataset.

A second filter was applied to the dataset which consisted of screening the titles and abstracts of all remaining documents, excluding those which not addressed the relationship between risk management and ISO 9001:2015. After that, 51 documents remained in the dataset, however, three were unavailable to researchers, resulting in a final sample of 48 documents (Table 2).

**Table 1** Bibliographic portfolio inclusion criteria

Planning	Bibliographic portfolio
Database	Web of Science Core Collection
	Scopus
Document type	Articles
	Proceedings papers
	Conference papers
Period	Jan 2015–Feb 2018
Category	All
Search string	'Quality' AND 'management' AND 'risk*' AND 'ISO' AND '9001'
Processing of data	Descriptive and content analyzes

**Table 2** Filtering process

Web of Science Core Collection	46 documents
Scopus	58 documents
First filter: duplicity documents	27 documents
Partial sample	77 documents
Second filter: documents outside the studied subject	26 documents
Partial sample	51 documents
Third filter: unavailable documents	3 documents
<b>Final sample</b>	<b>48 documents</b>

Initially, descriptive analysis was developed to identify aspects such as most relevant journals, total publications per year and most cited documents. After that, a content analysis was done by reviewing the full texts of all documents in the dataset, in order to group them by topic area, identify the main definitions and understand how risk management was applied in the context of quality management systems defined in ISO 9001:2015.

## 4 Findings

### 4.1 Descriptive Analysis

A descriptive analysis was conducted with the 48 documents in the dataset to identify the most relevant journals, the total publication per year during the timespan selected and the most cited documents in that period. Regarding the most cited journal, the Total Quality Management & Business Excellence was the main source of documents addressing the topic discussed in this document, with a total of 4 published documents discussing the relationship between quality and risk management in the context of ISO 9001.

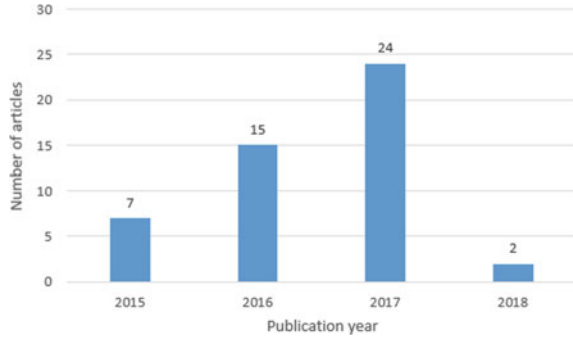
This is a widespread theme among the various types of publications since the 48 documents are published in 41 different sources. Table 3 highlights information about the journals that published at least two documents of the selected sample, thus serving as a reference for researchers.

The number of documents published between 2015 and 2018 is illustrated in Fig. 1, allowing to identify an expected trend towards an increasing volume of academic documents regarding ISO 9001 as an integral part of risk management. For instance, between 2015 and 2017, after the publication of ISO 9001:2015 version, the number of documents published by year in the topic increased, going from 7 publications

**Table 3** Journal information

Journal	SCImago Journal Rank (2016)	Journal impact factor (2016)	Quantity
Total Quality Management & Business Excellence	0.652	1.368	4
TQM Journal	0.362	–	2
Amfiteatru Economic	0.250	0.581	2
Gornyi Zhurnal	0.227	–	2
IOP Conference Series: Materials Science and Engineering	0.187	–	2

**Fig. 1** Distribution of documents published between 2015 and 2018



in 2015 to 24 in 2017, a trend that demonstrates the real interest of the academy in studying the risk management from the perspective of ISO 9001.

In order to identify which documents of the sample were most influential in the literature, Table 4 was developed to illustrate the three most cited documents during the period considered.

**Table 4** Most cited documents

Authors	Title	Year	Journal	Web of Science	Scopus
Muthu Samy G., Palani Samy C., Ammasaiappan M.,	Integrated management systems for better environmental performance and sustainable development—a review	2015	Environmental Engineering and Management Journal	10 citations	9 citations
Parra-López C., Hinojosa-Rodríguez A., Carmona-Torres C., Sayadi S.,	ISO 9001 implementation and associated manufacturing and marketing practices in the olive oil industry in southern Spain	2016	Food Control	6 citations	5 citations
Fonseca L. M.,	From quality gurus and TQM to ISO 9001:2015: a review of several quality paths	2015	International Journal for Quality Research	–	30 citations

First, it is interesting to note that none of them were published in the periodicals highlighted in Table 3, emphasizing that there is no direct relationship between the number of documents published by the journal and the number of citations per document. Subsequently, it is possible to verify, through the specificity of the journals of the most cited documents, that the researched topic permeates several areas of knowledge, being therefore a multidisciplinary subject.

The descriptive analysis of the dataset allowed us to identify and understand how ISO 9001 was discussed in academic research on quality and risk management, showing that it is a recent topic that is attracting the interest of researchers in such areas.

## 4.2 Content Analysis

Content analysis is a technique of textual analysis through the codification of information, aiming to analyze the content of documents in a systematic, objective and reliable way [28]. Therefore, the analysis developed in this article categorized studies into themes related to risk management and its application in quality management processes. As a result, three main categories were identified, namely: risk-based thinking; the influence of ISO 31000:2009; and integrated management system.

### **Risk-Based Thinking**

The main modification brought by ISO 9001:2015 revision was the risk-based approach in the quality management system. For that reason, risk-based thinking is the most studied subject among researchers on the subject. For instance, Bacivarov et al. [29] analyzed the updates proposed by ISO 9001:2015 and argued that risk-based thinking could be the beginning of a new era in the development of quality management systems. Similarly, Rybski et al. [30] also analyzed the changes introduced by 2008 and 2015 versions of ISO 9001 and concluded that the application of the 2015 version, which considers risks across the organization, increases the likelihood of companies achieving planned objectives and gaining greater credibility within their customers base.

Another relevant aspect uncovered was the need for companies adapting to the new mentality based on risk management. Fonseca [7] raised some challenges to be faced by organizations already certified, such as the adaptation to a more complex, demanding and dynamic market environment, and the search for a business model that takes into consideration the requirements associated with risk. In this sense, Parra-López et al. [31] analyzed the constraints imposed to the implementation of a quality management system based on the ISO 9001:2015 requirements and concluded that companies' management and supervision teams need to be more dynamic and willing to take risks in their strategies.

Considering risk management requirements present in ISO 9001:2015, Rodriguez et al. [32] proposed a model and partially implemented it in Rodriguez et al. [33]. As part of their work, the authors identified the strengths and weaknesses using



a SWOT matrix and addressed the main issues through a risk management plan. Continuing the studies on ISO 9001 implementation, Wong [34] recommended that organizations conduct an initial review of existing process, identify potential risks and initiate ongoing risk management. The author argues that regular evaluations of implementation effort could increase the effectiveness of the quality management system and prevent negative effects.

Chiarini [25] categorized sources of risk according to the risk-based thinking for European Small and Medium Enterprises (SMEs), revealing that the main sources of risks are: making defective products; poorly trained employees; and lack of risk assessment. The author argues his findings may help quality managers involved in the new approach proposed by ISO 9001:2015.

An exploratory research was done by Sari et al. [35] to identify the main changes between ISO 9001:2008 and ISO 9001:2015. As a result, they presented processes for transition, and evaluated possible impacts to organizations. Moreover, they concluded that for efficient transition companies must identify stakeholders' concerns, analyze internal and external organizational factors to formulate relevant strategies and objectives and register associated risks associated with business processes.

### **The Influence of ISO 31000:2009**

By incorporating the risk management into ISO 9001:2015, quality management also became a requirement in ISO 31000:2009—Risk Management. Thus, it is possible to find in the literature documents that discusses both standards. Palacios [36], for instance, argues that both standards are part of the quality management system, meeting a set of increasingly rigorous generic guidelines with complex standards.

Similarly, Benetti [37] examined the influence of ISO 31000 and ISO 9001:2015 on organizations, arguing that corporate risk management has emerged as one of the most important business activities in the recent years, and that ISO 31000 risk requirements may help in achieving the business strategy of organizations.

Barafort [38] analyzed risk management procedures across several ISO standards in order to identify what is best suited to information security. The author argues that ISO 31000 adapts to several professional areas and the integration with aspects of other ISO, such as ISO 9001:2015, creates a better structure to support information technology management.

The influence of ISO 31000 on the requirements for ISO 91000 quality management practices is so relevant that, according to Samani et al. [39], both are similar and complementary. The author states that risk management and quality management are essential to organizational performance and ultimately suggests the development of a risk-based quality management system to reduce the number of resources allocated and as consequence improve organizational performance.

### **Integrated Management System**

The implementation of an integrated management system is a viable strategy for organizations. In this regard, Giesen [15] proposed a risk assessment approach for integrated management contexts which takes into consideration the uncertainty that characterizes the process of business management whole process. The approach proposed by the author is based on fuzzy set theory and Monte Carlo simulation

as a way to provide reliable risk estimative and support decisions regarding quality, safety, and environmental management systems.

Following a similar research stream, Nagel-Piciorus et al. [40] summarized the experience regarding the development of integrated management systems in an organization from the health sector. The authors described the steps for merging common management systems (quality, laughter, health and environment) with defined strategic planning and control.

Similarly, Muzaimi et al. [41] presented the benefits from integrating and aligning components of management system and their implementation aspects. Moreover, the authors proposed the integration of four management systems (ISO 9001, ISO 14001, OHSAS 18001 and ISO 31000), arguing that an integrated management system can be used to structure the quality management processes for sustainable practices in organizations.

Finally, Muthusamy et al. [42] proposed a comprehensive model and a holistic approach focused on implementing an integrated management system, addressing mainly four stages, namely, awareness, cooperation, consonance and combination. The authors argue that an integrated management system provides a viable and rational approach to reduce costs, allowing an efficient use of organizational resources and an interesting strategy to increase business excellence.

## 5 Conclusion

In order to address the literature gap concerning the interdisciplinary aspects of quality and risk management, the present research aimed to review, analyze and outline a profile of the existing academic research regarding the risk management practices introduced by ISO 9001:2015 which would be incorporated into the organization's quality management system.

The method used to reach the aim was the bibliometric analysis, through a descriptive and later a content analysis. The documents (articles, proceedings and conference papers) were extracted from the Web of Science Core Collection and Scopus databases. The final sample that served as the basis for the descriptive and content analysis was composed of 48 documents published between 2015 and 2018.

Once the descriptive and content analyzes were completed, it was observed that the objective of drawing a profile on the insertion of risk management into the scientific productions focused on the study of the ISO 9001:2015 Quality Management standard was reached. In the first part of this research, a descriptive analysis was carried out with the proposal to obtain an overview about the relationship between ISO 9001, risk management and the quality management theme in the literature. It has been found that the subject is widespread in an important academic journal, showing that there are fields for research and publications. The association of ISO 9001 in scientific productions on quality management was established as a consolidated research relationship since between the years 2015 and 2017 the number of documents published more than tripled, confirming a growth trend, which should be

confirmed until the end of the year 2018. Another relevant aspect is the interdisciplinarity with other areas of knowledge, which stood out in the subjects discussed in the most cited documents of the sample. In the final part of the research, the content analysis of the sample documents selected, sought to map the main current topics discussed in the academic literature after the insertion of risk management in quality management systems with the advent of ISO 9001:2015. When categorizing the studies, three thematic areas became evident regarding risk management and its application in quality management processes. These are risk-based thinking, the influence of ISO 31000: 2009 and the integrated management system.

The risk-based thinking was the main change in the quality management system after the publication of ISO 9001:2015. For this reason, risk-based thinking is the most researched subject among scholars in the area today. The work centers on the updates proposed by the latest version of ISO 9001 and considers that risk management may be the beginning of a new stage in the evolution of quality management systems. By introducing risk requirements into ISO 9001, quality management brings with it ISO 31000: 2009—Risk Management. With this, one finds academic productions that study the relation between these two norms. As risk management is embedded in organizations, there is an influence of ISO 31000 in the corporate world and also in the applications of ISO 9001:2015 focused on the business strategy of companies. Finally, the integrated management system is a trend in organizations. By optimizing available resources and reducing individual implementation costs, it can be used to structure processes across an entire organization.

Based on these conclusions, it is necessary for academic studies relating to ISO 31000:2009 and ISO 9001:2015. In addition, journals editors need to encourage more research and publications on the relationship between risk and quality management. For industry, its appropriate analyze how managers are dealing with the advent of risk-based thinking and how the integrated management system can contribute to the achievement of their strategic objectives.

This article contributes to the researchers of the area because through a literature review based on bibliometric and content analysis it was possible to qualify how risk management is approached in publications focused on the study of quality management with the advent of ISO 9001:2015. However, as a limitation, it is mentioned that the study has only an exploratory character, in which the descriptive analyzes of the documents of the sample, are of subjectivity. Given the limitation presented, further research is suggested to continue the conversation regarding the topic. For instance, in addition to applying a quantitative methodology, we suggest exploring the shared role of ISO 31000:2009 and ISO 9001:2015 to contribute to the debate regarding the topic, approaching it from different perspectives.

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# Occupational Stress and Job Satisfaction Among Brazilian Managers: The Case of Commercial Area



José Wilson Franca Lelis, Neusa Maria Bastos Fernandes dos Santos, Alessandra Cristina Santos Akkari and Igor Polezi Munhoz

## 1 Introduction

Understanding how the work context affects people's behavior and attitudes in the organizational environment is extremely relevant, not only because of concern for people but because of the results and impact on the company's performance. In this sense, many experts agree that employees of an organization are their main source of competitive advantage. Thus, constant changes in the business world, increasingly competitive, can differentiate companies through their intellectual capital [1, 2].

Accompanying these frenetic transformations in the globalized world creates a climate of challenge and tension in the people who are involved in this process. These tensions, to a certain degree, can be motivating and challenging to reach and exceed the proposed results, generating a sense of fulfillment and satisfaction in professional performance. However, they can also be an element of disruption and sickness of the professional involved in the process, compromising the company's results.

The relationship between *stress* and *management position* was explored in literature [3], addressing stress among executives in ten different countries. This study highlighted the position of Brazil in second place in the ranking, presenting 40.9%

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of managers with stress. A recent study with 637 Brazilian managers indicated that 75.7% of them presented occupational stress, ranging from mild to moderate to intense levels [4]. Corroborating these literature results, data from the Psychological Center for Stress Control, in Campinas (Brazil), showed that about 70% of the individuals seeking care (treatment or prophylaxis) belonged to the managerial class [5]. In the commercial area, besides the tension and challenge in the exercise of management position, there is an additional tension in the responsibility of generating essential resources for the company's performance [2, 6].

Therefore, the objective of this article is to study the level of stress and the degree of satisfaction related to work among managers in the commercial area, as well as to evaluate if there is a correlation between the two parameters, in order to contribute to reflections on practices and policies aimed at optimizing the health and well-being of the individual.

## 2 Background

### 2.1 Occupational Stress and Job Satisfaction

Since the 1960s, stress has come to be recognized as an inescapable aspect of life, so that different responses to this process are explained by the way people face it [2]. Studying how stress situations are presented in the labor process and specifically in the exercise of the managerial function can be significant for practical actions in the process of dealing with an issue that is inevitable and is part of the labor relations. In this context, the concept of occupational stress is described as a subjective phenomenon expressed in people's recognition of their inability to cope with the demands of work situations [7].

The World Health Organization [8] defines work stress as a harmful physical and emotional response that occurs when work demands do not match the worker's ability, resource or need worker, which can lead to health problems and can increase the rates of accidents and work-related injuries.

According to the American Institute of Stress [9], in the USA stress is already a major cause of incapacitation for work and also mention the clear evidence of the association between occupational stress and cardiovascular diseases, hypertension, peptic ulcer disease inflammatory bowel diseases and even work-related musculoskeletal disorders. It is worth noting that, in Brazil, these diseases represent the main causes of requests for removal from work to the social security system [4].

Therefore, there is a growing interest in the scientific literature for the study of stress at work, particularly the negative impact of occupational stress on health and well-being of employees and, consequently, on functioning and effectiveness of organizations. In fact, inverse relationships can be observed between satisfaction and suffering at work and between satisfaction and occupational stress [10].

Job satisfaction has been defined in a number of ways but the central theme is similar and corresponds with a positive feeling resulting from an evaluation of its characteristics. So, a person who has a high level of job satisfaction presents positive feelings about work and his involvement with the work environment represents the degree to which the person identifies himself psychologically with his work and considers his performance important for his personal appreciation [11, 12].

In the last two decades, the administrative currents seem to converge towards the recognition of the central character of the human being, his attitudes and his behavior in the work. This recognition is in conflict with the practice of organizations based on the traditional management model that, in fact, has difficulties in dealing with human behavior, in the search for the expected results [2].

Without disregarding individual responsibilities, it is important to address the collective or, more specifically, the role of the organization in job satisfaction, and it is possible to evaluate how companies can promote the health and well-being of their employees. In addition, it must be considered that job satisfaction does not happen in isolation, depending on organizational variables such as structure, size, remuneration, working conditions, and leadership, which constitute the organizational climate [13].

## ***2.2 Management Role in the Commercial Area***

The transformations and singularities of managers' work remain necessary and relevant so that contemporary management continues to face questions and challenges that meet organizational demands, as well as managerial functions, remain essential. Thus, the managerial function has the virtue of nurturing organizational dynamics and guaranteeing business success since it is at the heart of the social, technological, cultural, political, economic and ideological processes that link strategies to operations. The intermediate position of the managers gives a type of work full of nuances, complexities, and dilemmas that deserve clarification and reflections of current or future managers [13].

Thus, the present study chose to specifically address the commercial manager responsible for the area that promotes the flow of information between the company and the market. In this way, the managerial function is a strategic position in all areas of the company, however, the commercial area is considered the neuralgic point between the conception and the elaboration of the business and the materialization of the results obtained through the revenues generated in the process commercial. Associated with these expectations is the complexity of the market, the daily performance metrics inherent to the commercial function that function as stress-potentiating elements. This network of functions and responsibilities puts the manager of the commercial area in a daily situation of exposure to stress in an ambiguous way to the satisfaction that can be generated in an area that allows many accomplishments [14, 15].



From this perspective, the importance of studies on the response of individuals to stress situations in work relations are essential elements for organizations to identify how individuals feel about their work in order to manage their human resources with the goal of achieving ever more challenging results.

### 3 Research Approach

In order to achieve the objectives proposed in the study, research of a descriptive nature was carried out, using a quantitative approach, with 114 commercial managers in companies of different segments of the Brazilian market. The data collection instrument was divided into three parts, starting with the profile of respondents with 13 questions that included demographic variables (gender and age, for example); functional variables (time in the company and salary range, for example); and variables related to the companies (branch of activity and size of the company, for example).

The second part referred to the Occupational Stress Scale (EET) [16], constructed, valued and composed of 23 items, using a 5-point Likert scale. The third part of the instrument was part of the Work Satisfaction Scale (EST) [17], validated and composed of 15 items, using a Likert scale of 7 points. To evaluate the internal consistency of each instrument, the Cronbach's alpha was calculated.

For the data treatment, were used the programs Microsoft Office Excel 2010 and SPSS 21.0. The level of statistical significance adopted was 5% for all tests, that is,  $p\text{-value} \leq 0.05$ . To evaluate the stress by EET, the average score of the questions below was calculated and categorized; low (1.00–2.00), medium (2.01–2.99) and high (3.00–5.00). For EST, the calculated mean score was classified as unsatisfied (1.0–3.9), indifferent (4.0–4.49) and tendency to satisfied (5.0–7.0).

To evaluate the correlation between stress levels and degrees of satisfaction, the Fischer's exact test was used. Thus, to answer the question "is there a relationship between occupational stress and job satisfaction in professionals who perform the function of managers in the commercial area?" the hypotheses H0 and H1 were assumed. To test the null hypothesis (H0) the Spearman correlation coefficient was applied, using the mean scores of the instruments that evaluated stress and satisfaction at work (EET and EST, respectively). The rejection of the null hypothesis led automatically to the analysis of the alternative hypothesis (H1).

H0: The level of stress does not correlate with the degree of satisfaction with the work.

H1: The level of stress is inversely proportional to the degree of job satisfaction.

## 4 Results and Discussion

Participants in the study were commercial managers who worked mainly in private companies (93.8%), medium or large (87.7%), mainly in the Commerce and Services sector (56.6%) and located in 16 states of Brazil, in addition to the Federal District, standing out the Southeast (51.7%) and South (27.2%) of the country. Among the 114 respondents, mean age was  $42.7 \pm 8.8$  years, ranging from 25 to 72 years, with male predominance (69.3%) in the role of commercial manager. The phenomenon of gender segregation in the labor market was observed, characterized by the lower speed with which women ascend in the career. In relation to schooling, 64% of the managers attended postgraduate studies, while about 11% had a master's degree or doctor's degree, which shows that 75% of the respondents deepened their basic education in postgraduate courses.

### 4.1 Occupational Stress and Stressors

The EET instrument presented Cronbach's alpha of 0.93, showing a very good internal consistency. The mean stress score of the population sample studied was  $2.24 \pm 0.61$ , ranging from 1.04 to 3.83, meaning an average level of stress among Brazilian commercial managers. Thus, 63% of the respondents are at least in the average level of stress; with 8% already reaching a high level, indicating the need for attention and action of the organization not to overcome the frontier of stress that pushes (eustress) to the stress that gets sick (distress). Corroborating this result, another study [18] evaluated the levels of stress among leading managers in Brazil, obtained a mean score of  $2.42 \pm 1.13$ .

Specifically, occupational stress can be defined as the process in which the individual perceives demands of work the stressors, which, when exceeding their coping ability, provoke in the negative worker reactions [3]. Regarding stressors, insufficient time to perform the work volume was identified as predominant; deficiency in professional training activity; and deficiency in the dissemination of information about organizational decisions. It can be seen that, in addition to the excess of work that often prevails in managers in the commercial area in the search for goals, the complexity in the scenarios that are presented by the constant changes in the socioeconomic and technological scenario directly affects the exercise of the function constantly requiring new training. It is important to note that the managers perceive as deficient the disclosure of the information coming from the decision process, appearing a contradiction in the exercise of a function responsible for linking strategies to operations [14, 15].

## 4.2 *Job Satisfaction*

The average score of the five dimensions of job satisfaction was found to be higher in the satisfaction dimension with colleagues (4.70), followed by satisfaction with the boss (4.69), satisfaction with the nature of the work (4.67), satisfaction with promotions (4.12) and, finally, satisfaction with salary (3.83). Thus, in the first four dimensions, the mean score was classified with a degree of satisfaction denominated state of indifference and as tendency to dissatisfaction in the satisfaction dimension with the salary.

In fact, 58% of Brazilian commercial managers are dissatisfied with the salary. This perception, which frequently appears in satisfaction studies, is broader and requires reflection, since, like other leadership functions, the remuneration of the commercial manager is usually among the highest salary levels of the organization. It can be seen that more than the absolute value, the relation of remuneration is associated with the time and effort required for the performance of the function, as well as the professional capacity and the question of career opportunities.

In terms of satisfaction with promotions, it is important to note that despite having already achieved a leadership position that is part of the bottleneck of opportunities in the hierarchy of organizations, there is an expressive number of people who tend to be unsatisfied (40.4%), which may indicate a desire for career development within the company.

Approximately 54% of the respondents showed a tendency towards boss satisfaction, although a tendency to dissatisfaction (22.8%) also occurred, higher than in the satisfaction dimension with colleagues, indicating that an expressive number of managers may present difficulty positive interlocution with the upper hierarchical level.

## 4.3 *Correlation Between Job Stress and Employee Job Satisfaction*

As shown in Table 1, stress has a negative correlation (i.e., the lower the job satisfaction, the higher the stress) and statistical significance in the five dimensions of job satisfaction: stress and satisfaction with colleagues ( $p = 0.009$ ); stress and satisfaction with management ( $p = 0.000$ ); stress and satisfaction with the nature of work ( $p = 0.000$ ); stress and satisfaction with promotions ( $p = 0.000$ ) and stress and satisfaction with salary ( $p = 0.000$ ).

Considering the statistical significance between stress at work and the five dimensions of job satisfaction, as measured by Spearman's correlation coefficient, which indicated a negative correlation, the null hypothesis (H0) was rejected in favor of the alternative hypothesis study (H1). Therefore, it is suggested that the level of stress is inversely proportional to the degree of satisfaction with the work, i.e., the higher

**Table 1** Correlation between occupational stress and job satisfaction

Occupational stress	Satisfaction with colleagues	Satisfaction with management	Satisfaction with the nature of work	Satisfaction with promotions	Satisfaction with salary
Spearman rank correlation coefficient	-0.243	-0.461	-0.464	-0.451	-0.371
<i>p</i> -value	0.009	0.000	0.000	0.000	0.000

the level of stress, the lower the degree of satisfaction at work and the lower the level of stress, the higher the degree of job satisfaction among Brazilian commercial managers.

## 5 Conclusion

Individuals who occupy the position of commercial managers and feel indifferent to the nature of the work point out the need to work on issues that transcend the financial relationship and reach the dimension of meaning, purpose, and engagement in the exercise of the function of commercial manager. Statistically, it has been proven that the lower the job satisfaction, the greater the stress, impelling reflections on practices and policies that focus on the satisfaction of the individual in his work environment, in order to optimize personal well-being and, consequently, performance and the organizational image itself. For future research and in order to overcome the limitations of this study, it would be interesting if this same systematization be applied in other areas, allowing a comparative study.

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# Exploring Complexity in Sustainable Biomass Supply Chain Management



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and Francisco Gaudêncio M. Freires

## 1 Introduction

A complex process or phenomenon is defined by interrelated and interdependent phenomena where human and organizational identities are built over time. They are characterized by efficiency/effectiveness, control, optimization and cooperation situations which create surprising responses and, sometimes with some degree of predictability [1]. Therefore, efficiency (doing things right) and effectiveness (doing the right things) are elements of strategy in supply chain performance. They are related to the pursuit of management, coordination, control and cost reduction within organization.

On the other hand, systems approach is used to describe a set of processes, methods and practices that aim to affect systemic change. This approach can help organizations to better manage complexity by striking a balancing between simplification (focusing on the intended outcome) and complexification (tackling multiple factors within a system at the same time). Likewise, it also requires building internal skills into organizations to help them face and adapt to new administrative boundaries in a holistic approach [2].

This paper presents an analysis of the complex systems in the context of the supply chain of renewable energies, i.e., Biomass Supply Chain considering an overview of

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the main works published between 2007 and 2017 on biomass supply chain complexity. Although the literature is scarce, this work shows the importance of systems approach considering: (i) improving the understanding of supply chain in biomass energy and (ii) developing a model for understanding the complexity in the biomass supply chain. This study represents a novelty in the analysis of the supply chain in biomass energy using systems approach, highlighting that complex systems modelling by applying system dynamics methodology provides harmony between its subsystems and processes, and understanding the system behaviour [3].

It is important to note that due to the nature of the research, a particular case study on biomass is not discussed. Therefore, this work proposes a framework to identify variables and supply chain flows, as well as analyse and simulate the behaviour based on the biomass supply chain complexity according to the proposed model using a system dynamics approach. This model is based on the seven complexity drivers identified in the biomass supply chain with the aim to improve the supply chain management behavior focused on a complexity perspective. On the other hand, significant opportunities exist to increase supply chain efficiencies through technology transfer and learning-through-doing with the aim to stimulate renewables deployment and integration [4, 5].

This paper is divided into seven sections. A brief review and discussion of the topics of this paper are presented in Sect. 2. Sustainable biomass supply chain is presented in Sect. 3. Section 4 presents the method adopted to select the references and organize them according to the focus on the complexity in the biomass supply chain. Descriptive analysis and framework of analysis are presented and discussed in Sect. 5. A summary and a proposed analysis model are presented in Sect. 6. Finally, conclusions, recommendations and future research are presented in Sect. 7.

## 2 Basic Concepts

Sustainable energy systems are considered complex socio-technical systems because of their interaction with various elements of the value chain, which allows them to develop, operate and maintain a diverse technical infrastructure. In a renewable energy system, e.g., there are institutional actors, which determine the regulations of the sector, as well as the controls for a better performance of the sector and its various processes [3].

On the other hand, complex systems modelling was based on systems theory, which is well established in engineering and biological and physical sciences because it is a convenient and useful way of seeing a whole as a collection of its interacting parts [6]. A branch of systems theory that recognizes the role of positive and negative feedback, in which systems can deviate from control, as in virtuous or vicious cycles, and in which systems can be kept within bounds, respectively, is the system dynamics [6]. Supply chain design in the energy sector is a process which requires a level of customer service with a high complexity status. Therefore, this research intends to

give an introduction about the complexity of the supply chain in the biomass process as a result of the data analysis collected in tertiary sources.

## 2.1 *Complex Systems*

Although there is no consensus on the definition of complexity, it is accepted that complex systems generally share some interrelated attributes, such as a large number of elements, emergent properties, nonlinear dynamics, feedback cycles and adaptive behaviours [7]. Complexity theory emerged at the beginning of the 20th century as an area of research in science (i.e., Biology, Chemistry, Physics, Philosophy, Mathematics, etc.), gaining interest in the systematization of meteorological studies. In the course of the same century, complexity theory led many researchers to realize that Newtonian linear causality (i.e., cause and effect) was not enough to explain primarily natural and social phenomena [8]. Complex systems are a set of parts that interact with each other through self-organization, but their result or external behavior is unpredictable [9]. In order to help organizations improve strategy and planning and contribute to the application of complexity theory, some models have been created [10].

In the context of this article, the biomass supply chain is considered as a complex system formed by a set of subsystems that interact with each other. This is because the biomass supply chain presents particular behaviours and practices, which can interact with indifferent ways of complexity, compared to other supply chains, e.g., the food supply chain [11]. Therefore, system dynamics becomes the tool to model and analyse the biomass supply chain due to its characteristics related to complex systems.

**Complexity in supply chain management.** Some authors agree that complexity is related to the number of elements within the chain, the variety of business processes, and the number of interactions among its elements which are driven by internal and external entities or drivers [12, 13]. Management decisions, as well as the tendency of organizational systems to create complexity are considered internal drivers, while demand uncertainty and high market dynamics are classified as external drivers [14]. On the other hand, an approach from complexity theory allows analysing the effects of strategies and activities in the system with the objective of recognizing some periodic and existing conflicts in the chain. Thus, the supply chain can be influenced by different types of natural and human resources, as well as by the social aspects in which the system operates [15].

It is well known that supply chain management ensures that the right items are in the right place at the right time and in the right quantities. Therefore, the study and analysis of complexity in supply chain management can identify, e.g., how many suppliers there should be and where, as well as production facilities, distribution centres, logistics companies, among others [16]. Thus, the goal of supply chain



management is to collaborate with all partners in the supply chain to improve visibility and speed of inventory.

### 3 Sustainable Biomass Supply Chain Management

Renewable energy resources are huge and fickle. For example, weather conditions and other environmental factors make resources dependent. Like many typical supply chains, elements of the renewable energy supply chain include physical, informational and financial flows [17, 18]. From the perspective of the physical flow, companies have increased the use of the sustainability concept in their manufacturing processes, logistics and product development with the objective of improving supply chain performance [18].

Biomass is obtained from a variety of sources, such as organic matter derived from living organisms, as well as from forest residues, crops, seaweeds, wastes from agricultural and forestry processes, and industrial, animal and municipal wastes. Similarly, conversion methods are diverse and depend on various factors, such as the type and amount of biomass, environmental standards and financial resources [11]. Biomass can be used to produce renewable electricity, thermal energy, or transportation fuels (biofuels) and it is the only source of fuel for domestic use in many developing countries.

#### 3.1 Operational Components of the Sustainable Biomass Supply Chain

Biomass supply chain management involves different actors that must interact with each other for providing adequate performance in all processes. Biomass suppliers, transportation and distribution entities, bioenergy production facilities, government and service companies who provide the incentives and the end users are some of the most important in the feedstock-to-bioenergy pathway. Due to the above, and despite the variety of paths that can be followed to convert biomass into bioenergy, Fig. 1 shows the main steps involved in the supply chain configurations [19, 20].

The complexity of the biomass supply chain involves aspects such as its variability, related to the availability and supply of feedstock, climate and seasons, the fluctuating chemical and physical properties of biomass, the geographical distribution and low transport density of feedstock, the local transport system and the distribution of



**Fig. 1** Biomass supply chain operational components

infrastructure, as well as the inconsistent demand. Due to the large number of stages that comprise the biomass value chain, biomass supply chain management focuses on managing the uncertainty in biomass source and availability, assuring the supply chain decision-making process [17].

**Biomass supply chain management modelling.** There are three main levels of decision-making in supply chain management: i.e., strategic, tactical and operational level [20, 21]. On the other hand, mathematical optimization techniques have been the most used in the planning, design and analysis of biomass supply chains, such as: mathematical programming (e.g., linear, nonlinear, integer and linear mixed integer), heuristic methods (e.g., genetic algorithms), multi-criteria decision analysis and the hybrid model [17, 18, 22]. Simulation optimization approaches allow for a quick, economical and nondisruptive assessment of a large number of scenarios, while providing decisions that can be implemented in a real-world situation. The pure optimization models are not able to capture all the uncertain parameters nor the dynamics of the system, so the simulation models provide solution to the problems related to the modelling of the biomass supply chain [3, 18].

In recent years, the use of different approaches of models of the biomass supply chain for understanding complex renewable energy systems have created the need to develop integrated frameworks in order to reduce uncertainty [11, 23]. Thus, some problems related to the level of complexity of multiple interactions involving economic, environmental and social elements, as well as critical components, such as performance and cost evaluation, have not been treated with traditional methods based on operational research [3].

## 4 Methodology

This paper is based on the bibliographical and documentary study and content analysis and synthesis of relevant literature considering the following topics: complex systems, complexity in the supply chain, and the supply chain of biomass [24]. Thus, this article took advantage of a review of the narrative literature, which was mainly from secondary sources and documents from selected sites, among them: WBA (World Bioenergy Association); REN21 (Renewable Energy Network); IRENA (International Renewable Energy Agency); and IEA (International Energy Agency). However, some primary sources of literature—such as peer-reviewed journal articles—were also considered based on the methodological process of content analysis [3, 25]. To collect a reliable number of articles, were selected the Scopus database using the following protocol: (i) define the keywords; (ii) define the unit of analysis and determine the criteria for inclusion and exclusion of documents; (iii) collection of publications; and (iv) evaluation of the quality of the content analysis.

Based on the previous protocol, (i) two groups of keywords were selected: the first group assembled the keywords related to the biomass supply chain, i.e., (“biomass

supply chain” OR “biomass logistics”), and the second group grouped the keywords in relation to complex systems: (“complex\*” OR “complex\* theory” OR “complex systems”); (ii) the unit of analysis defined for the research was only the research article, and the review focused on peer-reviewed journals written in English between 2007 and 2017 in the field “title, abstract, keywords” (conference papers, trade publications, books, book chapters, full content access denied, and theses were excluded).

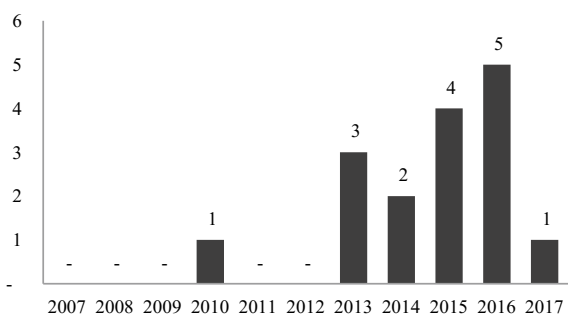
In the next step, (iii) and based on the keywords and the eligibility criteria, 27 articles were found. The abstracts of the 27 articles were analysed in the light of an exclusion criterion: articles in which the terms “biomass supply chain” or “biomass logistics” were not used in the sense of the research question were excluded (e.g., refining, biorefinery, production systems, p-graph). As a result of the application of these criteria, 11 articles were excluded and 16 remained for review and analysis. The objective of this process was to determine more broadly the articles focused on the supply chain of biomass, excluding those whose focus did not meet the objective. Finally, (iv) the complete contents of the 16 articles and documents from selected sites were examined based on the content analysis. The results and extended methodology are discussed in Sect. 5.

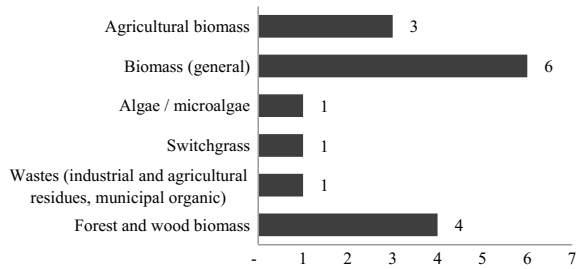
## 5 Findings and Discussion

### 5.1 Descriptive Analysis

Relevant articles are those that implicitly or explicitly elaborate on the concept of complexity in the supply chain, as well as factors (or drivers) in the development of the bioenergy sector. Figure 2 infers importance in the topic of the bioenergy sector and the performance of its supply chain in the last years. For example, risks are the principal barriers to investment in bioenergy technologies. This is because of the risks associated with the need to provide for the long-term supply of feedstock at an affordable cost and which meet appropriate sustainability criteria [5].

**Fig. 2** Distribution of papers over the time period from 2007 to 2017



**Fig. 3** Feedstocks in bioenergy production

On the other hand, the bioenergy production raw material discussed in the articles is diverse. Biomass and forestry, algae and microalgae, agricultural biomass and waste (industrial, organic, agricultural and energy crop residues) are among the types of raw material most used in the production of bioenergy (see Fig. 3). This is related to the growing demand for biofuels worldwide and the search for new sources of energy that do not affect food production and the need in understanding the importance of the sustainability criteria in their production [5, 26].

**Framework of analysis.** This article was initiated by a narrative literature review [24]. Sources of literature were mainly selected from secondary sources (e.g., important sites about renewable energy). The purpose of exploring the main reports was to be familiar with the main concepts, theories and themes about the sustainable biomass supply chain and its complexity. This literature formed the basis for the article and then focused on the research question with content analysis as the main method used. According to the content analysis, articles and documents were reviewed based on other work related to complexity in the supply chain in various sectors, e.g., [6, 27–29]. Therefore, the main factors (drivers) determining the performance of the biomass supply chain were identified. The purpose of this review is to deepen the current state of the biofuels market in the world from biomass. The following sections present the proposed analysis structure for the identification of the main factors of complexity in the biomass supply chain.

**Complexity drivers in sustainable biomass supply chain management.** Complexity in the supply chain increases as trends such as globalization, sustainability, innovation, and business flexibility also occur [28]. Increasing complexity in most industries has been a challenge for companies and the main reasons are attributed to the company's internal and external sources [29].

In recent years, organizations have found that managing their supply chain has led to a reduction in overall costs, improvements in service levels, better quality insurance and customer satisfaction; thereby giving the organization a competitive advantage [28]. Today's literature on the complexity of the supply chain is generally limited, and in the case of biomass, this research is intended to be the first for research. The literature review provides a broad consensus that no model fits all purposes. The way to approach complexity in the supply chain depends heavily on the type of complexity and where the supply chain is located.

**Table 1** Overview of the complexity drivers identified in the literature

Driver	Environment			Complexity type			Intercon.
	Int.	Interrel.	Ext.	Static	Dynamic	Decision	
Multiple types of biomass		X	X		X	X	X
Uncertainty	X	X	X		X	X	X
Process-related	X			X	X	X	X
Supplier-related	X	X		X		X	X
Distribution network		X			X		X
Market size		X	X		X	X	X
Production-related	X	X	X		X	X	X

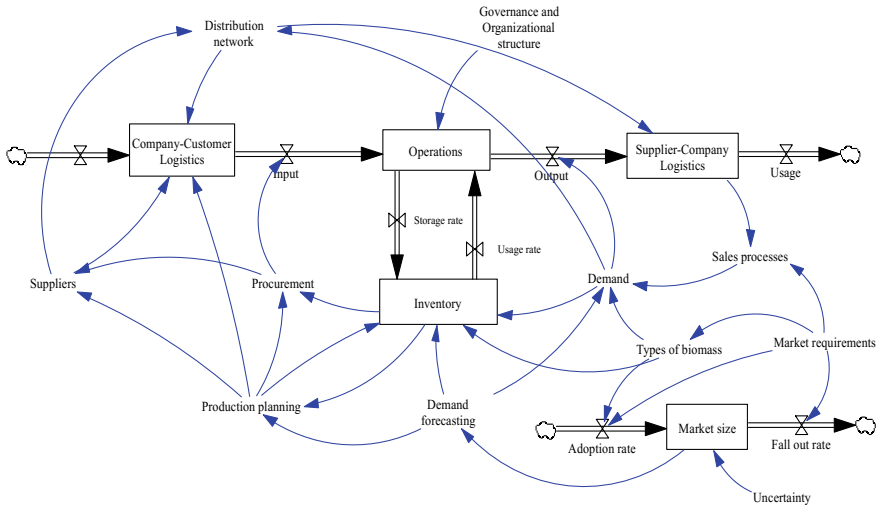
Considering the identified drivers, these may be associated with different types of biomass used in the supply chain processes. In the case of the waste industry and the forestry industry, logistical costs and the variety of processes and suppliers are considered the main drivers. In other cases, the supply chain faces uncertainties, which are sometimes related to biomass demand, production planning and logistic processes for storage, transportation, distribution and location [30–33].

Based on the analysis of the literature and the work presented by Serdarasan [28], this article presents an overview of the different drivers that are present in the biomass supply chain. The goal is to manage or tune drivers to handle dynamic complexity by centralizing and automating decision-making. On the other hand, the complexity of the supply chain accelerates with trends such as globalization, sustainability, customization, outsourcing, innovation and flexibility [28]. Therefore, Table 1 provides an overview of the different drivers that have been identified in the literature, classified by their environment (internal, interrelated, external), type of complexity (static, dynamic, decision-making), and their interconnectivity.

## 6 Summary and Proposed Analysis Model

In the process of developing and commercializing biofuels three objectives are highlighted: first, to produce sustainable fuels that can offer more life cycle carbon savings; secondly, to produce fuels with less impact on land use (e.g., agricultural and/or industrial waste), reducing competition for food or productive agricultural land; and, finally, to produce biofuels with properties that allow them to directly replace fossil fuels in advanced transport systems (e.g., aviation engines), or to be mixed in large proportions with conventional fuels [34, 35].

One of the most used biomass sources in recent years has been forest biomass, and its main factor of use has been the search for new sources of energy different from that of the first generation, such as those related to food [4, 26, 35]. Several studies have implemented optimization models that have proved to be ineffective in



**Fig. 4** Proposed model for complexity analysis (based on Afandi and Hansen [42])

dealing with the complex dynamics of the supply chain, and it has been necessary to integrate or use other tools for their analysis [30, 33, 36–41].

Based on the results presented in the previous section and based on the work of Afandi and Hansen [42], it is possible to structure a system dynamics model that describes the interrelationships and interconnectivity of complexity drivers. The model is built on Vensim PLE and illustrates how complexity drivers at different stages of the supply chain influence both positively and negatively. Figure 4 presents the basic model based on the analysis of complexity in the supply chain [42].

This model represents the main variables and flows of the biomass supply chain, and its objective is to simulate the behavior based on the complexity drivers identified, as well as to develop the model in any particular biomass supply chain according to the structure proposed by [3] as a methodology for applying the system dynamics approach in this type of supply chains.

## 7 Conclusions and Recommendations

Complex systems have been studied initially in the natural sciences and over time have been adapted to different applications in the various areas of knowledge. All these concepts provide useful information to understand the issues from the social sciences to the financial markets. Therefore, this theme offers a broader perception to address situations involving variables at the time of management decision-making and to analyse economic entities. According to the information previously mentioned, the supply chain is linked to complex systems, considering its structure, its

autonomy, the way of self-organization that works and the capacity that it has to face the challenges. In the addition of the above, a digital transformation in the biomass supply chain industry is required to integrate different technologies in renewable sector and, in this way, mobilize sustainable biomass feedstock supply in the future.

Through the analysis of the literature, this paper identified and explained the main topics about the supply chain of renewable energy, as well as practices related to its complexity, mainly biomass. On one hand, in supply chain analysis, agent-based models and dynamic network models are beginning to be applied to power systems. On the other hand, traditional mathematical modelling approaches have proven to be ineffective in dealing with dynamic and complex supply chains and the interaction between the up and downstream needs of the system. Therefore, system dynamics is the tool that describes the interrelationships and interconnectivity of complexity drivers identified in the literature.

Due to the nature of this paper, a case study was not discussed. This was the main limitation of the research, since validating the information in the real sector was not the focus of this paper but it could be part of future work in the area or as a research agenda initiative. This research aimed to identify and propose a framework for managing the main complexity factors and how they influence the three main business areas of the supply chain, i.e., upstream, downstream and internal processes of the company. It is important to emphasize that this proposal is not intended to be exclusive to academia, but rather to be used in managerial decision-making without a mathematical rigor or the complexity of models that require large amounts of information to solve problems. Therefore, for future work, analysing a biomass-specific supply chain, e.g., forest or waste industry, is an opportunity to validate the model.

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# Supply Chain Governance: A Study in Wineries from Brazil and Spain



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## 1 Introduction

The globalization of the economy, the technological advances and the increase of the complexity in the transactions apply competitive pressure for the organizations to adopt management strategies in order to improve the delivery format of their products and also their interaction with the Market. These strategies and finding new ways of competing in the market consist of a differential and also a way of survival for the organizations, as they provide greater flexibility and adaptability to them.

Since the 1980s, a number of scholars are attempting to understand the shifts in supply chain business, attributing changes to the closeness of the relationships between member firms in the chain [5, 6]. This means that organizations do not act alone, but rather seek long-lasting relationships and interactions in a supply chain seeking to gain competitive advantage when facing market challenges [15, 22].

One way to deal with these problems is to have supply chain governance with balanced decisions in the best interest of each organization and autonomous decisions of decision-makers, which contemplate all members of the chain [23]. Governance enables organizations to increase the satisfaction of their stakeholders through a collaborative relationship in the supply chain, ensuring that products and services are in the right quantity, place, time, and in the desired conditions. Governance

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contemplates the analysis of relationships between organizations, their structures and processes in a multidimensional way [13]. When it comes to family businesses in the wine industry, this is essential, since it impacts on the quality of the product and, consequently, on customer satisfaction.

Even though Supply Chain Management (SCM) and governance are widespread, there are still few studies focusing on governance analysis in the supply chain. The articles on SCM are concentrated mainly in the developed processes and in the activities of support and not in their strategies and management of companies [14, 19].

Thus, we intend to answer the following question: How are the Brazilian and Spanish wine supply chains structured, and also, how are their governance relations? Therefore, the aim of this study is to map the Brazilian and Spanish wine supply chains and their governance structures, so that wineries can seek greater competitiveness, both individually and in their supply chains.

In order to reach the objective proposed in this work, we start with bibliographical research based on the qualitative methodology and the research technique of in-depth interviews in small, medium and large wineries with Designation of Origin in Brazil and Spain. This work is divided into five sections: (i) this first one, which is introductory; (ii) the second one reviews the literature on supply chain management and governance; (iii) the third one describes the methodology and stages of the work; (iv) the fourth one presents the results of the research; and (v) the fifth is for the main conclusions, followed by the acknowledgments and references used in this study.

## 2 Theoretical Framework

### 2.1 *Supply Chain Management*

SCM is a philosophy that has spread since the 1990s, after the introduction of just-in-time (JIT) in production systems, highlighting the importance of strategic relations and cooperation with suppliers [25]. The relevance of the SCM in studies and organizations is due to globalization and the emphasis on competitiveness based on agility and quality to survive in a market with many uncertainties [18]. The authors assert that this competitive scenario causes organizations to be concerned about the management of the materials flow, resources, products and information being effective and efficient, both internally and among member companies in the supply chain. This new SCM environment is increasingly becoming part of the future of organizations, based on the increase of consumer demands, market competitiveness, technological evolution, and shortened product lifecycles [7, 11]. Demand becomes more and more unpredictable, with companies seeking to reduce costs to increase their participation in a competitive market and consequently the return on their investments.

However, there are still disagreements regarding the concept and scope of the supply chain. For [3, 4], the supply chain implies activities related to the logistics

of several companies, constituting an extension of business logistics. As to [16, 17], the supply chain has broader coverage than logistic activities, covering strategic and managerial functions.

It can be said that the supply chain includes the extraction flow of raw materials, going all the way through manufacturers, wholesalers, retailers, to end users [20]. From another perspective, the supply chain can be seen as a set of processes that go from one extreme to another in organizations, relating upstream and downstream processes of a focus company or focal company, whose members interact directly from the point of origin to the point of consumption [11, 16]. Key supply chain processes are established as [8]: customer relationship and service; demand management; processing of orders; production flow management; purchases/supplies and; Development of new products.

SCM aims at the satisfaction of the final client, performing interrelated actions, in which all those involved in the chain are committed. SCM is an integrated way to plan and control the flow of materials, information and resources, from suppliers to the end consumer, involving the different activities that add value to consumers, developing a beneficial relationship for all the ones involved along the supply chain [7, 8, 18].

SCM can also be conceptualized as a strategic and systemic coordination of traditional business functions and their strategies among and across companies in a supply chain, with the objective of improving the long-term performance of individual companies and the supply chain as a whole [7, 18].

Therefore, companies, in order to obtain better performance and remain in the market, seek, through SCM, to reduce the costs of their operations and to add value to the customer, attending to their needs with agility from the processing of the order to the delivery of the product, along with the flexibility and availability of the product at an affordable price and which makes use of a network of allied associations for the SCM.

## 2.2 Governance

Governance can be defined as the coordination of activities [12] in terms of hierarchy and leadership or their opposites—collaboration and cooperation [24], thus, governance structures can be considered organizational forms [2]. Governance “comprises both the way work is organized and the means by which it is coordinated” [1]. The word governance is used when it refers to “the processes of coordination among the actors of a given productive system, in its various areas of relationships, i.e., between the public and private sectors, at local, regional or global level” [21].

In the literature there are several approaches to governance, in which it is possible to establish structures to coordinate economic activities, making them strategic and fundamental for competitiveness. For [9], governance structures can be (Table 1): (i) market (through the price system); (ii) hierarchy (vertical integration), which

**Table 1** Types of coordination of economic activities

Williamson	Jessop	Gereffi	Humphrey and Schmitz
Market	Anarchy of exchange		Relationships through the market
	Self-organization	Chains managed by the producer	
Hybrid	<ul style="list-style-type: none"> <li>• interpersonal connection</li> <li>• self-organization between organizations</li> <li>• targeting between systems</li> </ul>	Chains managed by the buyer Chains managed by information	Network Almost hierarchy
Vertical integration	Hierarchy		Hierarchy

Source [2]

is based on the total ownership of the company’s assets, i.e. the internalization of all resources; (iii) hybrid (contractual), based on contracts and networks of partial assets properties among companies located in successive phases of the production chain [2].

This approach serves to analyze a company and how it is organized to obtain the materials needed for its operations and distribution, as well as how the business network defines its organizational structure. Thus, in the value chain, five types of governance were established [10]: (i) market; (ii) modular value chain; (iii) relational value chain; (iv) prison value chain; (v) and the hierarchical value chain. These types have arisen to assign different values to three main variables: (i) the complexity of intercompany transactions; (ii) the level at which this complexity can be attenuated by coding; (iii) and the extent to which suppliers are able to meet buyers’ requirements. For the authors, these types of governance say whether the level of coordination and asymmetry of power between buyers and suppliers is low or high.

This way, the great challenge of organizations is to develop their capacity to coordinate their relations with other companies, maintaining in their operations activities capable of generating competitive advantage and low transaction costs. In addition, other companies in the chain must be efficient and effective in carrying out the activities of their responsibility, minimizing the total cost of the supply chain.

## 3 Methodology

### 3.1 *Methodological Classification*

The research method adopts the dialectical methodology, understanding the work as a process of production of knowledge and application of this reality. This study is classified according to the following criteria [26]:

- Regarding the ends—descriptive and applied research, seeking the search for the collection and understanding of specific problems related to society or phenomena, with practical purpose;
- Regarding the means—field research based on empirical research within wineries in Brazil and Spain;
- Regarding the nature—qualitative research, with the purpose of describing the system, its strategies and meanings.

Furthermore, several research procedures were developed in order to collect the necessary information for this study. This research can be divided into two parts: (i) structuring; (ii) data collection and analysis of results. The structuring part refers to the introductory part of this study, constituting of bibliographical research and elaboration of the interviews to be realized within the wineries. The part of data collection and analysis of the results was performed through the selection of the wineries that participated in this research, interviews and data processing.

### 3.2 *Selection of the Interviewed Companies*

Family companies belonging to the Designation of Origin (DO) of the wine sector of Brazil (“Vale dos Vinhedos”—located in the South) and Spain (“Montilla Moriles”—located in Andalusia—South) were selected. In the case of Brazil, data were used from the Association of Producers (APROVALE) and DO, since the DO of the Vale dos Vinhedos is the only DO of the segment in the country. In the case of Spain, the SABI business database was used to discriminate, which was also due to the opportunity.

In the empirical study, 6 companies (3 from Brazil and 3 from Spain) participated, based on the size of the winery (small, medium and large) in terms of production volume. After selecting the wineries participating in the research, on-site interviews were conducted with family or nonfamily directors, in October 2016 in Brazil and in March 2017 in Spain.

### 3.3 Data Collection and Analysis

The data used to carry out this study come from secondary information about wineries, based on data base or information from DO, industry publications, company web pages, among others. The in-depth interviews were made with the managers of the selected companies, whose questions were related to the DO, family companies, governance structures and supply chain.

During interviews by the authors of this study, we chose to record them, for subsequent transcription and in order not to lose any necessary information for the study. From the data collected, the mapping of the wine supply chain of Brazil and Spain was made and the form of governance adopted by these supply chains was established.

## 4 Results

It is important to emphasize that the wineries interviewed are family businesses and that only wine was considered for this analysis. The supply chain of wines in Brazil and Spain, upstream and downstream, i.e., towards the supply and final consumers, was analyzed from the focus company (winemaking), as it can be seen in Fig. 1 (Brazil) and Fig. 2 (Spain).

In Brazil, the wineries, regardless of their size (small, medium or large), produce their raw materials (grapes), buying from other producers only when they cannot grow the necessary volume for their wine production. In addition, they do not sell the must to other wine-producing companies, but rather pass on/sell to other companies producing other types of products, such as juice, jellies, moisturizers and other health and beauty products, among others. Therefore, in general, the wineries hold the entire upstream supply chain and the downstream part is restricted. The products are sold predominantly in the wine House itself, another portion is distributed in the domestic market (supermarkets, restaurants, retailers, delicatessen, among others) and a very

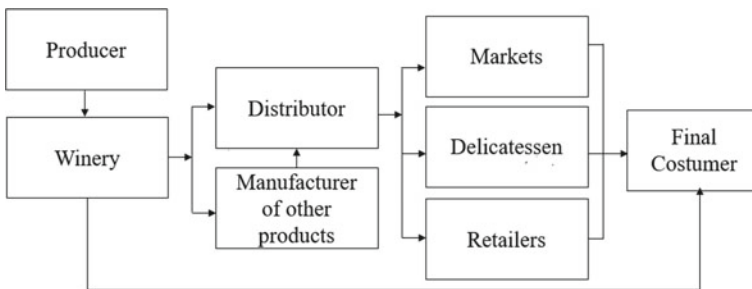
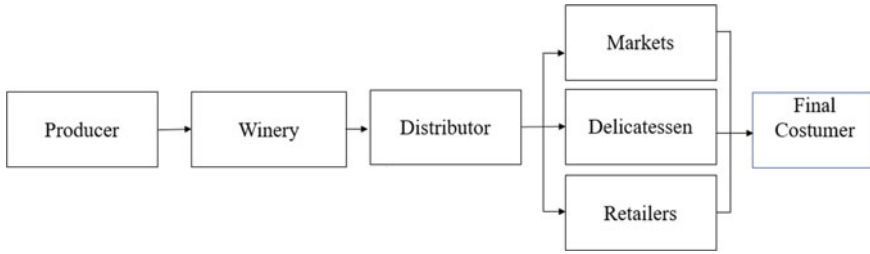


Fig. 1 Supply chain in Brazil. Source Authors



**Fig. 2** Supply chain in Spain. *Source* Authors

small portion is destined for exportation. It should be noted that Brazilian wineries are just turning their strategies to foreign trade, since their production is consumed internally and fomented by wine tourism.

Unlike Brazil, in general Spanish companies, (in the case of wineries interviewed), regardless of size, produce wine from grapes supplied by the members of the chain, or from pre-products produced by other companies. After the processing of its products, the commercialization is made to supermarkets, restaurants, retailers, delicatessen, among others, or as raw material (must) to other manufacturers that will produce their wines and sell in the market until the wine is distributed and marketed by the final consumer. In relation to the Spanish wineries interviewed, only the large ones market their products in the international market, the others only intend to do so. This way, along the mapped supply chain, various forms of coordination of economic activities (governance) were identified.

In the upstream part of the supply chain we noticed that the inputs/raw material are unique and specific (grape), and that the transaction is direct with the wineries or with manufacturers in the case of the wineries that buy pre-products. With regard to the power exercised by the companies in the supply chain, it can be stated that, in the companies interviewed, the closer to the final consumer the more power companies have, since these can influence the consumers' buying decision.

In the downstream supply chain, wineries have a direct relationship with market intermediaries, especially with distributors, ones who make the wine reach the supermarkets, delicatessen, retailers, among others, so that the consumer can have access to the wines. As for the governance, it can be said that there is regularity in the distribution and sale of products, which are also affected by the national and global economy. Relations between those involved in the supply chain are through means of the market or contracts, however, ensuring a relationship of friendship and closeness among the members of the chain. In Spain, such relations, especially with producers, are based on contracts, whilst even maintaining friendship and proximity, signing contracts ensures security in transactions.

In fact, the relationships between competing wineries are quiet and friendly, especially in Brazil, since most of them consist of a large family that has divided and decided to produce individually, manufacturing different and specific products, depending on the taste of the consumer. The differential for customers is the produc-



tion mode, which guarantees distinct quality and taste, the aging of the wine and the techniques used until reaching the product that will be marketed.

Regarding the distribution and sale process, it can be said that it is complex for wineries, since after the products leave the company to depend on the care of distributors, storage in supermarkets, delicatessen, retailers, among others. In Brazil, mainly, the wineries prefer direct sales to the final consumer through wine tourism or e-commerce, because in these cases it holds practically the whole chain of supplies upstream and downstream. To avoid potential problems, wineries establish close and direct relationships with all members of the chain, especially with supermarkets, delicatessen, retailers, etc. and also with consumers.

Based on what has been presented, it can be defined according to theories of governance that the type maintained by wineries and other members of the supply chain is hybrid, no matter what size of the company, since the size only differentiates them in terms of marketed volume and competitiveness, without changing the form of coordination. This is because there is an interpersonal connection and self-organization among companies, directing the actions performed by and between the systems.

## 5 Final Considerations

The mapping and verification of the coordination of economic activities allowed the study of small, medium and large-sized wineries in Brazil and Spain and, thus, conclude that they establish contractual relations, but always maintaining the relations of friendship and proximity with the other members of the supply chain.

The main difference between the Brazilian and Spanish wine supply chains is that Brazilian wineries usually hold the upstream part of the chain, while the Spanish wineries studied acquire raw materials from other producers. The focal company (winemaker) coordinates the upstream and downstream chain since it produces and transforms raw material into final product.

This study enabled us to show how the wine supply chain of one DO in Brazil is structured and how another one is in Spain. Although the development and structuration of operations in Spain are more advanced than in Brazil, the way the wineries operate in the market is almost the same, as well as the coordination of economic activities.

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# Productivity Increase in a Cellular Battery Line Using Lean Kaizen and Tools



Roberto Cartwright Brodie Murayama , Marcelo Duarte Vieira , José Carlos Reston Filho  and Rui M. Lima 

## 1 Introduction

The Brazilian electronics consumer market grows promising each year. This expansion culminates in greater customer expectations for better technological products at lower prices. Due to this, industries quest to reduce costs and eliminate wastes, Aoki [1]. Through a study of line balancing and Kaizen applications, many companies continue to achieve increasing profits growths. This article depicts the application of this principle, applying Kaizen methodology and lean manufacturing tools in a cellular battery assembly line in a company located in Manaus industrial hub. It was observed that the wastes seen in motion, time, inventory, and low output were reduced while increasing production volume amidst an improvement in line layout and floor space, Cheser [2]. The application of simultaneous engineering among design, maintenance, and process engineering foresaw JIG adaptation and machine adaptations that enhanced material flow and worker performance, Imai [3]. The Kaizen philosophy encourages the employees to make process improvement suggestions and is a cultural enabler, where every department should mutually support each other for the greater good and result, Imai [3]. Arrives at the conclusion that by the applica-

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tion of the Kaizen methodology with the chrono-analysis tool results are optimized, bottlenecks placated and employee engagement flourishes.

## 2 Lean Kaizen

According to Walter and Tubino [4], Lean manufacturing underwent a period of accelerated diffusion in the 1980s and 1990s. According to Ohno [5], lean manufacturing is widely considered the next big step in manufacturing evolution beyond the Ford model. For Bateman [6] the implementation of Lean Manufacturing is the best way to improve internal and external quality performance.

According to Bhamu and Sangwan [7] the concept of Lean manufacturing was generated in Japan after World War II when Japanese industries realized that they could not meet the huge investments needed to rebuild the destroyed facilities. Toyota produced cars with less inventory, human effort, investment, and defects, and introduced a large and growing variety of products. The benefits achieved were lead time improvement, processing time, cycle time, setup time, stocks, defects, scraps, and equipment efficiency.

According to Bayou and Korvin [8], the set of practices relevant to an organization becoming lean are Just-in-Time (JIT), Kaizen and quality management. For Dal Forno et al. [9] the implementation of lean manufacturing requires the involvement of people from the strategic, tactical and operational levels. Dal Forno et al. [9] state that the lean methodology allows the identification of activities that add value and those that are considered material losses and expenditure of information flow and people's time.

For Imai [3], Kaizen is not a philosophical novelty in the industry. The word Kaizen is a Japanese hybridism that integrates the terms Kai and Zen. The first means change and the second means good. The technique originated the middle of the last century through the studies of Masaaki Imai that were published in the book titled "Kaizen: The Key to Japanese Competitive Advantage". According to the author [3], there is the possibility that Kaizen was created within the Toyota Motors Company.

For Cheser [2], Kaizen is the key to promoting improvements that lead to success in competitive markets. Aoki in [1], affirms that Kaizen is a process that guides to continuous improvement gradually. For Melcher et al. [10], the continuous improvement comes from the mapping of processes that allows the visualization of waste. This initializes Kaizen processes. Kaizen combines several waste disposal tools with simple and efficient techniques.

## 3 Process Description—Current State

The manufacturing process analyzed was a cell phone battery production line composed of 19 employees with 23 operations. The line utilized a conveyor belt system which enabled material to flow from one production station to another. The

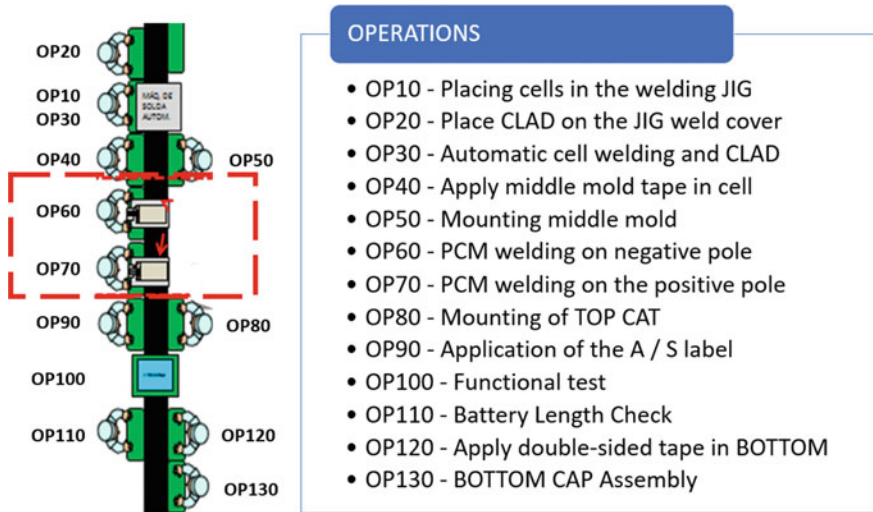


Fig. 1 Process flow detailing manual weld operations 60 and 70. Source Authors

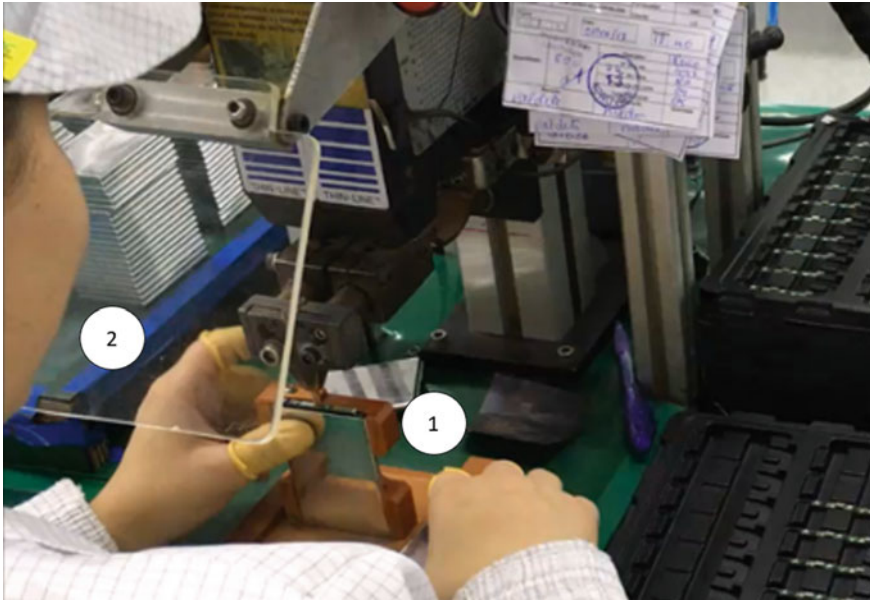
line utilized 19 manual processes and 4 additional steps required the usage of equipment to assemble the product. Production output was 833 units per hour per shift and the plant operated in 2 shifts. Operations 60 and 70, each performing manual weld was the area of the study, shown in Fig. 1.

In Operation 60 an employee was responsible for welding the assembled board to the prismatic cell. He used Myashi Uniteck HF 25 model equipment serial 06060336 with input power 220–240 V, 50/60 Hz to execute the activity. He would pick up the prismatic cell, position it in a holding JIG and apply 0.700 (KA) current for 2 ms welding the negative leads. This operation had an output of 833 pieces per hour and had a Work in Process (WIP) inventory of 90 units.

The assembled part was placed in a table next to Operation 70, which had similar steps. The employee would position the part vertically in the JIG and weld a different area of the board and cell, this time welding the positive leads. This operation was also cadenced with the prior one and its output was 833 pieces per hour. Between both operations, two employees were used. Figure 2 shows the holding JIG (1) and demonstrates the WIP (2) of cells waiting to be consumed in production.

## 4 Method Applied

Plant management, in a search for cost reduction, requested that the process engineers identify opportunities for improvements. The engineering team, composed of two product engineers, two engineer technicians, one mechanical technician mapped out



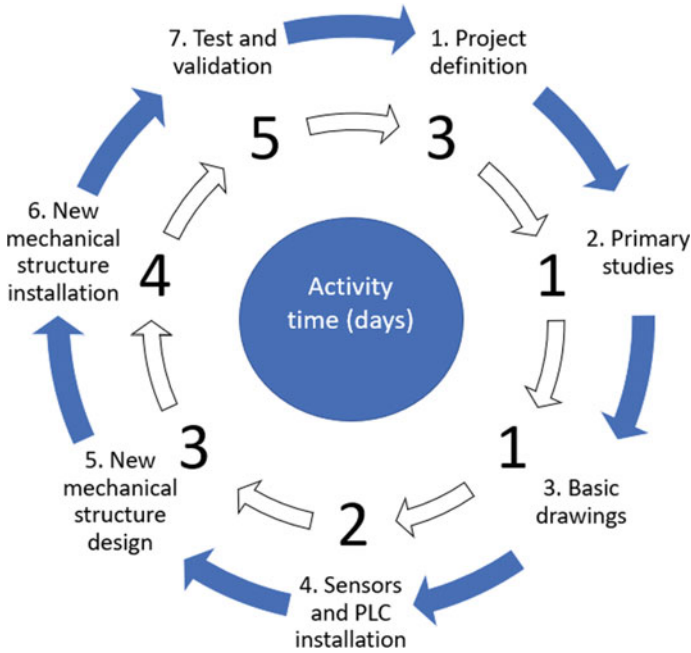
**Fig. 2** WIP inventory prior to operation 60 and positioning JIG. *Source* Authors

the line, identified the bottlenecks as being operations 60 and 70 in that it held the line output at 833 pieces per hour.

The team brainstormed ideas to what could be done to break that bottleneck and identified several action items. The actions included performing a preliminary analysis to the line, they studied the electrical and mechanical interfaces, created new prototype JIGs and tested their solution. The entire process took 19 days. The implementation timeline is depicted in Fig. 3. After identifying the manual welding operation as being the target area, the team analyzed the electrical characteristics of the equipment used and saw that both equipment utilized the similar profile and at different welding coordinates (Table 1).

The next step was to consider the welding positioning JIG as the intent was to combine both operations into one while not losing cycle time. Study was done on the JIG which previously had its welding point fixed and aligned to the region where it should be applied. There was no movement to the part or JIG, only the welding tip moved (lowering to the welding area). Figure 4 shows the JIGS positioning of operations 60 and 70 before the change.

Drawings and prototypes of the JIG were drawn up and a new JIG created, this time allowing lateral movement, left to right, and right to left incorporated mechanically. With this, the operator could pick up the cell, position it into the positioning JIG, pick up the board, and perform two welding steps with less component handling. Figure 5 shows the new JIG.



**Fig. 3** Project timeline. *Source* Authors

**Table 1** Machine parameters

Parameter	Schedule 1	Schedule 2	Min	Max
Initial pressure time (ms)	100	100	50	150
Cycle current 1 (KA)	0.700	0.750	0.6	0.8
Rise time of cycle 1 (ms)	2.5	2.0	1.5	3.5
Welding time of cycle 1 (ms)	2.0	3.0	1	3
Cycle down time 1 (ms)	2.5	2.0	1.5	3.5
Cooling time (ms)	3.0	4.0	2	4
Cycle 2 current (KA)	1300	1500	1100	1500
Rise time of cycle 2 (ms)	2.0	2.0	1	3
Welding time of cycle 2 (ms)	4.0	3.0	3	5
Cycle down time 2 (ms)	2.0	2.0	1	3
Final pressure time (ms)	200	200	100	300
Head pressure indication (bar)	4/4	4/4	3/3	4/4



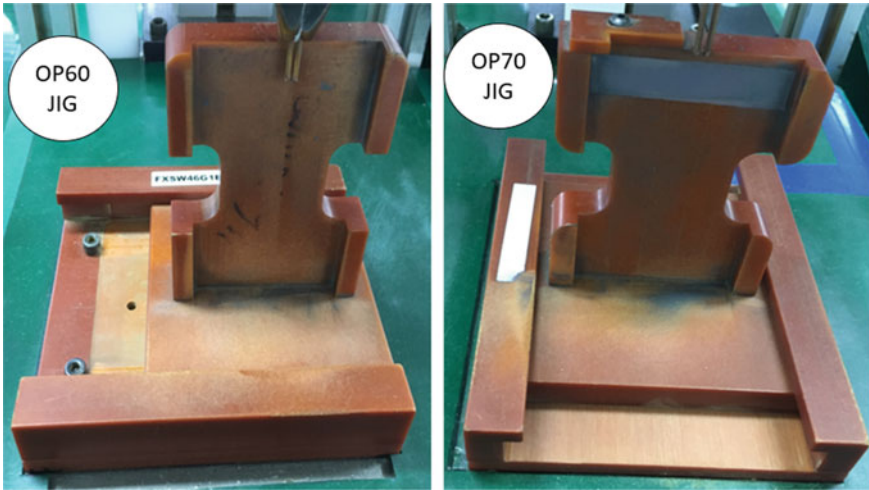


Fig. 4 Positioning JIG before. *Source* Authors

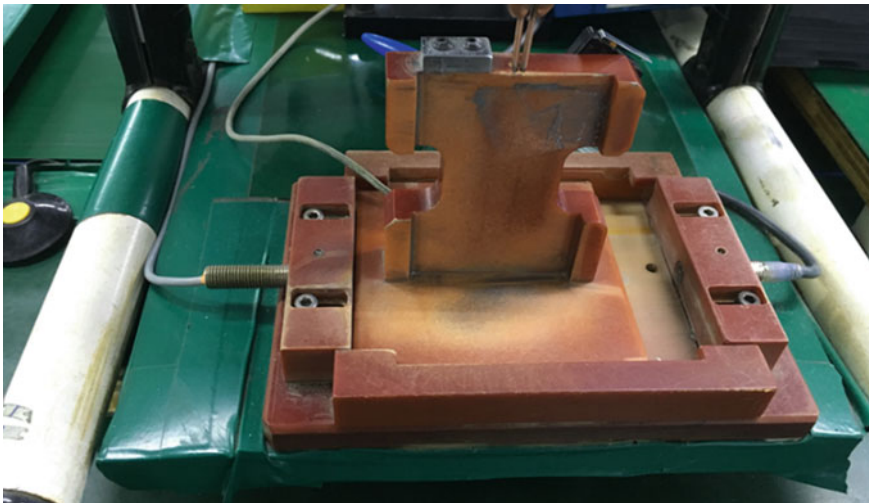


Fig. 5 New positioning JIG. *Source* Authors

After the electrical evaluation and mechanical JIG creation, the next step was updating the process by removing one equipment, rebalance the line, and update the work instructions.

Within 19 days, team conducted brainstorming session, process mapping review, identified an area for opportunity, analyzed the electrical and mechanical implications, created the prototype and final JIG to be used and made physical implementation in line.

### 5 Process Description—Improved State

The improved state of the line was a physical reduction of Operation 70 with one operator less. Not only was operation leaned out, but the output of the combined area improved from 833 pieces per hour to 879 pieces per hour due to less material and component handling and positioning. Figure 6 shows the combined OP60 and OP70 in a single workstation.

### 6 Results

The results achieved after this kaizen event was a reduction of two direct labor headcount, one per shift which resulted in a 12-month rolling savings of \$30.211,00. Output per hour increased from 833 units to 879 units or a gain of 5.5% with one person less. Line shop floor space also reduced by 72 cm by having operation 70 and its equipment removed from the line. Cycle time reduced 0.07 s by eliminating activity 70. The total cost of investment, creating the new positioning JIG in-house was \$1.374,00. More important than the actual numeral and explicit results was the soft benefit of enhancing team work and having the team believe in their ability to contribute and generate results.

According to Soares et al. view [11], a company that believes in continuous improvements promotes teamwork and supports idea implementation thru kaizen events, line flow mapping and values the contributions of all thru brainstorming activities creates value for its customers.

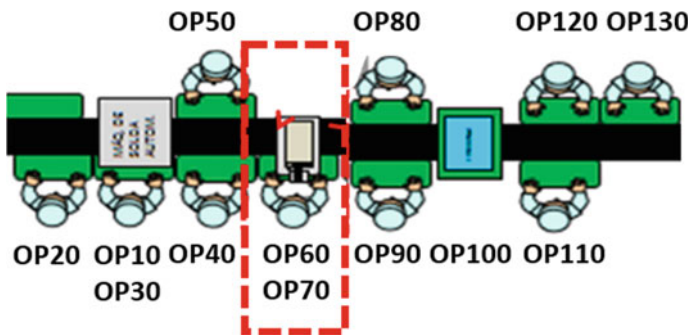


Fig. 6 Process flow combined operation 60 and 70. Source Authors

## 7 Conclusion

This paper records the application of lean manufacturing techniques in the production of cell phone batteries. From the combination of process mapping with the use of brainstorming and Kaizen, an intervention was proposed in a production line. The combination of two workstations and two operations required the creation of a new prototype for the JIG of tests that allowed lateral movement for the welding of steps OP60 and OP70 with less amount of operator movements. The text points out the improvement of indicators of annual operating costs, the number of operators in the line, the increase in productivity, the reduction of cycle time and the space required for work.

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# Lean Healthcare Project Leader: A Framework Based on Functions and Competencies



Thiago A. Souza, Mariane C. de Souza, Rui M. Lima, Letícia V. Pimenta  
and Marcelo S. Oliveira

## 1 Introduction

Costs associated with the health system have expanded at a worrying rate worldwide, it is believed that a significant portion of these costs may be related to the operational inefficiency correlated with care and administrative processes. Being hospitals a critical element of health systems, as demand increases, many hospitals have larger demands despite capacity constraints. Thus, to improve capacity utilization under higher restrictions on costs, hospitals must operate more efficiently with the resources they already have [5]. In this context, management systems emerge from manufacturing to the health industry with a focus on the operational excellence of hospital operational flows. One such system is Lean Healthcare, which has seen a growth in international interest in studies, over the last decade. With its origins on the Toyota Production Systems (TPS), the Lean management involves a range of approaches and tools [31]. It is widely suggested that Lean relies on effective leadership to shape and sustain the change process. For Aij and Teunissen [2] front-line professionals execute the processes, while leaders coordinate problem solving and team process management.

Organizations need adequate functional structure to deliver innovative products and services to deal with the different demands of the clients. In addition, the management of Lean projects becomes an essential factor to adapt the organization to the corporate dynamism, through management focused on objectives and strategies. According to Aij and Teunissen [2], the leadership of the project manager is recognized as important, but the specific attributes and behaviors of successful lean leaders

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in health care have been poorly defined. The literature on leadership behavior in lean organizations is lacking [2, 9, 18].

This study intends to contribute to the identification of the profile of the leaders of projects in the hospital area through an exploratory study carried out in a large hospital located in southeastern Brazil. Through an action research approach, this study has raised the functions of the Lean Healthcare project leader, their competencies, and proposes a DMAIC-based method for management of such projects in hospitals.

## 2 Lean Healthcare

The Lean philosophy, whose origins go back to the Toyota Production System, seeks to eliminate waste, that is, to exclude what has no value to the customer and to print speed and efficiency to the production system [29]. There are five proposed principles: specifying value, value flows, continuous flow, pulled output, and perfection [31]. The first principle focuses on specifying the “value” requested by customers. The second results in the identification of “value flows” and can be achieved by mapping flows in addition to ways of solving problems. The third covers creating “continuous flow” throughout these processes, that is, breaking the boundaries and divisions between organizational and professional groups to ensure that workflows are continuously attuned to value creation. The fourth emphasizes the importance of demand or “pull” responding to the needs of customers, rather than suppliers and internal rules of the business. Finally, the fifth strives for “perfection” or the idea that “lean thinking” must be a continuous activity embedded in the organization’s culture [28].

In the hospital area, in short, it can be said that the organization needs to understand what is valuable by the patient, map activities that add value (contributes directly to what the patient want) and activities that do not add value, identifying flows that meet the needs of patients. Put another way, lean health literature describes Lean as the solution to implement process standards, create flow and reduce disruption and errors [1]. A growing number of studies examine the implementation of Lean practices in the health sector, presenting the benefits to patient care and resource utilization [12, 13, 23, 27].

### 2.1 *Six Sigma and DMAIC*

Six Sigma is a structured methodology that seeks excellence in competitiveness by continuously improving the processes involved in the production of a good or service by means of a robust statistical basis, taking into account all the important aspects of a business [11]. The name is a reference to the letter Sigma “ $\sigma$ ” of the Greek alphabet, which represents the standard deviation of a normal distribution of values or measures. In the mid-1980s, Six Sigma appeared as an attempt to improve customer dissatisfaction with Motorola. Thus, the company invested in improving

this method and analyzing defects related to product quality per million occurrences, and for a process to be at the “six sigma” level should contain on average 3.4 defects per million. In summary, Six Sigma establishes a methodological way of solving problems directly interfering with the causes of undesired effects [4].

The Lean philosophy added to Six Sigma (LSS) is well known and important in the evolution of the quality management processes of the companies of different sectors. The Lean focuses on reducing waste, while Six Sigma focuses on reducing variability using a five-step method—definition, measurement, analysis, solution implementation, and process control (DMAIC) [11].

An integrated approach based on Lean Six Sigma data (LSS) has typically been applied in the health care sector [11]. As a result of studies using the LSS approach in health, there are examples such as reducing complexity when hiring staff; patient waiting time in the outpatient clinic, response times of diagnostic results and duration of patients stay; and further studies show an improvement in the maintenance system to manage mechanical malfunctions and irregularities such as collection errors or medication and delinquent medical records.

According to Takao et al. [25], the steps of the DMAIC method can be summarized as follows:

- *Define*: develop the scope of the project and validate its importance, train the team responsible for the project and identify the main needs of the clients;
- *Measure*: determine the focus of the problem, collect data, verify the reliability of such data, identify priority problems and establish the purpose of these problems;
- *Analyze*: determine the causes of each priority problem, analyze the process that generates these problems, identify and prioritize the potential causes of the priority problem and quantify the importance of potential priority causes;
- *Improve*: propose, evaluate and implement solutions for each priority problem; identify solutions to this problem; to test the proposed solutions on a small scale; develop and implement a plan for large-scale priority solutions;
- *Control*: ensure long-term goal achievement is maintained, evaluate achievement on a large scale, implement a plan to monitor performance and corrective actions in case of anomalies emergence, disseminate work and make recommendations.

## 2.2 *Lean Project Leader*

Aij and Teunissen [2] have identified behaviors and attributes specific to leaders in health settings and describe their association with the five fundamental principles of lean leadership described by Dombrowski and Mielke [9]. As a result of the research, five elements were found that lean leaders should use to improve culture: task identity, feedback, autonomy, belief in improvement, and honesty. Dombrowski and Mielke [9], in their study of leadership, proposed a conceptual model for an integrated base of the leadership system that includes five basic principles of lean leadership: culture of improvement, self-development, qualification, gemba and hoshin kanri. The five

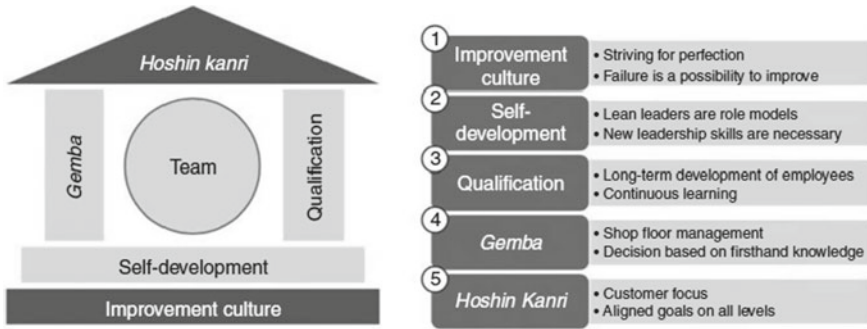


Fig. 1 Lean leadership model [9]

components contribute to the central concept of the team as the active central unit in a lean environment. Figure 1 illustrates the model developed.

For Aij and Teunissen [2], an important attribute for a lean leader is communication, used to facilitate contact, improve performance, hold employees accountable, and build and maintain relationships. Al-Balushi et al. [3] found that training can encourage employees to engage in lean thinking. For Aij and Teunissen [2] both leaders and workers are guided by a sensei, who provides objective feedback and guidance. Leaders should also learn to use specific lean tools, such as plan-do-check-act cycles.

The role of the project leader as a facilitator becomes even more essential since he or she must be a person with a macro view of all project resources and stages and is responsible for translating the strategies into processes that lead to the development of the company and teams. Its main responsibilities are, according to PMBOK [20], to plan the work to be carried out to meet the needs of the project, coordinate people and resources according to the established plans, ensure that the scope of the project is met through monitoring and mediation of progress and taking corrective action when necessary, ensuring that deadlines and costs are met, ensuring that project products meet quality criteria and are in compliance with established standards, conducting technology exploration, and evaluate the feasibility of its implementation.

Heldman [10] emphasizes the manager’s responsibility in a project and emphasizes the need for an effort to integrate the various components of a project. The composition of a team that meets the demands of projects effectively becomes paramount, and such a team is embedded in an organizational structure. Lloyd-Walker et al. [17] analyzed the career of 75 project managers and identified that those who remain in project leadership roles perceive both career change and career opportunities in the uncertainties they experience. On the other hand, as the work becomes more “projected”, the practices associated with the human element are modified in relation to this management [16]. Table 1 addresses the key competencies that a comprehensive project manager must present, according to some authors.

As shown in Table 1, the competencies and skills that were observed with greater relevance according to the literature are leadership, team building, communication,



**Table 1** Competencies and skills of project managers

Competencies and skills (alphabetical order)	Shtub et al. [22]	Kerzner [14]	PMBOK [20]	Dias et al. [8]	Aij and Teunissen [2]
Administration		x			x
Budgeting	x				
Business		x			
Coaching			x		
Communication	x		x	x	x
Conflict management		x	x	x	x
Decision-making			x	x	x
Gain confidence			x	x	
Human relationship	x				x
Influence			x	x	x
Leadership	x	x	x	x	x
Management support		x			x
Motivation			x	x	x
Negotiation	x		x	x	
Organization		x			x
Planning		x	x		x
Political and cultural awareness			x	x	
Relationship with the customer	x				x
Resource allocation		x	x		x
Team building		x	x	x	x
Technical competence	x	x	x		x

x—Competencies and skills detected in the presented studies

conflict management, and technical competencies. PMBOK [20] emphasizes that in addition to the technical skills related to the subject being developed, the Project Manager must have the following skills: (i) knowledge: training and experience with specific tools for project management; (ii) performance: the ability to put their knowledge into practice; and, (iii) interpersonal ability: refers to behavioral characteristics and their ability to converge efforts to project development, balancing available resources and existing constraints.

According to a study by Dias et al. [8], professionals pointed out the competencies developed by their project leaders to motivation, conflict management, team building, leadership and communication as the main premises for action. Additionally, the results of the work, both by Lloyd-Walker et al. [17], and from Paton et al. [19] indicate that many professionals have become project managers “by accident,”



rather than through carefully planned training with the prior acquisition of skills and abilities. In this direction, Kerzner [14] recommends that the “lessons learned” be recorded within each project. Such a source of information is the basis for consultation in future projects, in order to increase the level of maturity of this organization in the conduct of projects, mitigating the negative risks and potentiating the positive ones, that is, increasing the chances of success. The assumption is that a cohesive team can present significantly superior results and the behavior of the members of a project team is influenced by the leader’s performance and posture [6, 17, 21, 30].

From the point of view of Lima et al. [15] in relation to the skills of engineers and project professionals, the authors state that newly graduates starting a professional career may be highly knowledgeable theoreticians, however, there may be a lack of professional skills. To approximate this existing gap, universities and organizations have a joint responsibility to address and in particular, cooperate for the development of professionals with a profile aligned with the demand for practice professionals. Although there is a broad discussion on what skills are needed for project management professionals, there are also few articles on the subject, leaving a gap for research on the subject.

### 3 Methodology

This study was performed in a large hospital located in the Southeast region of Brazil. With about 150 years of history, Santa Casa de Misericórdia de Passos is a regional hospital of philanthropic character that serves the entire population of southwestern Minas Gerais. As a philanthropic institution, 70% of its patients are cared for by the Unified Health System (SUS), aimed at the Brazilian public health sector. The hospital contains about 300 hospitalization beds resulting in average monthly production of 1.031 surgical procedures, 180 hemodynamic procedures; 4.060 emergency care, 1.437 hospitalizations and an occupancy rate of 80%.

This institution started its Lean journey around 2016 by investing in leadership training and launching strategic projects in key flows, such as increasing efficiency of the surgical center, improving access management, reduction of cancer patient lead time, improvement of the drug chain, lead time reduction of prostheses flow, structuring of a Lean RH, improved bed turning. For each project chosen, a project leader was appointed by management, with responsibility for planning and conducting lean actions based on the training received. However, because the Lean application maturity level was initial and the culture was not consolidated in projects, the progress in the first months, naturally in this type of application, was slow and with many doubts stemming from the project leadership, mainly on how to conduct a Lean Healthcare project.

Thus, senior management decided to emphasize the exact analysis and definition of the functions and competencies that its Lean Healthcare Project Leaders should have to optimize the progress of the projects and consequently their results. To do so,

**Table 2** Working method

General steps	Performed activities
1. Workshop to define functions and competencies of lean healthcare project leader (Workshop 1)	Participation of 10 hospital employees divided into two groups, with six project leaders and four project participants. All with more than 5 years of hospital experience and with formation in areas such as administration, nursing, pharmacy, human resources, medical physics, supplies. As a result of this workshop, the basic functions and skills of a lean healthcare project leader have been raised
2. Workshop to define the DMAIC method to be followed in the projects (Workshop 2)	Participation of 20 hospital employees, with 10 project leaders and 10 project participants. All with more than 5 years of experience in hospital management and with formation in different areas as in the activity above. As a result of this workshop, the general actions based on the DMAIC method were set out to guide current leaders and future leaders of the organization
3. Analysis of the results of the workshops	Based on the results from Workshops 1 and 2, an analysis was conducted by the study researchers in conjunction with the management team responsible for the Lean Program at the hospital under study. This team was attended by the following collaborators: Operations Manager, Project Office Coordinator, Human Resources Supervisor and researchers from the University of Minho. The output of this activity is related to the adaptation of functions, competencies, and method of work based on the survey done in the previous stages
4. Development of the proposed framework	According to the analysis and definition of the functions, skills, and method of work Lean, a framework containing all the basic information was developed and presented to the project leaders as guiding document for the planning, execution and control of the lean projects of the study hospital

with the help of consultants and researchers from the University of Minho, a working method was defined according to the action research model.

The authors Susman and Evered [24] use action research as a method to correct deficiencies and generate knowledge in solving problems faced by members of organizations. Action research can also be seen as a cyclical process with five phases: diagnosis, action planning, action taking, evaluating and specifying learning.

Coughlan and Coughlan [7] in his research introduced the theory and practice of Action Research and described this cycle of the five steps, presenting how the implementation of Action Research was developed. According to Thiollent [26], action research seeks solutions through various forms of action through the knowledge of the people involved in the study. Researchers enlarge their own knowledge from empirical data contributions of other participants chosen in the process. This study occurred between July 2017 and January 2018, the general steps of the method applied in the study is described in Table 2. The participants of the study were informed about the objectives of the research and about the guarantee of anonymity, and thus, stated their consent to the dissemination and analysis of the qualitative data collected.

**Table 3** Functions and competencies raised by the groups during workshop 1

Group	Competencies	Functions
Group 1	Advertisement Commitment Communication Continuous improvement Critical analysis Delegate tasks Disseminate lean philosophy Empowering and developing people Focus on GEMBA Focus on results Innovation Interpersonal relationship Motivation Planning Systemic vision Team spirit	<ul style="list-style-type: none"> <li>• Keep project team motivated and productive</li> <li>• Manage the expectations of stakeholders, as well as ensure compliance with deadlines and project scope</li> <li>• Have qualification about the Lean philosophy, as well as its techniques and tools</li> </ul>
Group 2	Commitment Communication Focus on GEMBA Focus on results Innovation Interpersonal relationship Motivation People management Planning Resilience Share knowledge Systemic vision Team spirit Team training Technical knowledge	<ul style="list-style-type: none"> <li>• Be responsible for the definition of the project with the team and sponsors</li> <li>• Be responsible for the qualification of the project team and dissemination of the Lean concept in the areas involved</li> <li>• Ensure project results and alignment to customer needs</li> <li>• Be responsible for the schedule with the project team and sponsors</li> <li>• Carry out visits where the processes happen</li> <li>• Distribution of activities among the team</li> <li>• Awaken team involvement with lean philosophy</li> </ul>

## 4 Results

The Workshop 1, with two groups as referred in the methodology, allowed to raise the functions and competencies that each group believed to be the most important for a Lean Healthcare Project Leader. In addition, those involved should highlight the three most important competencies among all listed. The description of each group is presented in Table 3.

Regarding the functions raised by the group, they are related to the planning, execution, and control of the project as a whole, as well as functions related to team management, stakeholders, customer needs and project results, activities with strong connection with the PMBOK Project Management concepts [20]. These results confirm some of the main competencies referred to in the literature (Table 1).

Thus, the functions and competencies defined by the study, analyzing and synthesizing the results of Workshop 1, for a Lean Healthcare Project Leader would be:

- *Functions*: Responsible for the planning, execution, and monitoring of improvement projects based on the Lean Healthcare philosophy. Perform goals and opportunities deployment with project sponsors and senior management to set goals and project plans. Utilize the Lean philosophy techniques and tools to achieve project objectives by ensuring deadlines, scope and budget are met. Train the project team and other collaborators in order to maintain their motivation and expectations of project stakeholders. Manage and delegate tasks to the project team focusing on key project operations and tracking in GEMBA.
- *Skills*: Commitment, Communication, Criticity, Teaching (Leader Coach), Team Spirit, Focus on Results, Motivation, GEMBA Presence, Interpersonal Relationship, Lean Healthcare Project Management Technique, and Systemic Vision.

Given that the four most necessary competencies, according to researchers and collaborators involved in the study, would be Communication, Team Spirit, Focus on Results, and Systemic Vision. Without such basic skills, the project leader may have difficulty managing and achieving results in a hospital flow improvement project.

After analysis and definitions of functions and competencies, the results of Workshop 2, focused on the DMAIC-based activities method, are presented and that the Project Leader must go through a Lean Healthcare project in the organization. Thus, teams based on the literature on the DMAIC method added to the initial experience in lean project management by the hospital professionals and the influence of the researchers involved raised a list of activities and actions necessary for a project of this greatness in the organization to be executed. A list of 26 actions was analyzed and standardized as a roadmap of project leaders in the hospital, divided into DMAIC stages.

This list of activities (DMAIC method), added to the functions and skills defined by a Lean Healthcare Project Leader, gave rise to a management framework with the objective of integrating, synthesizing and streamlining the actions of the current project leaders in the organization and preparation of future leaders, as shown in Fig. 2.

## 5 Conclusion

The topic of project leadership in lean healthcare is essential for the application of lean projects in hospital environments, given that the importance of leadership in this journey is paramount to the success of improvement. The lack of literature on the subject and the isolated applications of projects in the hospital environment not contemplating the integration of a management system focused on lean improvements increases the need for research that helps hospital managers to guide teams and project leaders and lean healthcare.

Lean Healthcare Project Leader Framework					
Functions	DMAIC Method				
Responsible for the planning, execution and monitoring of improvement projects based on the Lean Healthcare philosophy. Perform goals and opportunities deployment with project sponsors and senior management to set goals and project plans. Utilize the Lean philosophy techniques and tools to achieve project objectives by ensuring deadlines, scope and budget are met. Train the project team and other collaborators in order to maintain their motivation and expectations of project stakeholders. Manage and delegate tasks to the project team focusing on key project operations and tracking in GEMBA.	<b>D</b> 1.1 Analyze Business Strategy 1.2 Declare Project Opportunities 1.3 Definition of Scope, Goal and Gains 1.4 Definition of Team and Training 1.5 Project Timeline 1.6 A3 1.7 Validation with Coordination				
		<b>M</b> 2.1 Current Value Stream Map 2.2 Measurement of Process Performance 2.3 Brainstorming 2.4 Conducting Interviews (Clients and Leaders) 2.5 Validation with Coordination			
			<b>A</b> 3.1 Quality Tools 3.2 Finding Cause (s) Roots (s) 3.3 Future Value Stream Map 3.4 Validation with Coordination		
				<b>I</b> 4.1 Definition of the Improvement Plan according to Future VSM 4.2 Implementation and Monitoring of the Improvement Plan 4.3 Validation with Coordination	
					<b>C</b> 5.1 Analysis of Previous Steps 5.2 Dissemination of Improvements 5.3 Define Monitoring Indicators 5.4 Project Documentation 5.5 Project Presentation 5.6 Team Recognition 5.7 Validation and Closing
		Commitment			
<b>Communication</b>					
Criticality					
<b>Focus on Results</b>					
GEMBA Presence					
Interpersonal Relationship					
Lean Healthcare Project Management Technique					
Motivation					
<b>Systemic Vision</b>					
Teaching (Leader Coach)					
<b>Team Spirit</b>					

Fig. 2 Lean healthcare project leader framework

This study conducted a qualitative and exploratory intervention in a large Brazilian hospital with the purpose of raising the functions, skills and guiding method that a lean healthcare project leader should base. As a result, it is noted that the functions of the Lean Healthcare Project Leader proposed by the hospital are, in some way, related to the project management framework proposed by PMBOK [20]. Among those, it is possible to identify planning, execution, and control of the project as a whole, in addition to assumptions derived from lean philosophy, such as visits to the GEMBA and a focus on waste reduction. The competencies raised in the study highlight transversal competencies related to Communication, Team Spirit, Focus on Results and Systemic Vision as the basics of any Lean Healthcare Project Leader and thus, combined with other technical and behavioral competencies, will generate improvements with projects at hospital.

It is important for hospital managers to structure improvement program based on Lean Healthcare by appointing and training good project leaders who follow a robust and simple methodology focused on results. Thus, Human Resources departments should be prepared and knowledgeable of the Lean philosophy so that they can structure the capacities and development of such leaders in communion with the hospital management system.

As a limitation of the study, the results of the improvements within the hospital based on the developed framework were not followed up to date, which is the next challenge for the authors.

Finally, it is suggested that the future work closely follow the action research cycle, so that authors can systematically improve the validity and reliability of the work.

And the replication of this study in other hospitals of different sizes and maturity levels in lean applications, interacting with more professionals linked to lean project management with the goal of making this model more robust.

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