Collaborative Research Network on Supply Chain 4.0

2nd International Symposium on Supply Chain 4.0 (ISSC4)

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September 3-4th, 2018

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2nd International Symposium on Supply Chain 4.0

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Welcome message

We are honoured to organize and host the *ISSC4-2018 – 2nd International Symposium on Supply Chain 4.0*, with a very special thematic orientation: "*Digital Transformation in SME (Small and Medium Enterprises)*". In the context of the 4th Industrial Revolution, SME are those struggling the most to keep the pace with the digital transformation. Many started to improve productivity through technology adoption, but the impact is often quite limited. The lack of financial and human resources, together with other barriers, are unsettling their digital strategies. But we strongly believe this can be changed with the right touch. For us, the best way to do so is through collaboration.

Collaboration between scholars and practitioners is very powerful, that is why the SC4 (Collaborative Research Network on Supply Chain4.0 - www.supplychain4.org) promotes the ISSC4. More than 20 researchers get together in this initiative to foster conjoint projects. Some of them are presented in the 2018 edition of this symposium. Other observers of the SC4 are also presenting new interesting initiatives in the field of Industry 4.0. Five thematic sessions, two keynote speakers and a round table complete the first day of the event. The second day is dedicated to discussing collaborative projects and planning the next year of SC4. For the first time, this day is also open to non-members of the SC4 network, hoping that new members embark on this initiative and start new collaborations, inspiring new friendships among researchers, engineers, managers and students from all around the world.

Have you all a wonderful ISSC4-2018!

Warm regards,

Prof. Luis Antonio de Santa-Eulalia, Ph.D.
Co-Chair of the Scientific Committee

Prof. Eduardo de Senzi Zancul, Ph.D.
Chair of the Organizing Committee

Organizing Committee

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Detailed Program – Day one – September 3th

Detailed Program - ISSC4 - 2018 | DAY ONE (Sept. 3rd 2018)
Second International Symposium on Supply Chain 4.0: Digital Transformation in SME (Small and Medium Enterprises)
September 3-4th, 2018, São Paulo, Brazil | Polytechnic School, University of São Paulo (USP)
Address: Av. Prof. Luciano Gualberto, 1380 – Butantã, São Paulo – SP, Brazil, 05508-010
Organized by the SC4 (Collaborative Research Network on Supply Chain 4.0) | www.supplychain4.org

Time				
8:00 - 9:00	Registration - Hall			
9:00 - 9:15	Welcome session - Room D2-15 (Online: https://www.youtube.com/engenhariadeproducao)			
9:15 - 10:00	Keynote speaker Prof. Marcelo Zuffo (Poli-USP): Advanced applications and trends in Industry 4.0 - Room D2-15 (Online: https://www.youtube.com/engenhariadeproducao)			
10:00 - 10:30	**Coffee Break - Room D2-116**			
	Thematic Session - Internet of Things (Chair: Prof. Paulo S. A. Ignácio) - Room D2-112 (Online: meet.google.com/gps-mwoh-nyz)		**Thematic Session - Digital Transformation (Chair: Prof. Luis A. Santa-Eulalia) - Room D2-114** (Online: meet.google.com/wef-pktg-jym)	
10:30 - 12:00	The importance of Internet of Things to Small-and-Medium Enterprises related to Sustainable Supply Chain	**Klayton E. Rocha**, Juliana V. Mendes, Virginia A. S. Moris	Digital plan: a design science approach for manufacturing small and medium enterprises (*via Hangout*)	**Fanny-Ève Bordeleau**, Sébastien Gamache
	Application of the Internet of Things in the healthcare field: a literature review	Thales B. Sousa, Igor F. Rocha, Franklin S. Loiola, Gustavo R. Conceição, Cássio G.L. Souza, **Sherfis G. Ruwer**	How Can SME Embark in a Digital Transformation in the Context of the 4th Industrial Revolution? (*via Hangout*)	**Martin Béliveau**, Luis A. Santa-Eulalia, Elaine Mosconi; Nathalie Cadieux
	Internet of Things-Based Product-Service Systems for spare parts in aerospace sensing enterprise: a conceptual framework (*via Hangout*)	**Youssef Abidar**, Luis A. Santa-Eulalia (*via Hangout*)	Main objectives and barriers of the enterprise adaptation project to Industry 4.0: a case study in a technologies supplier company	**Thales B. Sousa**, Fábio M. Guerrini, Marco Coghi
12:00 - 13:30	**Lunch (at the expenses of the participants) and Visit of the InovaLab@POLI [http://inovalab.poli.usp.br/] and Ocean USP-Samsung**			
	Thematic Session - Supply Chain 4.0 (Chair: Prof. Francisco I. G. César) - Room D2-112 (Online: meet.google.com/gps-mwoh-nyz)		**Thematic Session - Digital Transformation 2 (Chair: Prof. Rui T. Yoshino) - Room D2-114** (Online: meet.google.com/wef-pktg-jym)	
13:30 - 15:00	Supply Chain 4.0 Challenges	**Felipe C. Martins**, Alexandre T. Simon	Digital Twin – requirements and implementation	**Luiz F.C.S. Durão**, Klaus Shützer, Eduardo Zancul
	Supplier integration through Digital Manufacturing: a SME paradox	**Elias H.D.R. Silva**, Jannis Jan Angelis, Edson P. Lima	Analysing the possibility of dealing with uncertainty in ERP/MRP controlled environment with Demand Driven MRP	**Vitor E. Battissacco**, Kleber F. Espôsto
	U-Healthcare application in the Health Supply Chain – A framework proposal for the implementation of a Healthcare System based on ubiquitous technologies	**José M.B. Palma**, Francisco I. G.Cesar, Ieda K. Makyia, Paulo S.A. Ignácio	Educational Test Bed: A new teaching approach in the Industry 4.0	Marcela M.A. Pinto, Ana L.C. Basseto, **Rui T. Yoshino**, Joseane Pontes
15:00 - 15:30	**Coffee Break - Room D2-116**			
	Thematic Session - Applications (Chair: Prof. Juiana V. Mendes) - Room D2-112 (Online: meet.google.com/gps-mwoh-nyz)			
15:30 - 17:00	Towards automated risk assessment for pedestrian-vehicle safety in manufacturing (*via Hangout*)	**Ninad Pradhan**, Rupy Sawhney, Mohammad H. Khan		
	Application of Manufacturing and Automation techniques oriented to a service-based business using Internet of Things (IoT) and Industry 4.0 concepts. Case Study: Smart Hospital	**Camilo Cáceres**, João Rosário, Dario Amaya		
	Supporting supply chain digitization through lean startups: a case study from the household appliances industry (*via Hangout*)	**Pablo D. Valle**, Fernando Deschamps, José E. Pécora Júnior		
17:00 - 17:30	Keynote speaker: Egidio Ferraz (Schneider Electric): Schneider Electric's Vision for Industry 4.0 - Room D2-15 (Online: https://www.youtube.com/engenhariadeproducao)			
17:30 - 18:00	Roundtable - Room D2-15			
18:00 - 18:15	Wrap-up and closing session - Room D2-15			
19:00 - 21:30	**Conference Dinner** (at the expenses of the participants) Bráz Pizzaria Pinheiros - R. Vupabussu, 271			

ISSC4-2018 Web Site: Web site: supplychain4.org/issc4-2018/

Detailed Program – Day two – September 4th

	Detailed Program - ISSC4 - 2018 | DAY TWO (Sept. 4th 2018) Second International Symposium on Supply Chain 4.0: Digital Transformation in SME (Small and Medium Enterprises) September 3-4th, 2018, São Paulo, Brazil | Polytechnic School, University of São Paulo (USP) *Address: Av. Prof. Luciano Gualberto, 1380 – Butantã, São Paulo – SP, Brazil, 05508-010* Organized by the SC4 (Collaborative Research Network on Supply Chain 4.0) | www.supplychain4.org
8:00 - 10:00	Visits: InovaUSP & CITI 0 Interdisciplinary Center in Interactive Technologies [http://www.lsi.usp.br/citi/en/] - Meeting point at Room D2-116
10:00 - 10:30	**Break - Room D2-114**
	Meeting of the SC4 Network - Room D2-116 (Online: meet.google.com/xrc-tteb-oht)
10:30 - 11:00	Presentation of the SC4 network and main results so far
11:00 - 12:00	Presentantion of the research groups involved and their main projects (registration required)
12:00 - 13:30	**Lunch**
	Meeting of the SC4 Network - Room D2-116 (Online: meet.google.com/xrc-tteb-oht)
13:30 - 15:30	Future of the SC4 network
	Conjoint Research Projects
	Next ISSC4-2019
15:30 - 16:00	**Break - Room D2-114**
16:00 - 16:30	**Closing Session - Room D2-116** (Online: meet.google.com/xrc-tteb-oht)
17:00 - 20:00	**Happy Hour of the SC4 Network**

ISSC4-2018 Web Site: Web site: supplychain4.org/issc4-2018/

INTERNET OF THINGS

The importance of Internet of Things to Small-and-Medium Enterprises related to Sustainable Supply Chain

Klayton E. Rocha, Juliana V. Mendes, Virgínia A. S. Moris

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Purpose: The aim of this paper is to investigate the applications and impacts of Internet of Things (IoT) technologies in sustainable supply chain management focused on Small-and-Medium Enterprises (SMEs).

Design/methodology/approach: A systematic review of the literature.

Findings: The results show that the academia focus on the advantages that IoT provides to SMEs due to the use of the information that smart devices and sensors can generate.

Academic limitations/implications (if applicable): Limitations in terms of access to full text articles and a restricted number of databases, as well as the search including only publications in English.

Practical implications (if applicable): SMEs can be empowered by the valuable information that IoT systems provide, which can be an important competitive advantage.

Social implications (if applicable): SMEs are important to the labor market and the new IoT applications can contribute to both companies´ efficiency and new products and services.

Originality/value: IoT studies are increasingly importance in the past few years, but still focused on large multinational companies. This research focus on the advantages that SMEs are being able to leverage in the search for a more sustainable supply chain.

Keywords: Internet of Things, IoT, Small and Medium Enterprises, SME, Sustainable Supply Chain

1. Introduction

The Internet of Things (IoT) is the use technologies (e.g. sensors) that allows all things (e.g. products, processes, people, etc.) to communicate with different systems. This technology is part of the fourth industrial revolution, a new wave of development that improves not only manufacturing system (e.g. smart factories that can track in real time all their production), but also consumers (e.g. smart homes that can improve security and convenience to consumers) and governments (e.g. smart cities that can have a more efficient transport system)[1].

Big companies were always able to keep a strong advantage from its smaller competitors by heavily investing in technology development, however this scenario has started to change. In the past couple of decades, we have seen start-up companies disrupt business in a speed never seen before. For example, Uber -founded in 2009- was able to leverage the use of GPS tracker on mobile to re-invent transport systems around the world. Their strategic view on the urgency to leverage IoT applications also allowed them to lead the race for self-driving autonomous cars, competing against well stablished worldwide cars manufacturers (e.g. GM) [2]. The high advanced use of cameras, heat sensors and other IoT components has allowed Uber to start testing the technology in US. However, the stakes are high and accept no mistake, and just a few months later a fatal crash made Uber suspend their research on self-driving autonomous car [3].

This is a very dynamic scenario where SMEs can disrupt the most traditional business rapidly – and still be at high risk to be left behind by another start-up. In this way, our aim is to investigate how academia is following this trend of SMEs leveraging IoT applications and provide examples of the impacts this technology offers to one specific operation of the manufacturing process - the supply chain management for a sustainable future.

2. Methodology

The authors have developed a first review of the literature in 2017 with a broader focused around the topic of IoT applied to supply chain management [4], where it was found that the relevance of IoT to the academia has gained importance since 2010. The first study had the limitation of only one database as source of articles, and in this work, it was added more three databases and the scope of the research was narrowed to SMEs.

The systematic literature review continues to be based on a combination of several authors ([5], [6], [7] and [8]), following six steps.

a) Problem definition: How SMEs can compete with large corporations in the field of Sustainable Supply Chain?
b) Goals: Provide research directions on SMEs using IoT applications towards sustainable supply chain;
c) Primary sources: Web of Science (WoS), Compendex, Scopus, and Science Direct.
d) Strings: Initially we extracted the list of articles from the databases using three concepts
   i) **IoT**: "Internet of things" OR "Industrial IoT" OR "Internet of Objects" OR "Machine-to-machine" OR "Person-to-machine" OR "Person-to-person" OR "Internet of everything" OR "Internet of nano things" OR "Web of things" OR "IoT" OR "IIoT" OR "IoO" OR "M2M" OR "P2M" OR "P2P" OR "IoE" OR "IoNT" OR "WoT")
   ii) **Supply Chain**: Distribution OR Logistics OR "Supply Chain"
   iii) **Sustainable**: Reverse OR Sustainable OR "Closed-loop"
After that, it was analysed all the articles related to SMEs.
e) Acceptance: peer reviewed articles;
f) Classification: Scimago Journal Ranking (SJR) [9].

3. Results

Out of the four databases analyzed, we were able to identify 47 articles in the scope of the study in 3 out of the four databases. The Science Direct database did not have any article that matched the research criteria. Another important point to highlight is that although our range of search was from 2010 to 2018 (February), the articles that matched our study criteria were all very recent, as presented in the Table 1. This is a strong indicator that this field of research is brand new and yet to be further explored.

Table 1: Number of articles by database and year.

Database	2015	2016	2017	2018	**Total**
Compendex	1		1		**2**
Scopus		9	27	8	**44**
Web of science	1				**1**
Total	**2**	**9**	**28**	**8**	**47**

Note: 2018 search was made in February.

An in-depth analysis of the 47 articles allowed us to classify them according to their research methodology. Only 1 article (2%) used the survey methodology to analyze the determinants to implement RFID [10], 1 article (2%) used a literature review methodology to describe the history of innovation over the past 30 years [11] and the majority of articles (45 articles - 96%) used the case study methodology as presented in the Figure 1.

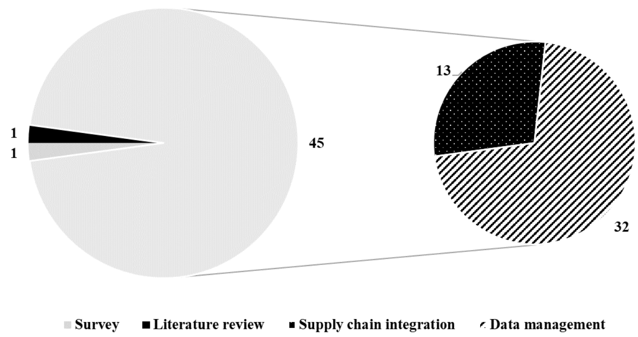

Figure 1: Number of articles by research methodology (left) and case study focus (right).

Our analysis was able to group the case studies in 2 categories according to the main focus of the articles: data management and supply chain integration.

The most common application of IoT is straight related to the integration of supply chain – meaning physical logistic operations along the different players until the delivery to the consumer.

This field of research has been more explored by researchers over the years, as IoT technologies can improve traceability and provide real time information for different parts of the supply chain [12] and [13].

Another important point to highlight specific to the SMEs´ studies is the suggestion of Third-Party Logistics (TPL) in the support of sustainable supply chain, with benefits for shipments and merging the storage space of inventories [14]. Kayvanfar *et. al* proposes the use of clusters managed by TPL to minimize costs and connect SMEs to local markets [15] [16].

The authors suggest new analysis to optimize the truck´s sequence (e.g. picking process) and stochastic models.

A new trend of research found in this study is the relationship with data management. The internet revolution has allowed the number of electronic data generated in the world to increase immensely, and this seems to be the most important advantage that has being researched in the field of sustainable supply chain management for SMEs.

IoT technologies can provide important information to small companies, that can use it in a smart way to overcome barriers of competition imposed by large companies. Several examples use those information to product development [17], [18] and [19].

Another important application identified is related to the improvements in Life-Cycle Assessment, as IoT technologies can help the monitoring of the whole supply chain [20],[21], [22],[23],[24].

The framework proposed by Shukla and Tiwari (2017) [25] connects local farmers in Malaysia that are geographical spread in the country to export palm oil. The technology such as sensor and satellite allows the farmers to keep their records in place (e.g. pesticides use). Those records are part of a complex process to obtain a sustainable production certification mandatory to export the product.

While two other studies use the principles of real-time data by applying IoT systems (e.g. sensors) in several key process of a supply chain [26],[27]. With this technology, it is possible to create "Virtual Enterprises" (VE) and connect several SMEs that are responsible for different parts of the supply chain (e.g. research, manufacturing, logistics, sales). The improvements in communication helps companies to increase overall efficiency and mitigate risks.

The authors suggest further research to explore economic viability of such implementations.

4. Conclusion

This study focused to explore the state of the art around the use of IoT technologies by SMEs in sustainable supply chain process. It was clear that this is a very recent topic of research (3 years), and because of that, the stage of research is still under development. For example, we were able to identify the small volume of literature review articles and survey articles in this field. However, an important contribution of this analysis was the identification of 2 clear focus of research for the case studies.

The first one is the most traditional one – the benefits of supply chain integration. Including for example the capacity to share information in real time to connect different players.

The second one is a new trend of research – the benefits of IoT related to data management. The internet of things can provide an important competitive advantage to SMEs: information. And SMEs can be more flexible and agile to adapt their business model to leverage those information in a smart way.

This study was limited to articles in only 4 databases, so it is suggested to increase the number of databases to have a more robust analysis.

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Application of the Internet of Things in the healthcare field: a literature review

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Purpose: This paper presents a literature review on Internet of Things (IoT) application in the healthcare field. Bibliographical search indicates healthcare is one of the most prominent sectors for IoT application, but some challenges need to be addressed.

Design/methodology/approach: This paper has qualitative approach and was developed through literature review. The issues were explored in papers published in journals indexed by Scopus and Web of Science.

Findings: Within the healthcare field, IoT can be used to ambient assisted living, medication, population health management, smart medical implants, anomaly detection, among other applications. However, IoT use in healthcare is still highly concentrated in cloud-connected devices providing data from electrocardiograms, fetal monitors, temperature monitors and blood glucose level sensors. Some benefits of IoT adoption in healthcare are: ease of use, cost reduction, greater involvement of doctors, availability and accessibility, online assistance, better efficiency for healthcare resource management and international collaboration. For the consolidation of IoT in healthcare, some challenges such as data management, scalability, interoperability, standardization and regulatory affairs, interfaces and human-factors engineering, security and privacy must be overcome.

Academic limitations/implications (if applicable): This paper was based on information of papers published in journals indexed in two bibliographic databases. Despite these databases to be the most relevant sources for the world science, books, conference papers and magazines certainly can have useful information.

Originality/value: As IoT use in healthcare sector is recent and its academic research is in consolidation phase, information provided in this paper can point hot topics of the area.

Keywords: Internet of Things, Healthcare, Literature Review, Scopus, Web of Science.

1. Introduction

The Internet of Things (IoT) was introduced in 1999 and can be defined as a sophisticated network of addressable and interoperable objects with Radio Frequency Identification (RFID) technology, where each of these objects connects to a server that efficiently provides suitable services [1]. The IoT utilizes many different technologies such as RFID, Bluetooth, Global Positioning System (GPS) and short-range communication, for connecting everyday objects to the internet and automating tasks like identification, localization, management and scheduling [2].

Is expected that healthcare environments will be revolutionized by means of IoT applications [1]. The growing rate of the aging population has brought various challenges in healthcare service and one promising method to deal with such problems is to adopt the IoT technologies and make the medical service systems more intelligent [3].

IoT can be extremely beneficial for people who do not have access to immediate healthcare facilities and treatments, and the main motivation for evaluating its potential as a solution of improvement is that this technology would aid in decentralizing a wide variety of medical services [4]. Through IoT, many advances have been made in healthcare monitoring and control, interoperability and security, pervasive healthcare, drug interaction checking, etc.; and these achievements have demonstrated the effectiveness and promising future of IoT-based healthcare system [3]. Despite the existent success, ambiguity and technical challenge still exist in relation to the question of how to rapidly and systematically establish and deploy an intelligent IoT-based healthcare system that involves big data management [3].

Aiming at maximizing the capabilities of IoT in healthcare field, various researchers and organizations have been devoted to the development of IoT-based technologies for medical applications [3]. The literature about the theme has increased constantly in recent years. So, the motivation of this paper is to present a literature review of scientific production on IoT in healthcare field.

The structure of the paper is arranged as follows: Section 2 presents the methodology used for finding papers related to the theme. Section 3 presents the main results of literature review, while section 4 concludes the paper.

2. Methodology

The methodology used in this paper aims to obtain results capable of addressing the progress of scientific production on application of IoT in healthcare field. As its purpose is to analyze the world progress of literature on the theme, the bibliographic search selected only journals since there is no unified metric to quantify the quality of a conference proceeding, book or other sources.

For this study, Web of Science database was chosen because it is published by Thomson Reuters and is the most important source of information for bibliometric analyses in the sciences [5]. Scopus was used because it is the largest bibliometric database, is compared to the Web of Science in terms of information coverage [6], while at the same time it is more comprehensive [7], indexing 22,794 peer-reviewed journals, compared to 14,498 from the Web of Science [8].

To find the papers analyzed in this study, the terms "Internet of Thing*" and "Healthcare" were searched in the fields "ARTICLE TITLE, ABSTRACT AND KEYWORD" in the Scopus e "TOPIC" in the Web of Science. Soon after, the following filters were applied: (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (DOCTYPE, "ar")). Considering that some papers are duplicated (i.e., they are indexed in the two databases), some papers just mention the terms in abstract and keyword (then, they are deleted of the analysis), the final number of 270 papers was studied.

3. Results

For the development of this paper, descriptive dimensions were used to absorb relevant information of the papers. The content of the papers was further assessed by means of the following descriptive analysis:

- What are the main benefits of using IoT in healthcare sector?
- What are the main challenges for such research area?
- In which journals are such papers published?

Use of IoT in healthcare sector and its benefits

By 2020, the main applications of IoT occur in healthcare and manufacturing sectors [9]. According to Yin et al. [3], the paradigm of IoT for healthcare consists of three parts: master, server and things. Master includes the doctors, nurses, and the patients, who have their specific permission to the system by end-user devices [3]. Server acts as the central part of the entire healthcare system, being responsible for prescription generation, data base management, data analysis, subsystem construction and knowledge base management [3]. Things refer to all the physical objects (including the patients and human resources) that are connected through some communication technology [3].

The most common application of IoT in healthcare is in wellness, using devices for measuring daily activities such as walking, running or riding a bicycle [10]. Application of IoT in healthcare system has a huge potential to improve patients' quality of life, as it enables constant monitoring of vital body functions, tracking of physical activities of a person and aids rehab physical therapy [10].

Such an IoT-based system would allow standalone recovery process, minimizing the need for dedicated medical personnel and could be used in both hospital and home conditions [10].

In the health IOT, the specialized sensor devices can be used to monitor remote health and notify the emergency information, e.g., blood pressure, hearth rate, etc. These data can help the doctors to rescue the patients. In cloud-based health IOT, patients' medical/health data is managed by the cloud service providers [11].

The healthcare information and service can be accessed by personal computing devices (laptop, mobile phone, tablet, etc.), through mobile internet access (WiFi, 3G, LTE, etc.) and under the authentication of the individual, which implies that IoT in healthcare services will be mobile and personalized [12].

Challenges for successful application of IoT in healthcare sector

It should be noted that IoT has been widely used in medical and healthcare areas, but according to Sheikh et al. [13], these are limited to cloud-connected devices providing data from electrocardiograms, fetal monitors, temperature monitors and blood glucose level sensors. Some studies point there is a lack of researches and experiments of IoT usage in assisting and measuring performance of physical therapy [10].

There are three main challenges while we do the analytics process in the implementation of IoT in medical fields [14]. Firstly, in the field of medicine, almost every day new measuring devices and equipment's will be introduced, which requires periodic updating of the IoT devices. Secondly, every time depending upon the condition of the patient, the data to be collected will differ as directed by the physician. Thirdly, the sensory data will produce heterogenous modalities, and this heterogeneity is a challenge for the machine learning approaches as it handles homogenous data.

Other great challenges for consolidation of IoT in healthcare sector are security, privacy, standardization, and scalability, as well as the question of how to design devices and protocols to collect, share, process, and validate data across different application domains in ways that are economically efficient, technologically robust, scientifically reliable, and ethically sound [16].

In general, the results of the literature review present beyond these challenges, other issues also should discussed for consolidation of IoT in healthcare sector. These issues can be summarized under the following aspects:

- Interface among humans and devices;
- Wearability;
- Knowledge and skills related to smart healthcare;
- Safe localization;
- Confidentiality;
- Sharing, reliability and newness of data;
- Management of human contact with patients;
- Auditability of the enterprise;
- Incident response;
- Transformation of disease diagnosis methods of physicians in machine-readable forms;
- Communication and data management;

- Quality of service (rigorous reliability and maintainability of the system, for avoiding delay, improper connection or data loss; easy implementation of biomedical sensors into body human); and
- Sustainability (low power consumption, biomedical sensors of low cost, use of rare earth metal or any sort of toxic elements in the biomedical sensors).

Most productive journals

Fig. 1 presents the annual distribution of papers published. This research area is quite recent, as the first paper on application of IoT in healthcare sector was published in 2011. It is possible to observe that the number of publications presents constant growth over the years. It is important to note that by the end of June 2018, 102 papers have already been published.

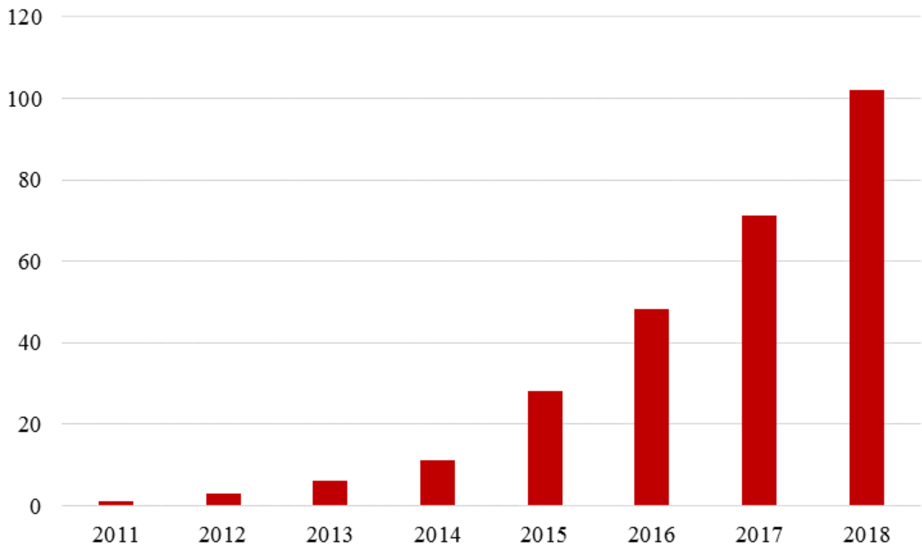

Figure 1: Yearly distribution of published papers.

The 270 papers related to the theme were published in 134 journals. The papers have been published in journals of researches in information technology, health, engineering, business management, environmental management, knowledge management and marketing management. Table 1 presents the list of journals that published more than 1 paper.

4. Conclusions

This paper contributes to structuring a theoretic outline of the knowledge domain on IoT application in healthcare sector. Such research is important, as like the industrial sector, the healthcare sector will account for 20% of the market share of IoT applications in 2020.

It was possible to verify that 270 papers on the subject were published in 134 journals indexed in Scopus and Web of Science until June 30th of 2018 and that the number of papers published has increased extensively.

Table 1: List of most productive journals.

Journal	Number of papers
Future Generation Computer Systems	21
IEEE Access	17
Journal of Medical Systems	14
IEEE Communications Magazine	9
Pervasive and Mobile Computing	7
Sensors	7
Applied Sciences	6
IEEE Internet of Things Journal	6
International Journal of Smart Home	6
Computers and Electrical Engineering	5
Cluster Computing	4
Computers in Industry	4
IEEE Transactions on Industrial Informatics	4
IT Professional	4
Journal of Biomedical Informatics	4
Wireless Personal Communications	4
ARPN Journal of Engineering and Applied Sciences	3
Computer Networks	3
IET Networks	3
Advances in Electrical and Computer Engineering	2
Biomedical Research	2
Computer Communications	2
Healthcare Informatics Research	2
IEEE Intelligent Systems	2
IEEE Internet Computing	2
IEEE Sensors Journal	2
IIOAB Journal	2
Indian Journal of Science and Technology	2
International Journal of Advanced Computer Science and Applications	2
International Journal of Applied Engineering Research	2
International Journal of Bio-Science and Bio-Technology	2
International Journal of Distributed Sensor Networks	2
International Journal of Engineering & Technology	2
International Journal of Grid and Distributed Computing	2
International Journal of Pharmacy & Technology	2
Journal of Ambient Intelligence and Humanized Computing	2
Journal of Management Analytics	2
Journal of Network and Computer Applications	2
Journal of Theoretical and Applied Information Technology	2
Pollack Periodica	2
Technological Forecasting & Social Change	2
Wireless Communications and Mobile Computing	2

Results point the main benefits of adopting IoT in healthcare are overall view of patient conditions, fusion and integration with different technologies, wide monitoring, ease of use, costs reduction, greater involvement of doctors, availability and accessibility of information, better efficiencies for healthcare resource management, online assistance, and international collaboration.

This research revealed that the main challenges for consolidation of IoT in healthcare sector are data management, scalability, interoperability, standardization and regulatory affairs, sustainability, interfaces and human-factors engineering, information security and privacy.

Limitations of research and opportunities for future papers

The limitations of the paper result from its scope and applied research method. As the bibliographic search selected only publications compiled in English, relevant contributions in other languages may have been ignored. The sample of papers considered was extracted from only two databases, which may have disregarded relevant studies published in other sources. Finally, the limitation of space imposed on a scientific paper to be published at this symposium prevented a deeper analysis of the results obtained in the literature review.

Despite the limitations mentioned above, it is believed that this work will offer motivation for future research on the theme. As theoretical research represents an initial step in the development of a research topic, future papers can provide more systematic information on the topics discussed, examining a wider set of bibliographic sources. From our perspective, studies that measure the return on investments of IoT devices in healthcare will be very useful for the consolidation of research area.

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Internet of Things – Based Product – Service systems for spare parts in aerospace sensing enterprise: a conceptual framework

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Purpose: The main objective of this paper is to define how Internet of Things (IoT)-based Product Service System (PSS) can be employed to enhance service parts management performance.

Design/methodology/approach: A conceptual framework for deploying Internet of Thing-based Product-Service Systems for spare parts in aerospace Sensing Enterprise were proposed. The potential benefits are illustrated for the aerospace industry.

Findings: The voice of the customer has become the focus of today's company instead of focusing only on the cost and quality of the product. For the OEMs, the value they offer to their clients, with regards to the life cycle of a product, is the reliability of the products in terms of maintenance, repair and availability of spare parts. The availability of spare parts forces companies to invest more in inventory management in order to keep a minimum stock to meet customer demands, especially for parts with a long lead-time such as parts made from forgings or castings. Despite of the abundant number of academic literature on spare parts inventory management, few papers focuses on aerospace spares parts inventory management using Internet of Things-based Product-Service systems for spare parts in aerospace Sensing Enterprise.

Practical implications: OEMs should include the consideration of Internet of Things-based Product-Service Systems for long-term aerospace service parts development.

Originality/value: The paper propose a conceptual framework for deploying Internet of Things-based Product-Service systems for spare parts in aerospace Sensing Enterprise.

Keywords: Spare parts, Internet of Things, Product Service System, Sensing Enterprise, Aerospace.

1. Introduction

During the past few years, information technology adoption has generally caused great positive impact on companies' performance [1]. The wireless communications and net-working enable a novel paradigm named the Internet of Things (IoT). The concept was first introduced by Kevin Ashton in the year 1998 and has gained increasingly more attention in the academia and industry [2]. IoT in aerospace could help providing a quick response to the customer with regards to service parts, creating what is called a PSS (Product Service System) approach [7], in which additional services (e.g. spare parts inventory management) are added to traditional physical products (e.g. an aircraft) to create value from the customer's point of view.

In this case, OEMs must have a rapid reaction to the customers' requirements by providing maintenance and spare parts services in short time to avoid aircraft on ground (AOG). Responsiveness and getting back to the customer quickly, addressing any issues or questions, are a key requirement to improve the overall customer experience. The availability of spare parts forces companies to invest more in inventory management in order to keep a minimum stock to meet the intermittent customer demands. Maintaining inventories of infrequently ordered parts is expensive for an airline, knowing that an aircraft may remain in service for decades and needs spare parts for their entire working life. As a result, the costs of inventory and storage are increasing [3].

Based on our literature review, the existing literature lacks a conceptual framework organizing the main concepts of IoT concept with regards to aerospace. To address this gap, we proposed a conceptual framework for the implementation of spare parts based on IoT in Sensing Enterprise. The Sensing Enterprise concept is shifting boundaries – towards a borderless enterprise, where collaboration and continuous interactions among smart objects are central to the new scenario. Sensing enterprise concept goes further to a direct presence, "sensing" data and transforming it into knowledge for business operation and provide support with the smart dust in the clouds as a new form of computing systems.

The main objective of this framework is to help define how Internet of Things (IoT)-based Product Service System (PSS) can be employed to enhance service parts management performance. More specifically, this paper identifies the main implementation phases, the technologies to be employed and the required practices to succeed an IoT-based PSS project. In order to do so, we employed a literature review methodology to propose a conceptual framework to summarize and organize the key concepts. It may help the service parts companies to identify the necessary elements, communication, visibility mechanisms and structure required for IoT-based PSS implementation. This allows the service parts enterprises to react quickly in demand change.

This paper is organized as follows: after this brief introduction, Section 2 discusses the literature concerning PSS and IoT; Section 3 proposes the framework to organize the main concepts in this field; Section 4 outlines some conclusions and proposes future works.

2. Literature Review

The objective of this section is to review the main works related to IoT, PSS and Sensing Enterprise in spare parts aerospace context. This section provides an overview of the papers that concentrate on this subject between 2007 and 2017. Table 1 summarizes the papers contribution on IoT Based PSS.

3. Proposed conceptual framework

In the management of service parts, a gap still exists between what has been largely investigated and proposed in the scientific literature on IoT. The authors attempt in writing this paper has been to try to overcome it, proposing an IoT Based PSS Application for Spare parts in Sensing Enterprise framework for supporting the service parts. The proposed conceptual framework highlights the process, main technology and implementation phases identified in the literature regarding the spare parts service once the IoT is implemented in aerospace.

Spare parts process

The traditional process management of service parts for after-sales service, in aerospace, encompasses planning, fulfilment and execution of service parts through activities like demand forecasting, parts distribution, warehouse management, repair of parts and collaboration processes with all the relevant parties in the after-sales service [2]. Adopting IoT in spare parts supply chain enabled condition monitoring, spare parts, and equipment repair services. Moreover, equipment OEMs can remotely monitor parts life cycle and function in their customers' plants, anticipate potential failures, order the parts and often execute repairs before the failure occurs. Thus, IOT can be beneficial for monitoring asset health to predict failure and repairs. This can reduce maintenance cost and usage of inventory. In a conventional demand forecasting, after the item is forecasted, an application of reordering policy is issued and sent to the OEM. The

OEM then dispatches the demanded spare part. The intermediate processes take a considerable amount of time. Using IoT platforms, as the OEMs have real-time data about the parts, processes like policy issue and lag time can be eliminated [2]. The proposed conceptual framework highlights the processes identified in the literature regarding the spare parts service, once the IoT is implemented in aerospace. The method focuses on business process impacts of IoT, and its application in the aerospace industry. The novelty of Internet of Things (IoT) technologies requires a new process approach where hardware and software will enable objects that can be equipped with identifying, sensing, networking and processing capabilities, to interact and to communicate with each other over the Internet, to accomplish desired objective.

Table 1: Papers contribution on IoT Based PSS.

Author	Contribution
Zancul *et al.* (2016)	Demonstrate a method for adopting IoT-enabled PSS. The application pointed out that this approach can be useful to support companies' adoption of IoT in a PSS context. The method was applied to the machinery industry.
Espíndola *et al.* (2012)	Demonstrate that IoT application in PSS could provide a scalability. By using a case study, they conclude that for adopting PSS by adding value, use and customization; require new technologies for its implementation.
Nilsson *et al.* (2016)	The paper suggests using visual mapping systems approach to show and analyze included actions, physical artifacts, and relations within the system in order to gather the stakeholder's requirement for Integrated Product Service Offerings (IPSO) implementation is structured way.
Rondini *et al.* (2016)	Propose a new concept Product-Service Concept Tree (PSCT) to identify PSS solutions that meet customers' needs in order to select the best PSS solution to implement.
Zancul *et al.* (2016)	Proposes a method for adopting an Internet of Things (IoT) enabled product-service system (PSS) considering business model and product enhancements. The method focusses on business process implications of IoT and its application in the machinery industry.

Technology

IoT provide other benefits as visibility and transparency allowing the enterprise to react rapidly to disturbances events, which represent the main characteristic of Sensing Enterprise, using IoT technology [11]. This concept allows any object communicates with others objects through Internet, and provide information in real time with new technologies, like RFID and sensors, to facilitate the exchange of goods and services in global supply chain networks [11].

As stated by Boza *et al.* (2016), IoT in Sensing enterprise is structured in three levels as follow:

1. Edge level: *this level is formed by the physical part of IoT. ID-technologies and Sensors below to these level (Tan et Koo, 2014). This level gives to the objects the physical part to store information and give them intelligence.*

2. Access Gateway Level: *objects need a network to send and receive information between these. The management of these network bellows to this level.*
3. Application Level: *in this level, objects acquire intelligence through implemented software. These objects can communication also with an application in a computer or a smartphone.*

Table 1: Papers contribution on IoT Based PSS (Continued).

Barquet *et al.* (2013)	Propose a framework to support the adoption of PSS employing the business model concept to guide the company on the analysis to implement product–service systems (PSS).
Vasantha *et al.* (2012)	Suggest creating a requirement lists when developing an (IPSO) and involve the key stakeholders in that process the maturity level is weak.
Bandyopadhyay *et al.* (2011)	Demonstrate that in aerospace and aviation industry IoT can help to improve safety and security of products and services. By storing these pedigrees within a decentralized database as well as on RFID tags, which are securely attached to aircraft parts, an authentication of these parts can be performed prior to installing them in an aircraft. In this way, safety and operational reliability of aircrafts can be significantly improved.
Uddin *et al.* (2016)	-Propose an integrated technological approach based on Internet of Things (IoT) concept to better predict spare parts demand and enhance the spare parts supply chain .efficiency. The introduced model is particularly advantageous in high-value assets' spare parts management. - In a conventional demand forecasting, after the item is forecasted an application of reordering policy is issued and sent to the OEM. The OEM then dispatches the demanded spare part. The intermediate processes take a considerable amount of time. Using IoT platforms, as the OEMs have real-time data about the parts, processes like policy issue and lag time can be eliminated.
Ngai *et al.* (2014)	Propose analytical mode based on Radio Frequency Identification (RFID) in the maintenance of supply chains of aircraft parts. This model helps us gain a better understanding of the relationships between various costs incurred and the RFID effect on an aircraft maintenance tracking process.
Whitmore *et al.* (2015)	The Internet of Things (IoT) application in industry is reflecting in a new concept of enterprise named Sensing Enterprise. IoT provides information in real time with new technologies, like RFID and sensors, to facilitate the exchange of goods and services.
Boza *et al.* (2016)	IoT provide other benefits as visibility and transparency allowing the enterprise to react rapidly to disturbances events has structured IoT in three levels.

The proposed conceptual framework favors an integrated technological approach based on IoT concept, to better predict spare parts demand and to enhance the spare parts supply chain efficiency. The introduced framework, IoT technology, is particularly advantageous in high-value assets' spare parts management as in aerospace [2]. This concept allows the enterprise to be pro-active in the decision making, by anticipating certain events and to react in a more timely manner, when certain events occur. Adding a service to a company that offers products, is a way to create value to the customer. In aerospace context, providing an IoT to improve spare parts management is to be perceived as offering value added to the customer, such as visibility and transparency, allowing the enterprise to react rapidly to disturbances events [11].

Implementation

Zancul *et al.* (2011) suggest three main phases shown required for successful PSS implementations, which are as follow: Preparation, Implementation/Realization and Measurement of results. The main benefits of the PSS are measured at the stakeholder's level. The IoT implementation should follow the three phases as follow:

- Phase 1: *contains the preparation based on the stakeholder's requirement.*
- Phase 2: *is the implementation and realization of the IoT based PSS.*
- Phase 3: *is the measurement of results.*

Besides, all the gathered data are stored in the enterprise system allowing all internal business units to react and make decisions with regards to spare parts demand [2]. The proposed conceptual framework is based on the IoT technology, concepts to be adopted to have a Sensing Enterprise and the implementation process. It helps the service parts to identify the necessary elements and structures required for IoT deployment. Therefore, the implementation of this framework provides a standard way to build and deploy IoT applications in aerospace service parts. In practice, problems are usually much more complicated than the framework that we presented in this paper. However, the insights and implementation process proposed in this research can be helpful in implementing IoT in a real-life. The framework that we are proposing can act as a building block. We therefore, consider the results of this paper as a foundational element that enriches the toolkit of aerospace companies.

The three main parts are summarized in Figure 1.

1. Final remarks

Adopting IoT-based PSS platform in aerospace OEM operations to meet customer demands and have a rapid responsiveness is paramount. The main benefits is providing better predictability of demand, inventory visibility, accelerated product service and most importantly, sustainability and quality. Therefore, the challenge resides in the aerospace regulations, since the IoT is based on wireless communication. This challenge is more crucial for the military service parts that forces a permission to manage these parts. Besides, Implementing IoT in supply chain may be vulnerable to potential hackers. Thus, caution needs to be taken to protect the system.

In this paper, we presented the basics of spare parts management challenges in a supply network, as well as the main elements of inventory management. In addition, we treated the state of the art of the IoT-based PSS in Sensing Enterprise. The main goal is to identify all the research papers that has addressed this topic to organize the main processes, technologies and implementation phases in this field. Then, we proposed a conceptual framework for internet of things-based product-service systems for spare parts in aerospace Sensing Enterprise. This framework may help any enterprise desiring to apply IoT to improve the spare parts management. A possible future case study will be proving this framework in a real company to see if these concepts help to apply IoT. Moreover, this paper aims to invite supply chain management researchers for more research work in this area benefiting aerospace companies from the big technology changes.

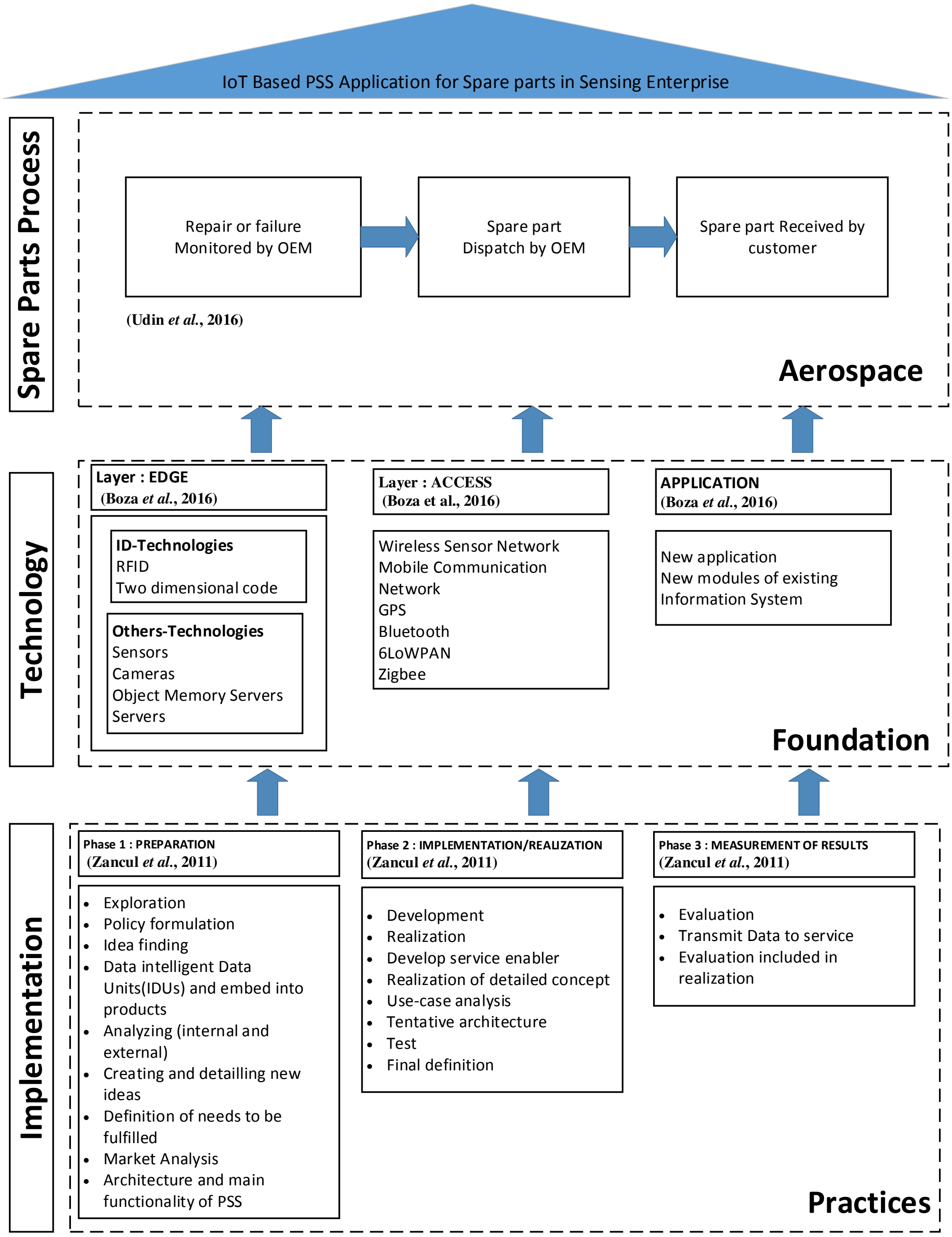

Figure 1: Conceptual Framework of IoT Based PSS Application for Spare parts in Sensing Enterprise.

The expected benefits of adopting the proposed framework include on-time parts delivery, reduced inventory of spare-parts and reduced costs. However, the implementation of such framework should be guided by an overall methodology within application-specific contexts.

The main limitation of this paper resides in a few papers focuses on the implementation of IoT in service parts in aerospace. Besides, as it was mainly focused on service parts in aerospace, this study has not considered other aspects of supply chain management, such as information, people and organization. Future research is thereby requested to further explore the impact of these aspects.

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DIGITAL TRANSFORMATION

Digital plan: a design science approach for manufacturing small and medium enterprises

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Purpose: Manufacturing small and medium enterprises (MSMEs) lack the resources to plan their digital transformation alone. We develop a method to help MSMEs elaborate a digital plan that is coherent with their digital performance, business strategy, objectives, and operational issues.

Design: We define digital performance based on the academic literature. Then, we apply design science research to structure the iterative development of the digital plan method.

Findings: We have completed three iterations in 15 MSMEs. The managers are generally satisfied with their digital plan and have a good adoption intention of the projects in their plan. The largest qualitative impact is the help in the establishment of priorities of the digital projects.

Academic limitations: We plan a fourth iteration cycle based on the evaluation of the previous phases and a longitudinal study on the adoption and impact of the digital plans. Finally, we wish to improve generalization with a statistical validation of the model on a larger and more diverse sample.

Practical implications: With a digital plan, we expect MSMEs to adopt digital projects better aligned with their strategy and improve their business performance. Once generalized to a larger sample, this project could help legislators to adjust funding and regulations to the reality of MSMEs.

Originality/value: To our knowledge, no single model defines the digital performance in MSMEs. This can support further academic studies. The digital plan method will help managers and analysts in MSMEs to get ready for the digital transformation, while staying aligned with their strategy and situation.

Keywords: Manufacturing small and medium enterprise, digital performance, digital plan, digital transformation

1. Introduction

The digital transformation is the integration of digital technologies into business practices [1]. Enterprises move one-step at a time. The HUB Institute [1] uses the notions of small wins, which encourage progress, as well as "fail-fast" that allows to test small-scale projects, learn from mistakes and avoid delays and errors due to digital projects' vast proportions. Such a strategy requires careful planning, which requires resources. However, manufacturing small and medium enterprises (MSMEs) lack human and technological resources [2, 3]. Hence, this research aims to develop a method to help MSMEs elaborate a digital plan coherent with their digital performance, business strategy, and operational issues. Since no author agrees on a common definition of digital performance, we suggest one to assess the strengths and weaknesses of companies and to facilitate the development of a digital plan of actions in line with theirs issues and business goals. This will ensure optimal impact in their digital transformation approach.

2. Theoretical background

Strategic planning and control of processes through lean manufacturing are prerequisites for digital transformation [1, 4, 5]. This section covers all the steps required to engage a digital transformation process. It also summarizes the current state of literature on digital performance definition.

Strategic planning

Strategic planning is necessary to give direction to a company [1, 4]. Without this step, enterprises navigate their digital transformation without direction, making decisions and investments unprofitable and inefficient [1].

The Business Development Bank of Canada (BDC) [6] defines strategic planning as the exercise of putting in place a sound business strategy that guides decisions and actions for long-term growth. According to the BDC, strategic planning takes place in three main stages: strategic analysis, orientations, and implementation.

Strategic analysis is a preliminary assessment of a firm's situation, its expectations, issues and scope of planning, a definition of its current vision and an analysis of its strengths, weaknesses, opportunities and threats [6]. The orientations include reviewing its vision, mission, business objectives and strategic priorities, establishing action-oriented operational plans that include resources and allocated budget, and financial projections to assess estimated profitability of strategic planning [6]. The implementation includes the development of an action plan for a period of 12 to 24 months as well as the implementation and evaluation of the previously set targets [6].

Process optimization

Industry 4.0 was initiated in Germany to represent the ability to offer mass customization to its customers [7]. Mass customization requires operational flexibility and quick reaction time. Agile manufacturing utilizes the tools of lean manufacturing, namely Total Quality Control, cell layout, maintenance system, reduction of set-up times, elimination of wastes, continuous improvement, Kaizen, Kanban, and small production batches [8]. Investing in digital technologies without process control reduces the potential benefits of these technologies [5]. Lean organizations develop a culture of continuous improvement and control of their processes, allowing them to align their activities flexibly in relation to their business strategy [5]. Furthermore, optimizing processes eases the identification of operational issues since the organization has a greater control over its processes.

Digital performance

Several authors have suggested definitions of digital performance [1, 7, 9–11]. The success of a digital transformation requires a transformation of a firm's digital leadership, culture and organization, technology management, data management, decision-making system and customer experience, as presented in Figure 1.

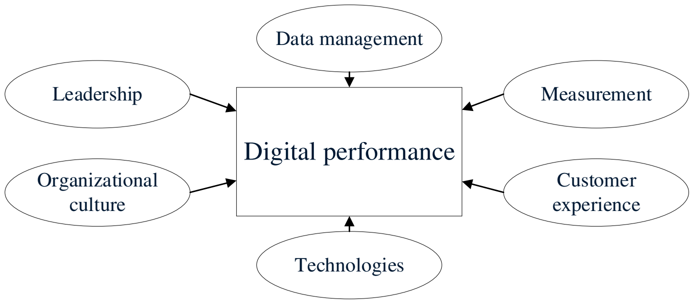

Figure 1: Dimensions of digital performance

Leadership is the process by which a person influences a group of people to achieve a common goal and requires informed, visionary, voluntary and exemplary management [1]. Organizational culture is a specific way of business responding to problems. It characterizes the company and distinguishes it from others in its values, its approach to problem solving and reactions [1, 7]. Technologies represent the collection of techniques, skills, methods and processes used in the production of goods or services or in the accomplishment of objectives [1, 11]. Data management is the totality of the company's activities aimed at acquiring, controlling, protecting, delivering and improving the quality of the data and information assets of the company [11]. Performance measurement represent the repeated action of using technology-related data and resources to assess the performance of an organization [1]. Customer experience is the effort to provide a solution instead of a product to the customer, in terms of design, associated service, and communication throughout the product lifecycle [1].

3. Research design

We apply design science research (DSR) guidelines [12] to develop a method for the elaboration of a digital plan in MSMEs, as presented in Figure 2. DSR aims at creating new artifacts to solve existing or new problems and to extend humans and social capabilities [12]. The research process contributes to knowledge and the artifacts help business improve their productivity and efficiency [13].

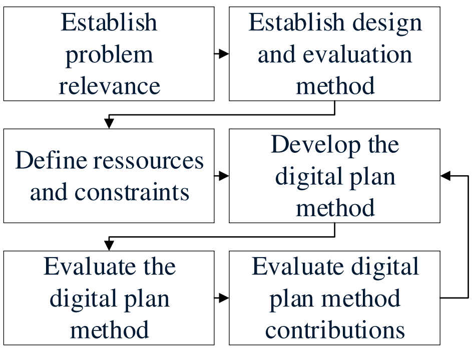

Figure 2: Development steps, adapted from Hevner et al. [12]

We established problem relevance through a review of academic and professional literature as presented in section 2. In accordance with the guidelines [12], we adopt an iterative design with empirical testing after each phase. We evaluate the adoption intention and the satisfaction of managers one to two weeks after the submission of the digital plan and again six months later through a web survey. Because digital projects span several months, a second evaluation allows the evaluation of adoption. Adoption intention items are derived from existing literature [14].

The developed method had to respect several constraints set by the local government. To be eligible for public financing, the digital plan must include an assessment of digital performance and must evaluate operational issues in a minimum of five critical business processes. Although no limit was set on the size of companies, this method is oriented towards small and medium enterprises who represent a vast majority of enterprises in our region and might not have the sufficient resources to develop a digital plan on their own.

After identification of the context, relevance, design and constraints, the iterative development began. The first phase lasted from October 2017 to January 2018. Evaluation for Phase 1 of the development was made on a single MSMEs. Several changes were made following this first digital planning exercise. We changed the wording of several digital performance evaluation items, which were deemed too "academic" by the managers. The model for digital performance, however, was unchanged. We put a greater emphasis on the business strategy and business objectives discussion. Finally, we suggest to the MSME to undertake lean manufacturing or process optimization activities before the digital planning exercise. This optimization is not mandatory, but will facilitate the recommendations as the process is better controlled.

Phase 2 started in February 2018 and is still underway as of the submission. The following sections detail the development, evaluation and expected contributions of the method.

Digital plan method

According to the literature, digital initiatives must be aligned with the business strategy for them to provide a competitive advantage [1, 15]. Technology must serve business objectives and seek to solve operational issues [15]. A digital planning exercise must thus consider a company's business strategy and objectives. A recent strategic planning exercise is required before starting the digital planning exercise. Participating companies must state their main objectives as well as their current issues in a form before the first digital planning meeting. These objectives and issues are then discussed with the executive team of the MSME and the researching team.

In addition to alignment with business objectives and issues, a digital plan must respect an organization's level of digital performance, sometimes dubbed readiness [16]. This ensures an organization can increase its digital performance in small steps, which improves success chances [1]. For this research, we adopt the digital performance definition presented in section 2. Evaluation of each of the dimensions is made through a self evaluation by the managers of the different organizational functions. A functional evaluation allows the identification of digital opportunities to solve operational issues [17]. Finally, the managers and business researcher evaluate digital opportunities which are relevant to the organization's situation and group them in an organizational digital plan. This plan gives the MSME orientations to align its digital transformation.

4. Method evaluation and discussion

In Phase 2, we send a satisfaction and adoption intention web survey addressed to the manager responsible for the digital transformation, with items from existing literature [14], four to six weeks after the plan is accepted by the MSME. Participation to this survey is not mandatory and only one reminder is sent. Two out of four enterprises who have received the survey have filled it. The other MSMEs have either not completed the digital plan process or have had their plan for less than four weeks as of the submission of this paper. Qualitative feedback was also requested directly after the submission of the digital plan. Because of the small survey sample, only qualitative feedback will be discussed in this paper. Further results will be presented at a later time.

Plan perceived usefulness

Objectives declared by the managers before starting the planning process include reducing cycle time, improving productivity and reducing administrative passing time. A digital transformation can help companies reach these goals and so managers feel the digital plan is useful to their organisation. However, impacts on the business model, value proposition or competitive advantage are mentioned less often by managers. There is a risk to overlook long term effects of a digital transformation if the impacts on the business strategy is not considered [1, 6].

Plan perceived ease of application

Some managers feel overwhelmed by the projects in their digital plan. Even when splitting the projects into smaller steps, they still fear not having enough time and manpower to dedicate to their digital transformation. Several requested further coaching to help their project managers plan their actions, while others stated they would need to hire more resources.

Digital plan adoption intention

While all managers who participated in this study wish to apply at least part of the digital plan, some declared wishing to start in the near future. The later managers are the ones who felt they might not have sufficient resources. Further answers to the web survey could help establish whether the perceived ease of application is the most important factor for the adoption intention.

5. Conclusion

The digital planning method suggested in this paper helps MSMEs set priorities in digital projects aligned with their business objectives, operational issues and digital performance. The plans are perceived as useful by managers. Managers are generally satisfied with the process and the plan, but they fear a lack of resources will hinder the application of the plan. Many would like to have more support in their first steps after planning. Furthermore, several managers focus on the day-to-day impact of technologies more than on the long term strategic impacts.

This paper highlights the need for consultants to support MSMEs in their digital planning and digital projects. It also opens research opportunities. Further studies are planned to evaluate the adoption intention of the digital plans and a longitudinal study of the impacts of the digital plans on participating enterprises. Finally, we wish to evaluate the digital performance definition in a future study.

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How Can SME Embark in a Digital Transformation in the Context of the 4th Industrial Revoution?

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Purpose: More and more firms are learning about the benefits of the fourth industrial revolution and how the new technologies can benefit their organizations. Larger enterprises, normally have the resources to invest in these industries 4.0 technologies but it's confronted by the need to change. Start-ups that does not have a lot of resources to invest however can design their business model and strategy according to the new reality. Small and medium-sized enterprises (SME) have a double challenge of having a pre-existing structure and limited resources. This research aims at answering these questions: a) How to create a strategy for digital transformation for SME and what should this strategy contain? b) What does SME need to re-think to successfully transform their business in the industry 4.0 era?

Design/methodology/approach: The main method used for the research is the pragmatic approach with an action research strategy. The researcher is accompanying a medium size manufacturer for Original Equipment Manufacturer (OEM) in their digital transformation.

Findings: The results helped to develop a model that describes the digital transformation to a new business model in three stages: 1) Determining the level of industry 4.0 maturity by measuring nine dimensions; 2) What to focus on when determining its digital transformation; 3) How the nine dimensions must be reached to be in sync with each other's in the new business model.

Academic limitations/implications: The research is based on the observation of only one organization digital transformation. The model must be tested in other circumstances to raise its validity and robustness.

Practical implications (if applicable): Findings will help business owners and managers in their digital transformation.

Originality/value: The paper combines several notions into a comprehensive model for organization to use as a roadmap to a digital transformation in the fourth industrial revolution.

Keywords: Industry 4.0, Digital Transformation, Strategy, Business model, SME manufacturing.

1. Introduction

Firms are at the eve of the Fourth Industrial Revolution, where information, technology, and human beings are connected like never before. Many decision-makers see it as an engineering project or computer science project to raise the efficiency of the way they do business. The result is continuous improvement of the firm, and therefore some authors see the Industry 4.0 as just tools for the Lean Production systematic method [1]. The principles of a new way for human-to-human, human-to-machine and machine-to-machine to communicate and how decision-making and supply chain management will be affected, meaning that Industry 4.0 can offer more profound changes in every organizational aspect. Recently, news business models are being tested with Industry 4.0 technologies, for example, *servitization*

[2], mass customization products [3], *unscaling* production [4] and virtualization [5]. To fully benefits the Fourth Industrial Revolution, firms will need to transform their company by including the choice of technologies at the same level as their value creation for its client's and the appropriate organizational structure. All three must follow a strategy to work. Strategy must pilot the change to digitalization and not the technology [6, 7]. In this context, businesses need to consider their limited resources (financial, human, information, knowledge, etc.). Larger enterprises normally have the resource to choose technology that will help them cope with the coming revolution, but they will have difficulties changing their organization to meet the new economic challenges. Just think of smart manufacturing of firms like Siemens and Volkswagen. As for startup, they have limited resources but will be able to work on innovative business models and choose what technologies will suit them best. The best example is Uber which, in less than 5 years, changed the taxi industry forever. Small and medium-sized enterprises (SME) face the double challenge of limited resource and with an already existing structure. Some say that they will be the hardest hit because of its complexity and the need for resources [8, 9]. These can be both a hinder, and yet, can be a source of innovative way of doing business. It is argued that to achieve this, the SME firms need to have a digital transformation strategy so they can become an Industry 4.0 enterprise. The research will answer two questions: a) How to create a strategy for digital transformation and what should this strategy be? b) What does SME need to re-think to successfully transform their business in the Industry 4.0 era?

2. Literature Review

This section will present a summary review of the Industry 4.0 technologies, how to evaluate a firm's maturity and readiness for the Fourth Industrial Revolution and an overview of digital transformation strategy for firms.

2.1. Industry 4.0 technologies

When the industry 4.0 was first presented, both the Internet of Things (IoT) [10] and cyber-physical system (CPS) [11] were the main technology of the revolution. Since then, it is wildly accepted that cloud computing, collaborative robots, big data, artificial intelligence, additive manufacturing, and simulation/virtual reality [12, 13] are also part of the industry 4.0. As time goes by, there will probably be more technological families associated with the Fourth Industrial Revolution. What makes this era a revolution is being able to combine technologies to make things which were previously impossible. For example, knowledge data could be combined with the use of artificial intelligence to operate a collaborative robot cell to build a Ikea furniture without instructions [14]. This brings human-to-human, human-to-machine, and machine-to-machine communication seemingly and with great fluidity. Industry 4.0 technologies can be represented by four design principles: technical assistance, interconnection, information transparency and decentralized decisions [13]. The integration of technology in businesses is called the digital business strategy [15], and thus Industry 4.0 is digitalizing the operations and by extent how the workplace is managed [11].

2.2. Maturity

Firms are at many levels of readiness to face the changes of the Fourth Industrial Revolution. There a few models that exist to help measure the maturity of enterprises: IMPULS – *Industrie 4.0 readiness* [16], Empowered and Implementation Strategy for Industry [17], Price Waterhouse Coopers Digital Operations Self-Assessment [18], The connected Enterprise Maturity Model (EMM) [19], the Assessing of IT and software of the SIMMI 4.0 models [20] and the Adoption Maturity Model (AMM)[21]. These models help enterprises to evaluate how ready they are and give some indication of what dimension of the organization they must work on to be ready. Some are specified to one or a few dimensions of the firm. For instance, SIMMI 4.0 [20] focus only on the IT readiness of an enterprise. It is worth mentioning that the AMM model is the only one that uses interviews to asses a firm in its readiness, but give an in-depth look at one's strategy, maturity and performance. From all these tools to evaluate a firm readiness to face of the Industry 4.0 era, the one that gives a global assessment of the enterprise is the Industry 4.0 Maturity

Model from Schumacher, Erol, and Shihn [22]. It not only evaluates the technology readiness and maturity, it also evaluates eight other dimensions as illustrated in Table 1. These dimensions give a global view of the firm strengths and weaknesses to face this new era. But like the others, lacks in giving a global strategy, but specific area to improve. Business owner and SME manager need an overall vision, a strategy if you will, of what to do to transform their business [7].

Table 1 – Dimensions and maturity items of industry 4.0 Maturity Model

Dimension	Examples of maturity
Strategy	Roadmap, strategical resources, business model, etc.
Leadership	Leaders, management competences, coordination, etc.
Customers	Customer data, digitalization of sales/services, etc.
Products	Digitalization of products, etc.
Operations	Decentralization of processes, interdisciplinarity, collaboration, etc.
Culture	Innovation, knowledge sharing, etc.
Employees	Technological literacy, openness to new technology, autonomy of employees, etc.
Governance	Regulations, protection of intellectual property, etc.
Technology	Existing information and communications technology (ICT), machine to machine communication, mobile device, etc.

2.3 Transformation strategy

Some authors studied digital strategy in big firms [23, 24] without looking at what and how to change the preexisting dimension of the organization. A published literary review [12] shows that there is still very little interest in the link between Industry 4.0 and business strategy and even less in how to successfully transform a firm to be ready for the new era. As stated in the introduction, strategy must pilot the change to digitalization and not the technology [6, 7]. Some will argue that a digital transformation is similar to *Business Process Reengineering* (BPR) as defined by Hammer and Champy [25], but the change is more profound than just process. There are three studies which discuss digital transformation in SME. The first is the work of Matt and all [23], which states that a firm needs to transform itself in the digital world by considering three dimensions: new added value for the firm and costumers, change to its organization and the use of technology. To that, SME must consider its resource limitation, which is mainly financial. The second is a roadmap from Schallmo and al. [24] that helps the firm cross five steps in changing one business model: digital reality, digital ambition, digital potential, digital fit and digital implementation. The third is a three-stage maturity model (3SMM) that first envision the SME in the 4.0 era, then develop a roadmap to help enable the changes and finally enact the change in it market, product, process and value network projects [26]. All three have their strengths and weaknesses, which will be discussed later in this paper.

3. Methodology, limits and ongoing study

The Digital transformation strategy concept for SME is still under development. For the moment, the concept is a combination of work previously done and assembled so that SME owners and its managers can use it as a roadmap in their transformation. A study is being held in an SME firm (200 employees) that supply original equipment manufacturer (OEM). The study is an action-research project where the research team accompanies and support the firm in its digital transformation. The action-research is appropriate to understand the change in a complex organization [27] and it is flexible to evolve from discoveries made on the field [28].

At the moment, the evaluation of the maturity of the firm was done and will determine the transformation strategy in the coming months. The data was collected via observation, discussion, and semi-structured interviews. Using the data, the researchers inputted the information in the chosen maturity assessment model to analyses the firm readiness to the industry 4.0. The full cycle has not been done yet and thus no final results are available. Also, there will be a need to do the experiment in more firms to validate the concept.

4. Digital transformation strategy concept for SME in the fourth industrial revolution

Many SME owners and managers are tempted to digitalize their business to be competitive. However, a transformation is a risky and complex thing for them. Some, like the 3SMM models [29] is more project driven and thus more contained to help reduce the risk. Industry 4.0 technology can transform a firm with the right strategy. Inspired by Matt and al. [23], Schumacher and al. [22] and Schallmo and al. [24] work and integrating the PESTEL tool (political, economic, socio-cultural, technological, legal and environmental) [30] to evaluate external organization influence, the digital transformation strategy concept for SME in the fourth industrial revolution was created.

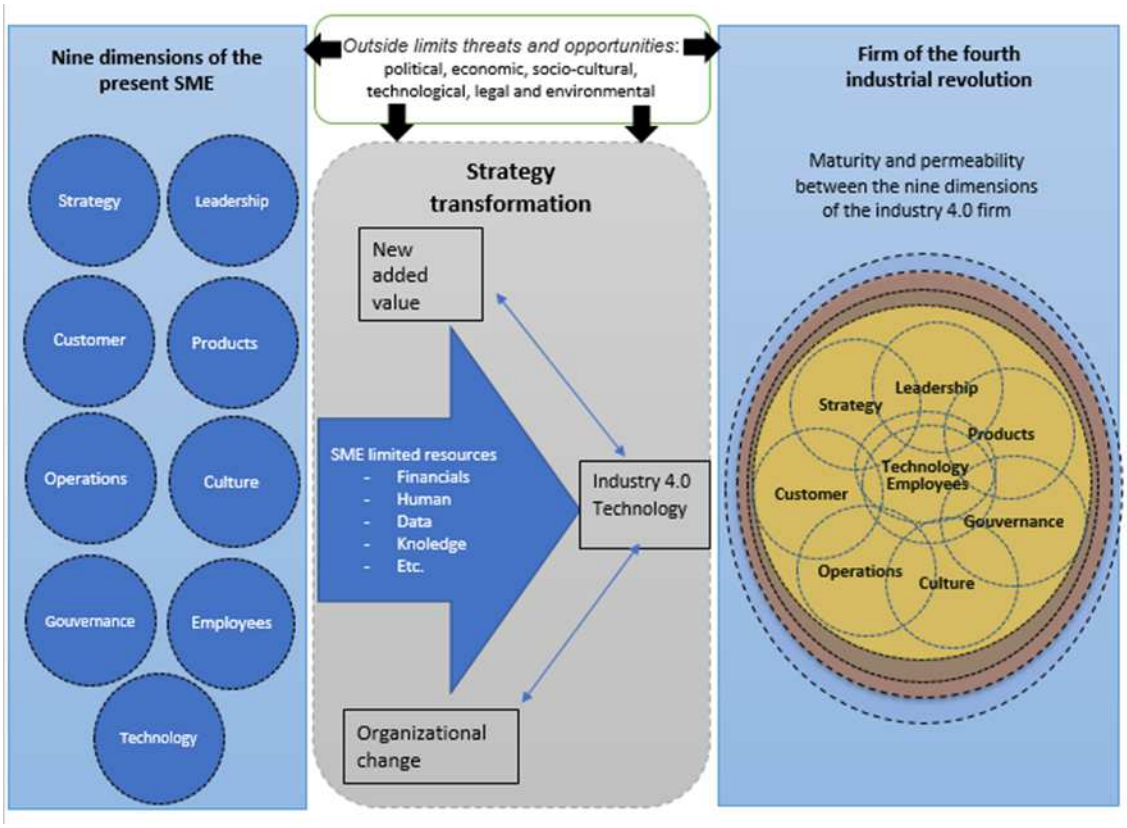

Figure 3 - Digital transformation strategy concept for SME in the fourth industrial revolution.

The concept combines several notions into a comprehensive model for organization to use as a roadmap in their transformation. The concept consists of three stages: the present SME, the strategy of the transformation and the firm of the Fourth Industrial Revolution. This is presented in Figure 1.

The first stage is to evaluate the present SME where one assesses the firm readiness and maturity. As stated in the maturity review section, there several models already in existence. The Industry 4.0 Maturity Model from Schumacher and al. [22] has the advantage of giving a broad portrait of a firm readiness and is easy to use by answering 65 questions. The Industry 4.0 Maturity Model analyze nine dimensions and rate the maturity is graded from 1 (less ready) to 5 (mature and ready). In figure 1, the dotted line around each dimension to show that they influence each other. For example, the technology literacy will influence the current technology of the firm or the use of customer data. The PESTEL will also influence the nine dimensions. For example, if the government include technology know-how in their school's curriculum, it will raise technology literacy for future generations.

The second stage uses the work of Matt and al. [23] to understand what a digital transformation needs to have to bring the firm to the next level in digital and by the same time Industry 4.0 maturity. The three following dimensions must be carefully chosen: the new added value, the organizational change, and the technologies selected. Contrary to Matt and al. [23] model, financial aspects are not the only limited resource, because the present model considers also human resources, data, knowledge, physical assets, intellectual property, etc. These limits are important as they are also a source of innovation and create new business models [31]. This stage adopts the five steps of Schallmo and al. [24] with the exception that a digital transformation is fluid and non-linear because of external influence (PESTEL tool) and of limits that cannot be overcome. There is also the factor that the firm may not be at the appropriate maturity stage in one of its key dimension and will need to be addressed before going forward.

The third stage is the objectives, which is having all the nine dimensions mature enough to consider the firm as an Industry 4.0 organization. By addressing and integrating its new added value, organizational change, and technology with its pre-existing resources, it can mature in most of its dimensions. What separates a firm in transformation with a firm that is ready for the industry 4.0 revolution is how to be in sync with each other's dimension in its new business model. Industry 4.0 is not simply dimensions of a firm, but how mature and permeable these dimensions are to each other.

5. Conclusion

The Fourth Industrial Revolution is well underway and firms want to benefit its full potential. For SME, this can be an opportunity to redefine themselves and be an important competitor in the world market. By taking this road, these SME can create new and innovative business models. However, redefining mean change and if it does not have a clear picture, it will result in small improvements or worse, sending their limited resources on something with no or little benefits. In this study, a concept that helps SME to create a strategy for digital transformation was presented by identifying what the new added value is, what the new organization should be and what technology they should use while considering their limited resources. What SME need to re-think to successfully transform their business in the industry 4.0 era was also mapped.

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Main objectives and barriers of the enterprise adaptation project to Industry 4.0: a case study in a technologies supplier company

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Purpose: To facilitate the understanding of the business adaptation project to Industry 4.0, this paper presents a Goals Model of the adaptation process. This model presents the main goals to be achieved, main constraints to the project and the opportunities that can be obtained with the success of the adaptation.

Design/methodology/approach: The presented Goals Model was developed through the For Enterprise Modeling (4EM) method and the information was obtained through a case study conducted in a Brazilian company that supplies technologies related to Industry 4.0.

Findings: Strengthening the company competitiveness, increasing production efficiency, processing large amounts of information, increasing integration between enterprise systems and operational safety are the main goals pursued by companies that want to achieve the Industry 4.0 paradigm. However, to achieve these goals, it is necessary to overcome the resistance of many employees, to spend large financial resources and to integrate correctly all the systems of the company.

Academic limitations/implications: This paper was developed based on a single case study to explore the issues at hand. Further research should provide more systematic information on the research topics addressed here, examining a larger number of companies.

Practical implications (if applicable): The Goals Model provided can help companies interested in achieving the Industry 4.0 paradigm to review its strategies and know opportunities that can be obtained from the successful development and completion of the project.

Originality/value: This paper presents a Goals Model of the adaptation process to the Industry 4.0 paradigm. Literature signals the need of frameworks based on enterprise modeling to help in the theme development.

Keywords: Industries 4.0, Enterprise Modeling, Goals Model, Case Study.

1. Introduction

Efforts around the world have been made to improve the productivity and efficiency of industries and this improvement can be achieved through the integration of Information and Communication Technology (ICT) with manufacturing [1].

In some of the most advanced economies of the world there is a movement aimed at improving the productivity and efficiency of industries through ICT. National and regional governments are developing and launching new initiatives and programs such as Industries 4.0 in Germany, Industrial Internet and Advanced Manufacturing in the USA, Made in China 2025 and Internet + in China, and La Nouvelle France Industrielle in France [2, 3].

Among the initiatives developed, Industry 4.0 is the one that has achieved more prominence. The term Industry 4.0 was officially presented to the German public by Kagermann, Lukas and Wahlster in 2011 during the Hanover Fair [4]. Industry 4.0 combines intelligent machines, systems, production and processes to form a sophisticated network, emphasizing the idea of consistent scanning and linking of all production units in a manufacturing facility by creating real-world virtualization in a large information system [5]. Industry 4.0 should be an integration and assimilation of concepts such as cyber-physical systems, internet of things, internet of services, intelligent manufacturing, mobile computing, cloud computing, industrial wireless networks, big data, sustainable manufacturing, autoconfiguration and self-optimization of production processes, and product customization [6, 7].

Industry 4.0 needs of advanced modeling methods [8]. Techniques of enterprise modeling and associated visual languages are very important and useful in supporting the development of smart enterprises [9]. So, to facilitate the understanding of the business adaptation project to Industry 4.0, this paper presents a Goals Model of the adaptation process. This model presents the main goals to be achieved, main constraints to the project and the opportunities that can be obtained with the success of the adaptation. The paper was developed through the For Enterprise Modeling (4EM) method. The necessary information for the modeling was obtained through a case study carried out in a Brazilian company supplying technologies for Industry 4.0.

This paper is structured as follows. Section 2 describes the methods used to search, organize, and analyze the literature, to structure the case study and select the best method of enterprise modeling. Section 3 presents the Goals Model developed. The last section presents the conclusions related to this work, pointing out the main limitations of the research.

2. Methodology

This research was developed through a case study and the modelling enterprise method. It is a research of qualitative approach, providing greater proximity between the researchers and the problems studied; and it has exploratory character, providing correlations between the objects of study to collaborate with future researches.

At first, for the development of this work, an exploratory bibliographical review on fundamentals, principles and concepts of Industries 4.0 was carried out. Due to its wide use and impact in the international academic community [10], we analyzed only papers published in the Scopus and Web of Science databases. To select the publications of interest, the following terms were searched through the title, abstract and keywords: “Industr* 4.0”, “Intelligent Manufacturing”, “Smart Compan*”, “Smart Enterprise”, “Smart Fabric”, “Smart Factory” and “Smart Manufacturing”.

A single case study was used because it provides better understanding of the details analyzed [11] and of the context in which the phenomena occurs [12], and is suitable for the initial phases of a research that is in the exploratory phase [13]. The case study was based on an interview script, to obtain information that would enable the development and subsequent presentation of enterprise models related to the process of enterprise adaptation to the Industry 4.0 paradigm. The interview script was provided to the professional interviewed (an electrician engineer) before the conversation. The interview was recorded, and the recording was transcribed to provide an accurate interpretation of what was said. The company that participated in the case study has an industrial unit in Brazil, has 30 employees, is classified as a medium-sized company (according to its invoicing) and is one of the national leaders in the supply of software for manufacturing industries.

Enterprise modeling is a technique used to study the operation of a company, considering it from its functional, operational and/or resource points of view [14]. With the purpose of performing the enterprise modeling and presenting a Goals Model of the enterprise adaptation project to the Industry 4.0 paradigm, the 4EM method was used, as it is the best method for enterprise modeling [15, 16], covering the requirements of enterprise modeling projects [17, 18].

4EM method provides systematic support to analyze, understand, and document a business, its objectives, business processes and support systems [19]. Through 4EM it is possible to clarify all current corporate functions, present requirements and necessary reasons for organizational changes, to present alternatives to those requirements, as well as to provide logical and coherent criteria for the evaluation of these alternatives [19]. The 4EM is composed of six models: Goals, Business Rules, Processes, Actors and Resources, Technical Components and Requirements, and Concepts.

In this paper, a Goals Model is presented. The Goals Model describes the vision of business strategy, focusing on the goals and problems that need to be addressed to achieve those goals [19].

3. Goals Model of the enterprise adaptation project to the Industry 4.0 paradigm

According to professional interviewed, for a company to achieve the Industry 4.0 paradigm it needs to evaluate what the market offers; analyze what is important in the short, medium and long term; define organizational strategies; create pilot projects; and disseminate the project in other industrial units. According to experience gained by the professional in implementation projects, the areas most affected by the adoption of Industry 4.0 technologies are IT, automation and top management.

Figure 1 presents the Goals Model of enterprise adaptation to the Industry 4.0. The main goal desired by a company that aims achieve this paradigm is strengthening competitiveness (Goal 1), due to the great competition and technological development imposed by the market. Achieving this goal, a company can have increased revenues (Opportunity 1) and reduced expenditure (Opportunity 2).

Strengthening competitiveness (Goal 1) is directly supported by the increase in productive efficiency (Goal 2), which when is achieved results in: increase in the quality of products and processes (Opportunity 6), sustainability of productive operations (Opportunity 8), decrease in variability (Opportunity 7), decrease of scrap, recall and rework (Opportunity 5), stock reduction (Opportunity 3) and decrease in product delivery time (Opportunity 4). For increasing productive efficiency (Goal 2), it is necessary to confront the cultural resistance of employees (Constraint 1), since, according to the interviewed professional, in many companies the people who work in shop floor feel intimidated to know that they are being monitored. In the view of the professional interviewed, training to deal with the technologies provided by Industry 4.0 is a good option to eliminate this resistance.

Increased production efficiency (Goal 2) is supported by the processing of lots of information (Goal 3) and operational safety assurance (Goal 5). The lack of investment in communication infrastructure, industrial wireless networks and machine sensing (Constraint 2) difficults the processing of lots of information (Goal 3). If such processing is achieved, it enables greater business integration (Opportunity 9).

Operational safety assurance (Goal 5) enables a reduction in non-scheduled downtime (Opportunity 12), reduction in accident risks (Opportunity 13), compliance with safety standards (Opportunity 14) and predictive maintenance of machines (Opportunity 15). However, for these benefits to be achieved, it is necessary to confront the cultural resistance of employees (Constraint 1).

Integration among systems (Goal 4) supports the processing of lots of information (Goal 3) and enables error reduction (Opportunity 10) and real-time decision making (Opportunity 11). However, for integration among systems (Objective 4) to be achieved is necessary to overcome the cultural resistance of employees (Constraint 1) and eliminate the plurality (Constraint 3) and customization (Constraint 4) of existing systems in a company, since many of them have interface unfriendly.

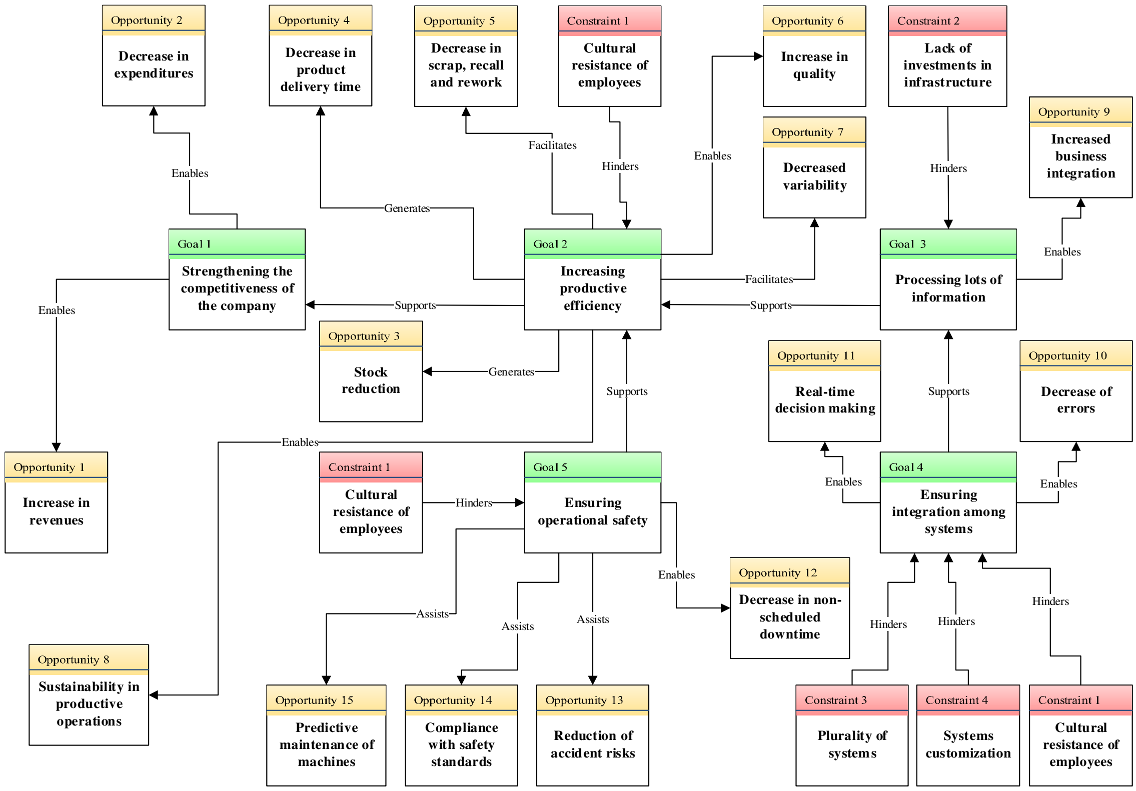

Figure 1: Goals Model.

4. Conclusion

The initiative known as Industry 4.0 has received great attention for its potential to bring together a set of technologies that can help to achieve greater efficiency in productive processes. Industry 4.0 represents the fourth industrial revolution, and it is a great opportunity and a very complex and demanding challenge for companies.

Considering that enterprise modeling assists in the development of intelligent enterprises and Industry 4.0 needs advanced methods of enterprise modeling, this research had the purpose of developing and presenting a Goals Model of the 4EM method for the enterprise adaptation project to the Industries 4.0 paradigm. Through a literature review on methods used for enterprise modeling, it was verified that 4EM is the most appropriate, since it is quite comprehensive.

The Goals Model facilitated the understanding of the strategies, detailing the goals desired by an organization and opportunities arising from the adaptation to the paradigm, as well as the visualization of the constraints that prevent the achievement of the goals. According to the professional interviewed, despite the increase of productive efficiency (Objective 2) not be the main goal of an enterprise adaptation project to Industries 4.0, it is essential for Brazilian companies at the present moment, as due to the economic crisis many organizations are decreasing the work shifts while maintaining the quantity of products and services provided. Yet, according to the professional, more than 50% of companies do not have well-defined goals when adopting Industries 4.0 technologies, and just follow trends or what competitors are doing, and in doing so, adopt technologies that are not appropriate to its need. Thus, the presented Goals Model is an initial step towards the construction of a formal and well-recognized framework and can become a reference for future acquisitions.

Limitations of research and opportunities for future papers

This paper presents some limitations, as it was developed based on a single case study to explore the issues arised. Further research should provide more systematic information on the research topics addressed here, examining a broader set of organizations. Considering that the information of this case study comes from the experience of a technology supplier company of Industry 4.0, further studies should contemplate the vision of user companies.

Future research can analyze a larger number of companies, develop the other models of the 4EM method and incorporate them into the Goals Model presented here, to contribute more significantly to the development of the thematic.

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SUPPLY CHAIN 4.0

Supply Chain 4.0 Challenges

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Purpose: Industry 4.0 has brought technological advances in all industrial fields, including the Supply Chain, which has been extensively studied over time in order to strengthen the competitiveness of companies. Thanks to these technologies, such as Internet of Things, Big Data, Cyber-Physical Systems and Cloud computing, as well as their subsystems and devices, full integration of the Supply Chain is becoming possible. However, impacts of Industry 4.0 technologies on Supply Chain, both positive and negative, are not totally clear and identified. This paper aims to identify and present an analysis of the challenges that companies will face when implementing Industry 4.0 technologies in the Supply Chain.

Design/methodology/approach: In order to achieve this purpose, a systematic literature review was conducted aiming to select and analyze relevant works about these challenges.

Findings: This study identified seventeen challenges grouped into four macro-groups: technical, financial and legal, technological and sociocultural. It is noted that these challenges require greater attention from the academia and industry in order to mitigate them and allow Supply Chain operations performance optimization.

Academic limitations/implications: As a future work, it is intended to verify how companies perceive these challenges as a decision factor regarding to the process of implementing the 4.0 technologies.

Originality/value: This study contributed in identifying the challenges related to the Supply Chain 4.0, which require further studies in order to minimize/eliminate them and achieve full Supply Chain efficiency through the use of available technologies.

Keywords: Supply Chain, Supply Chain 4.0, Industry 4.0, Challenges.

1. Introduction

Supply Chain (SC) has been intensively studied and great efforts have been done in order to integrate and strengthen the competitiveness of companies. Nevertheless, the SC function, which is responsible for coordinating internal activities of companies, as well as between their customers and suppliers [1], is becoming increasingly complex [2], requiring the use of innovative technologies to allow greater integration of processes among its members [3].

Through the emergence of the fourth industrial revolution, there are great opportunities to integrate and connect companies and their respective resources [4] in order to increase performance in terms of time, money and resource use [5]. [1] note that integrating SC processes and making information transparent among customers and suppliers enables companies to engage in collaborative action. This leads to increased flexibility, productivity and quality, as well as the possibility of optimizing their business processes [6, 7].

The digitalization of processes and activities of the SC, as a result of the application of the technologies of Industry 4.0, has gained more and more attention by both industry and the academia [5]. However, it is still observed that the real impacts of such technologies on SC [8], whether positive or negative, are not totally clear and identified. Under this focus, this paper aims to identify and analyze the challenges that companies must face when implementing the technologies of Industry 4.0 in SC.

This work intends to provide a better understanding of the obstacles of using the Industry 4.0 technologies in the SC. Once the problems are identified, new studies may focus on the minimization and / or elimination of these problems, allowing better results in integrating the SC and using the potential offered by technological innovations.

This paper is structured in five sections, including this introductory one. Section 2 presents the bibliographic review, contemplating a brief understanding of Supply Chain 4.0. Section 3 presents the methodological procedures. Section 4 describes the results obtained in the study. Finally, it concludes with the presentation of conclusions and future research opportunities in section 5.

2. Literature Review

Supply Chain 4.0 (SC4.0) is defined as "a series of interconnected activities concerned with coordination, planning and controlling of products and services between suppliers and consumers" [5]. Its objective is to generate new ways of adding value to customers and suppliers, besides generating more revenue through the integration and coordination of its processes [5, 8]: forecasting, acquisition, manufacturing, distribution and sales and marketing [9]. Six characteristics of SC4.0 which should cover all the customers and suppliers are presented by [4] in their work (Table 1). Thanks to the technologies from Industry 4.0, companies are allowed to increase flexibility, productivity, reliability and responsiveness in their operations. Moreover, by enabling the reorganization of the entire operation in real time, companies have the possibility to reduce the bullwhip effect and the costs associated with the operations of the supply chain [10].

Table 1: Characteristics of SC4.0.

CHARACTERISTICS	DESCRIPTION
Instrumented	Systems with sensors, RFID tags, meters and other integrated components capable of generating data for decision making.
Interconnected	Supply chain's members fully connected, including their assets, IT systems, products, and other smart objects.
Intelligent	Intelligent systems capable of making decisions in order to optimize their global performance by collecting and analyzing large volumes of data.
Automated	Numerous automated activities which aim to replace less efficient resources (including labor).
Integrated	Integrated supply chain activities, involving collaboration among members, making decisions together, making use of common systems and sharing information.
Innovative	Ability to develop and aggregate new values through more efficient solutions.

Source: Adapted by [4].

3. Method

The method to achieve the objective consists of three structured stages, according to Figure 1.

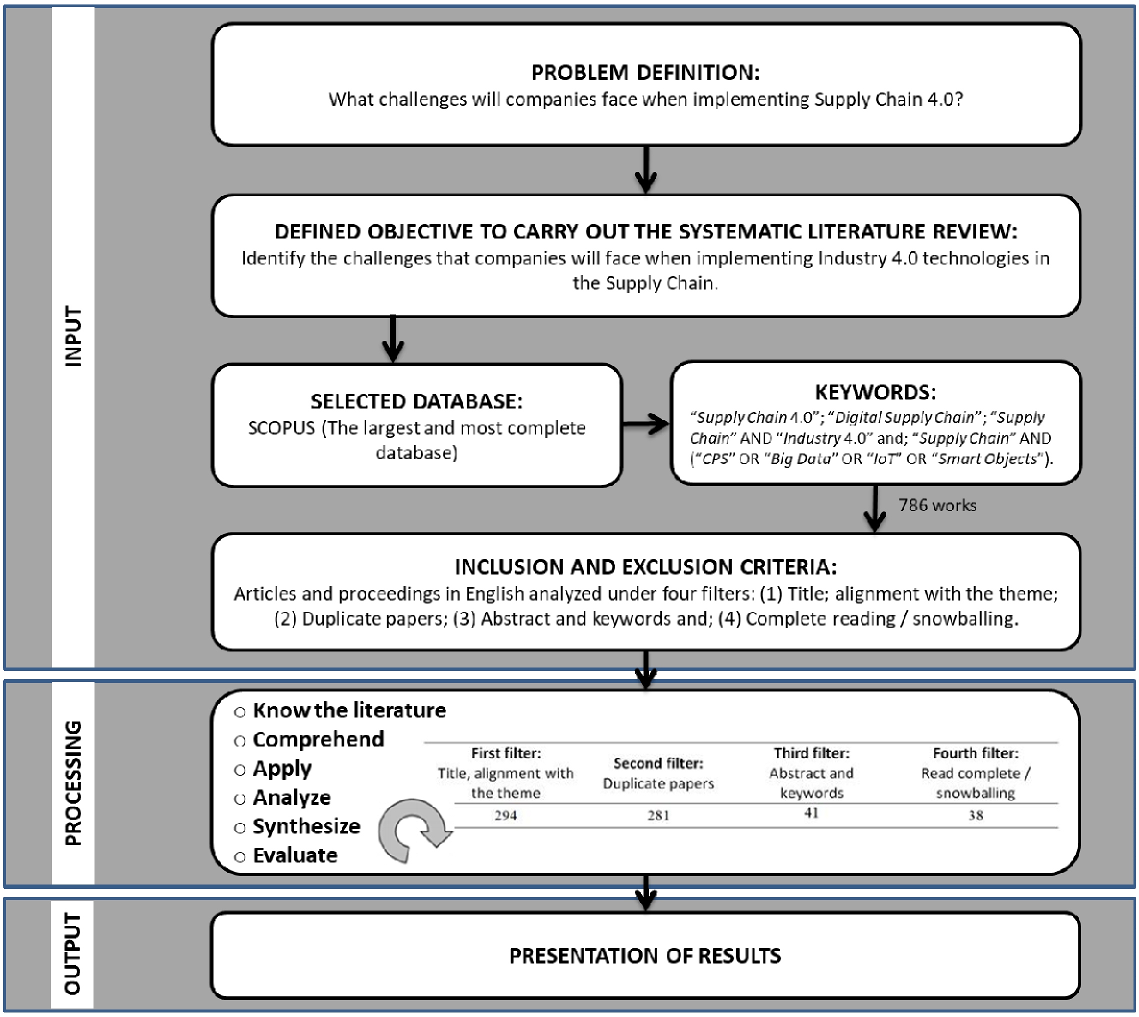

Figure 1: Systematic literature review process [Source: [11]].

4. Results and Discussion

A total of 786 articles and proceedings were identified (Table 2) and were analyzed according to the inclusion and exclusion criteria, resulting in a total of 38 selected papers. The quantities of filtered papers in each criterion are shown in Table 3.

Table 2: Papers found by systematic literature review performed.

	Supply Chain 4.0	Digital Supply Chain	Supply Chain AND Industry 4.0	"Supply Chain" AND (CPS OR Big Data OR IoT OR Smart objects)
Number of papers retrieved from the SCOPUS database	1	42	84	659

Source: Authors.

Table 3: Results obtained by systematic literature review's steps.

First filter: Title, alignment with the theme	**Second filter:** Duplicate papers	**Third filter:** Abstract and keywords	**Fourth filter:** Read complete / snowballing
294	281	41	38

Source: Authors.

It is observed in the 38 works that the topic "challenges" within the context of SC4.0 is gaining increasing attention over the years, with the largest amount of publications made between 2016 and 2017 (Table 4), demonstrating concern in order to minimize challenges and maximize benefits.

Table 4: Papers published by year.

Year of publication	Papers published
2010	2
2011	0
2012	1
2013	4
2014	1
2015	1
2016	13
2017	11
2018 (April)	4

Source: Authors.

A systematic literature review identified seventeen challenges that companies must face when implementing Industry 4.0 technologies in the SC (Table 5). Analyzing the challenges presented in Table 5, it is observed they can be classified into four macro groups, as shown in Figure 2: technical challenges, socio-cultural challenges, technological challenges and financial and legal challenges. Table 6 shows the percentage of articles and published proceedings that present the challenges of each macro group.

Table 5: Challenges of the implementing Industry 4.0 technologies in SC.

Authors \ Challenges	Compatibility	Complexity	Reliability and interoperability of systems	Lack of robustness	Scalability	Challenges in storing, discovering and sharing data	Security / privacy	Financial investiment	Legislative policies	Immature Technologies	Different dynamics and time structures of manufacturing processes	Lack of initiative, skills and / or insufficient knowledge	Lack of ability to combine data / obtain qualit data	Fear of change	Man-technology relation	Human Resource Replacement / Dismissal	Strategic alignment between functions, companies and governance
[12] Benabdellah *et al*. (2016)						x	x								x		x
[13] Bhargava *et al*. (2013)							x										
[14] Burmester *et al*. (2017)							x										
[15] Büyüközkan e Göçer (2018)		x	x				x	x	x				x		x	x	
[16] Ch e Rao (2018)							x										
[17] Chang et al. (2018)							x										
[18] Charmekh *et al*. (2017)							x										
[19] Corici *et al*. (2016)							x										
[20] Dweekat e Park (2017)			x														
[21] Fraj *et al*. (2017)				x			x										
[22] Gu (2017)			x			x											
[23] Haddud *et al*. (2017)	x	x		x		x	x	x			x		x		x	x	x
[24] Hallman *et al*. (2014)							x					x					
[25] Harrison *et al*. (2016)	x							x									
[26] He *et al*. (2016)							x										
[27] Hiromoto *et al*. (2017)							x										
[28] Ivanov *et al*. (2016)											x						
[29] Kshetri (2017)							x										
[30] Kynast e Marjanovic (2016)		x						x		x					x		x
[31] Lópes *et al*. (2012)					x		x	x									
[32] Lu *et al*. (2013)							x										
[33] Luszcz (2017)							x										
[34] McDonald *et al*. (2016)							x										
[35] Ong *et al*. (2016)													x				
[36] Pirpilidis *et al*. (2016)							x										
[37] Richey Jr *et al*. (2016)							x										
[38] The Digital Supply Chain Initiative (2016)							x										
[8] Tjahjono *et al*. (2017)									x						x		
[39] Tu (2018)								x									
[40] Xu *et al*. (2013)	x	x				x											
[41] Wang *et al.* (2016)													x				
[42] Wazid *et al*. (2017)							x										
[43] Weber (2010)							x		x								
[44] Wilding e Wheatley (2015)							x										
[4] Wu *et al*. (2016)										x		x		x			
[45] Yan e Wen (2010)							x										
[46] Zeiner e Haas (2013)	x	x			x		x										
[47] Zhong *et al*. (2016)				x	x	x	x										

Source: Authors.

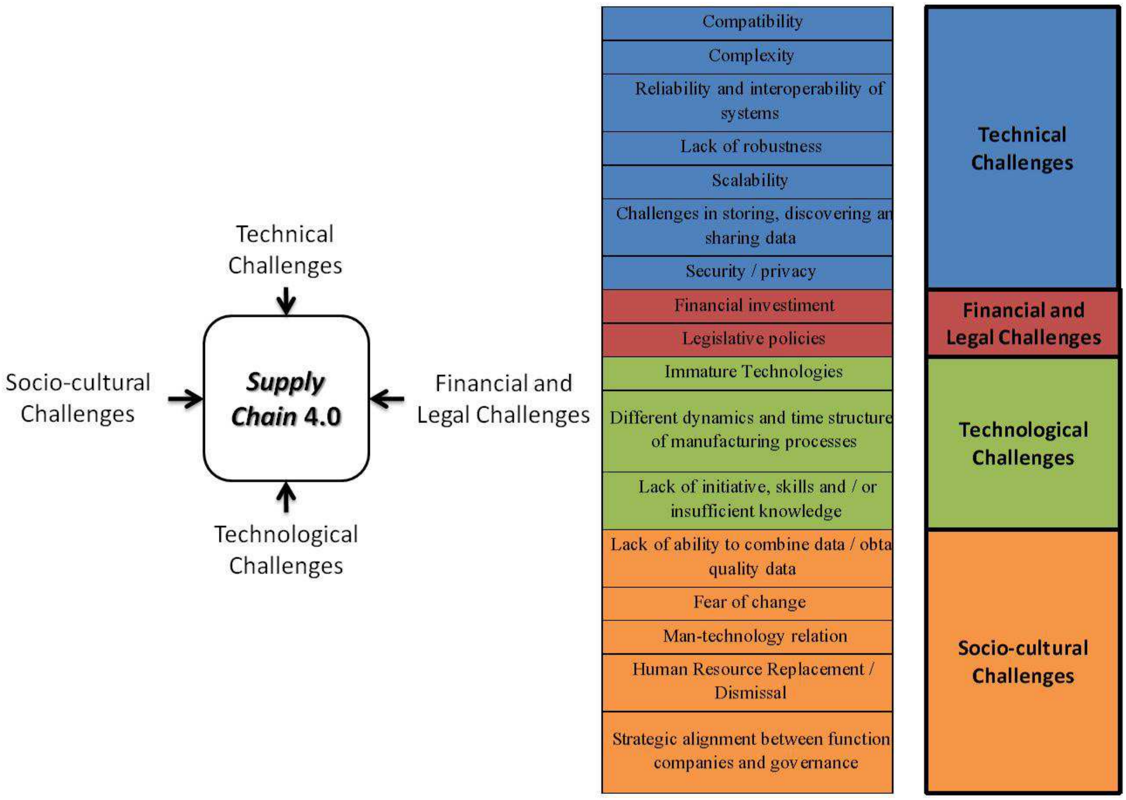

Figure 2: Challenges of SC4.0 [Source: authors].

Table 6: Percentage of papers addressing each identified challenges.

Classification of challenges	Percentage of papers presenting such challenges
Technical	84,21%
Socio-cultural	23,68%
Financial and Legal	21,05%
Technological	10,53%

Source: Authors.

5. Conclusion

Numerous challenges are identified in the literature when analyzing the concept SC4.0. Although integrating internal activities, systems and other resources of the company, as well as its customers and suppliers allow companies to obtain benefits such as performance, quality and cost reduction, it can bring great challenges as well.

This study contributed to identify the challenges related to SC4.0. In all, seventeen technical, socio-cultural, technological and financial and legal challenges were identified, and further studies are required in order to minimize and even eliminate them to achieve full SC efficiency through the use of available technologies. This was done considering just works from Scopus database, a limitation of the present paper although the selected database is the largest one. In addition, future work intends to verify with companies how these challenges are perceived by them as a concern and decision factor regarding to the process of implementing those technologies.

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Supplier integration through Digital Manufacturing: a SME paradox

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Purpose: This research explores the use of digital manufacturing systems for the integration of large enterprise supply chain with its suppliers, mostly small and medium-sized enterprises.

Design/methodology/approach: A survey of 113 managers, users, implementers and researchers working on digital manufacturing and Industry 4.0 was conducted to identify key factors that need consideration when firms implement and use digital manufacturing.

Findings: Survey results showed that it is essential in this new industrial context that companies aiming to use digital manufacturing pursue digital integration with their suppliers, seeking a decentralization of manufacturing. However, according to these experts, the adoption of such systems also depends on specific characteristics that make feasible the implementation and use of these complex and costly systems, and that do not fit to the reality of most suppliers, such as a wide range of products, complex supply chain and long-term projects with high complexity. It results in a paradox challenge since there is a need from the large companies' side but few and unclear incentives for the suppliers' side.

Originality/value: This paper contributes in two main areas. It provides a new perspective for incentives beyond financial returns to connect those suppliers by digital manufacturing systems, creating new ways to add value through an integrated and connected supply chain. It also explores the issues in an SME context which has been greatly underrepresented in the Digital Manufacturing research.

Keywords: Digital manufacturing, supplier integration, distributed manufacturing, Industry 4.0.

1. Introduction

Global manufacturing and supply chain face the challenges of future manufacturing environments, where products in the market are rapidly customized and service-oriented with a very short life cycle [1,2]. The introduction of Industry 4.0 technologies into manufacturing impacts the whole supply chain. Traditionally, collaborations between suppliers and manufacturers are crucial to reduce time-to-market, but such organizational structures are no longer sufficient. Technological advancements have touched almost all aspect of life cycle, greatly affecting supply chain processes. Digitalization has a disruptive transformative effect across industries, generating value and network effects. Considering that a key focus of organizations is to keep and strengthen their core competences in a competitive market, Digital Supply Chains (DSC) are an important element of supplier relations [3,4].

Digital manufacturing (DM) is increasingly important in this technological scenario as one of the areas of knowledge within the Industry 4.0 agenda. DM is a set of tools used for information management that assists decision-making throughout the manufacturing life cycle. According to suppliers of DM systems, in an environment that demands more product diversity and faster time-to-market, the ability to collaborate globally with all stakeholders and the flexibility to produce any product anywhere is critical. DM systems provide a concurrent view of engineering disciplines and intelligence to all stakeholders throughout the production process. This supports the reduction of time-to-market, and enables a collaborative environment for the extended network and supplier integration [5–7].

This research explores under which conditions DM use is appropriate, and the use of DM systems to integrate supply chain of a large enterprise with its suppliers, mostly composed by Small and Medium Enterprises (SME). For this, a survey was conducted addressing experienced professionals in digital manufacturing use and implementation to capture the appropriate conditions for DM adoption in an Industry 4.0 context, and if DM is an appropriate system to assist the supplier integration as a way to decentralize the manufacturing process.

2. Research Design

The questionnaire is designed to answer the following two research questions:

(i) Do companies benefit from the digital integration with their suppliers seeking decentralization of manufacturing? and;
(ii) in which conditions are DM system implementation and use not appropriate?

The appropriateness regards aspects such as company size, project complexity, extension of supply chain, and variety of products. A survey was conducted with people from three key groups: (i) users from industry that employ various DM tools on a daily basis; (ii) consultants who assist on a DM implementation process; and (iii) researches exploring DM use. The survey is comprehensive, and incorporates a variety of respondents, such as users, managers, implementers and researchers on digital manufacturing and Industry 4.0 from several countries, enterprises, and research institutes. This has the benefit of supporting the capture of the broader organizational changes related to technological change. The Qualtrics software was used to operationalize the survey.

Only questionnaires that contained answers to all questions were considered as valid. The collected data was tested for index stability using Cronbach Alpha coefficient. The reliability test for the data collected resulted in a Cronbach's alpha of 0.850 [8,9].

A total of 113 completed surveys were received. Table 3 presents the sample composition of respondents based on their main professional activities. 20% of the respondents come from industry, 69% are researchers working on DM, and 10% of the respondents are consultant directly dealing with the implementation process.

Table 1: Table captions should always be positioned above the tables.

Professional Activities	Frequency	Percent
Industry	23	20,3%
Consulting	11	9,8%
University or R&D centre	78	69,0%
Other	1	0,9%
Total	113	100%

Also, more than 70% of the respondents answered that they have a degree of high knowledge, competent or expert, in the subject. Only 6% claimed to be novices or advanced beginners. More than 90% of respondents work with more than two digital manufacturing tools. This information is important since it shows respondents work in the three phases of digital manufacturing: Design-, Production-, and Control-centered. This significantly reduces bias that could negatively influence data quality.

3. Results

In this section, results are presented regarding the two research questions, starting with the issue of the benefits of digital supply chain integration using digital manufacturing. The survey results show that 93 (82.3%) of 113 interviewees agree that digital integration with supplier through digital manufacturing systems brings long-term benefits to the company. Among the benefits, it can be mentioned, for instance, the integration of data into a unique platform, which makes for a more efficient project coordination, allowing up front identification of problems before suppliers deliver the final product. This helps both in reducing rework and the risks involved in the project. Other benefits are also related to cross-enterprise transparency of information, such as the incorporation of both internal and external supplier information, coordination or integration across supplier management process, quality control, and manufacturing decentralization.

As for the second research question on appropriate conditions, the results reveal that the implementation of digital manufacturing systems is only feasible under certain conditions, mainly because of systems' complexity and cost that may not be aligned with the company conditions. 104 (92.1%) of 113 interviewees pointed out one or more organizational characteristics where digital manufacturing is not an appropriate solution for the company. Figure 1 shows the most cited conditions by the interviewees.

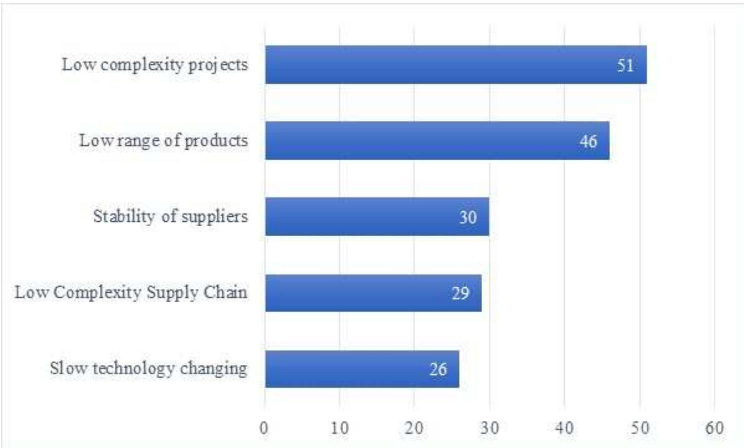

Figure 1: Conditions most cited as not appropriate for DM use

The low project complexity was the most commonly cited condition, having been cited 51 times. This was followed in order by the low range of products (46), stability of suppliers (30), low complexity supply chain (29), and slow technology changing (26). Digital manufacturing systems are designed to deal with projects that need to align and integrate data and processes with 3D technologies. The obtained survey results are coherent with such DM theory, since it posits an increased manufacturing intelligence in environments where variables cannot be well predicted or the effects of second order are too complex to be analyzed in a static way. It is also worth noting that operating under some of the conditions does not make the use of DM unfeasible, but being under several of the conditions may make DM implementation and use unfeasible in practice. For instance, in the aerospace sector almost all organizations use digital manufacturing systems. These organizations have both highly complex projects and supply chains and rapid technology change, but the range of products are low and supplier stability is high.

4. Discussion

In this section it is discuss the implications of the results obtained in the study. As cited by Stark [10], reduced time-to-market drives significantly benefits for a company, such as efficient managerial practices, increase margin revenue, gain market shares, among other benefits that make the company be one step ahead of the competitors. Strategies that large organizations have used to reduce the time-to-market is to have a greater focus on its core business, decentralize manufacturing, and also to digitize the supply chain [11,12]. For instance, companies that develop complex products with thousands of different parties have increasingly required that suppliers not only deliver a part within certain specifications and at the right time, but also deliver a digital product or process that enables traceability and simulations [13].

However, this decentralization also creates some barriers in relation to the anticipation of project phases. One of the benefits that digital manufacturing systems can provide is breaking these barriers by allowing agile manufacturing strategies to connect and to integrate various parts of the manufacturing process. Digital integration with suppliers within a common platform allows the anticipation of several phases of the project. For instance, considering the manufacturing lifecycle, the integration of suppliers allows the product assemblability processes - through the use of digital mock-up tools - to be anticipated even before the parts are completely developed by the respective suppliers and requiring just a few changes when the part is finished. Teams working on process development, ergonomics, or manufacturing ramp-up could anticipate their activities in their projects. However, achieving such benefits requires increasing integration and connectivity with the suppliers. This means that large companies that develop complex projects have sufficient incentives to use digital manufacturing systems by pursuing time-to-market reduction, as well as having the resources required for their adoption. However, the same incentives are not seen on the (primarily SME) supplier side, that develop a small number of products, do not have the same project complexity, and often being suppliers of competing companies that do not meet the same standards or do not use the same systems.

Thus, it can be seen a paradox in the obtained survey results. Although there are clear benefits of digital integration of suppliers using digital manufacturing tools, implementation and use of digital manufacturing systems is not compatible with most supplier capabilities due to the high cost and complexity of adopting the technology. This means that in the long term there is a likely conflict of interest between the companies.

In this way, some incentives beyond financial returns must be created to make the digital integration feasible. For instance, one of the plausible solutions would be for the contracting company to provide the system and specific training in the tools needed for its main suppliers. The cost to the contracting company is relatively low and may provide several advantages, such as improvement in the project quality and the final product, traceability of the development process, anticipation of project phases and improvement in the long-term supplier relationship.

5. Conclusion

This research explored the use of digital manufacturing systems for digital supplier integration and the appropriate conditions for its adoption. The results show that although it is not a technological barrier, the adoption of DM systems is not feasible in certain organization due to their characteristics. Despite DM system providing appropriate features for suppliers' integration and many large enterprises adopting it, there are few incentives for SMEs, which also happen to compose the majority of the suppliers, to adopt the technology due high complexity and cost. This, could create a conflict of interest between large companies and their suppliers in the long run. To solve such conflicts, incentives must be created beyond short term financials, breaking the buyer-supplier paradigm and encouraging longer-term partnerships. Moreover, it is noteworthy that the conditions prohibiting digital manufacturing systems are found where adoption most likely would be successfully adopted. For example, where environmental complexity is low the implementation complexity is also low and thus more manageable. But due to the cost and complexity of DM technology adoption, the returns are poor for those companies. An external market change could be required, to reduce the cost of adoption or addressing the right incentives, for example, supporting further SME adoption, since market characteristics are a greater barrier than technological ones.

This research contributed to theory by presenting a discussion on the adoption of digital manufacturing systems by small and medium enterprises, a topic poorly explored in the literature. In addition, the research empirically contributed by presenting a new vision of creating incentives so that the integration of suppliers allows the benefits of manufacturing decentralization. While contributing to a better understanding of digital manufacturing the study does have its limitations. The number of respondents per professional activity are not equal, relying on response from a higher number of scientific researchers than practitioners, managers and implementation consultants. However, a percentage convergence was observed among the groups, limiting the possible selection bias. The second limitation concerns the lack of an in-depth case study or interviews to better understand the further directions regarding digital supplier integration. In this sense, future efforts will address more in-depth empirical studies to better structure the path for digital manufacturing adoption by SME.

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U-Healthcare application in the Health Supply Chain – A framework proposal for the implementation of a Healthcare System based on ubiquitous technologies

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Objective: The objective of this article is to present a framework for the application of a healthcare model based on ubiquitous technologies, allowing the implementation of a U-Healthcare System.

Design / methodology / approach: Systematic review of the literature.

Results: In this study a reference structure was constructed for the development of U-Healthcare, using the following characteristics: (1) The factors of a health-based technology system; (2) The enabling technologies of a ubiquitous system; (3) The evaluation of the impacts of this technology through the Health Technology Assessment (HTA)

Limitation / academic implications: To expand the research through a systematic literature review and compare it with other frameworks for U-Healthcare application, at the same time to identify their characteristics and compare them with case studies, which these frameworks were applied. Also, as a research proposal, to establish a case study with the application of the proposed framework and evaluate the level of adherence of the proposed model.

Practical implications: The expansion of time, space, beneficiaries and services may be the biggest factors that can benefit in a U-Healthcare system.

Social implications: U-Healthcare uses the convergence of information technologies to provide disease prevention, diagnosis, treatment and post-administration of diseases.

Originality / value The proposal of a structure considering the characteristics associated with the U-Healthcare technologies, with the HTA and Model Health systems have not been described in an integrated manner as shown in this work.

Keywords: "U-Healthcare" "ubiquitous computing" "health technology assessment (HTA)" "health system".

1. Introduction

Ubiquitous computing (U) is a concept that emerged based on the view of Mark Weiser (1991). The following quote describes his view of ubiquitous computing: "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."

Ubiquitous Health Systems (U-Healthcare) can be defined as the environment where healthcare is available to everyone, anywhere, with no dependence on time and location, and where the technologies that enable U-Healthcare will be assimilated into our daily lives, making them invisible [2].

U-Health uses the convergence of information technologies to provide disease prevention, diagnosis, treatment and post-administration of diseases [3].

U-Healthcare has been recognized as an important sector that can address not only the social issues that arising from the ageing society, but also improve the health of the most vulnerable or remotely located people. It can also help create a new business model for healthcare and telecommunications [4].

Ubiquitous health service (U-Healthcare) is a service in an omnipresent environment using mobile broadband and wireless technologies. This allows us to receive mobile health services in situations with or without the intervention of medical specialists [5].

The definition of U-Healthcare involves two perspectives, one of them is the domain of applying the technologies that allow ubiquitous computing and the other is the concept that perfectly integrates health into our daily lives [6].

To meet these perspectives, it is important to discuss the counterpoints of health technologies, which emphasizes the lack of scientific evidence to justify the incorporation and use of new technologies, the cumulative incorporation of technologies, and consequently unnecessary rising cost for the health sector. Health Technology Assessment (HTA) is an instrument for decision-making and efficiency in the allocation of resources, it is also fundamental to the sustainability of the system and equity in the health service delivery [7].

Guaranteeing access, stimulating innovation and regulating the use of technologies are preponderant factors that interfere in the sustainability of health systems, that is, in the capacity of health benefits to be maintained over time [8].

Health care technology is the complete set of technical tools and procedures offered by science to healthcare providers to decide on prevention, diagnosis, care and rehabilitation [9].

Decision-making in health care is intrinsically complex, since several goals need to be balanced, usually through the involvement of many stakeholders. One set of tools widely used to improve efficiency in the allocation of technologies and resources is the Health Technology Assessment (HTA) [10].

According to INAHTA (The International Network of Agencies for Health Technology Assessment), HTA is a systematic evaluation of the properties and effects of health technology, which address the direct and intended effects of this technology, as well as its indirect and unintended consequences. It aims mainly to inform the decision-making on health technologies [11].

Therefore, there is an opportunity to use information technology in a more integrated way in the health sector to improve the quality, safety and efficiency in the provision of health services to people [12].

Based on this context, we identify the importance of this research in generating a reference framework for the development of a U-Healthcare health system model. However, it is important to include in this structure the assessment of the impacts of the application of these technologies, since U-Healthcare allows to receive medical care in conditions different from the existing models of care, diagnosis and treatment from the health systems. This work develops a reference for small and medium hospitals to use this structure in their U-Healthcare implementation strategies. The scientific opportunity of this article lies in the gap in scientific publications that integrate U-Healthcare and Health Technology Assessment (HTA).

2. Methodology

The frameworks are useful tools for positioning and relating a reference structure to others, but also useful for comparing concepts, principles, methods, patterns, models and tools in a particular domain of interest [13].

Through a literature review, this work will present a framework that allows directing the actions for the implementation of a U-Healthcare System, based on the following approaches: (1) Proposed model of technology-based health system (2) U- Healthcare Enabling Technologies, (3) HTA (Health Technology Assessment), observing its characteristics as a basis for the development of a framework for the U-Healthcare application.

The literature review was developed using as reference the characteristics of the technology-based health system proposed in the works of [14, 15]; the approaches on the application of U-Healthcare were researched in the authors' works: [4, 16, 17, 18, 19, 20, 21] ; and the analysis in relation to the impact fields of ATS - Health Technology Assessment, demonstrated in the work [22, 23, 24, 25, 26, 27, 28, 29].

To search for articles were defined the keywords: u-healthcare, ubiquitous computing, healthcare system, health technology assessment, health technologies.

The databases used were: Proquest, Google Scholar, Capes Newspapers. Delimiting the research period between 2004 and 2018.

3. Results

The framework obtained with the research was developed considering the need in the process of implementing a U-Healthcare Health System to use a reference structure with the following components:

(1) Proposed model of technology-based health system: The next generation of health systems must be created in synergy with mobile medical computing for emergencies, medical sensor technologies and communication technologies. The expansion of time, space, beneficiaries and services can be the biggest factors in an ideal health system and should be able to cover the following characteristics: Intelligence, Completeness, Understanding, Interactivity, Perpetuity, Accessibility, Green Information Technology. Table 1 describes the characteristics of these factors [5].

(2) U-Healthcare Enabling Technologies: U-Healthcare is activated by embedded applications in the environment. Innovation / technological advance allows a variety of applications and services that fits into three different classes of technologies: computing, communication and biomedical sensing. Through these technologies can be established the primary and secondary value proposition of U-Healthcare [21].

(3) Health Technology Assessment (HTA) has been defined as a form of research guidelines that analyzes the short and long-term consequences (e.g., social, economic, ethical, legal) of technology application. The objective of HTA is to provide decision makers with information about guidelines and alternatives [30].
HTA is used to assess and calculate the value of new medical technologies as well as to inform coverage decisions. In order to establish a standard terminology, HTA covers the following fields: efficacy, effectiveness, risk, security, cost and social impact, ethical and legal, described in Table 2 [22, 23].

Table 1 – Characteristics of the proposed health system

Intelligence	It must be not only knowledgeable, but also offers expert decisions in connection with health services.
Completeness	Ensure that information technology is complete (protected, standardized and secure).
Understanding	Comprehensive services for medical treatment, well-being and healthy living.
Interactivity	Instead of the supply-demand chain, apply a proactive concept to interactive relationships.
Perpetuity	Knowledge can be perpetually recreated by PHR (Personal Health Records) or CBR (Case-based reasoning)
Accessibility	There are no regulations in force; free flow of information in order to exchange knowledge
Green Information Technology	Energy efficient, environmentally friendly.

Source: [14]

Table 2 – Definition of HTA fields

(1) Efficacy	Probability that individuals in a life definition will benefit from the application of a technology problem under ***ideal*** use conditions.
(2) Effectiveness	Probability that individuals of a defined population will benefit from the application of a technology problem under ***normal*** use conditions.
(3) Risk	Measurement of the probability of an adverse or undesired effect and the severity of that effect on the individual health in a defined population associated with the use of a technology applied in a given health problem under specific use conditions.
(4) Security	Acceptable risk under specific condition.
(5) Costs	Cost (of opportunity) in health and the value of the best alternative, not because of using scarce resources to produce a given good or service.
(6) Social, ethical and legal impact	Not all the impacts related to effectiveness, security and costs, including the secondary economic consequences for individuals and communities.

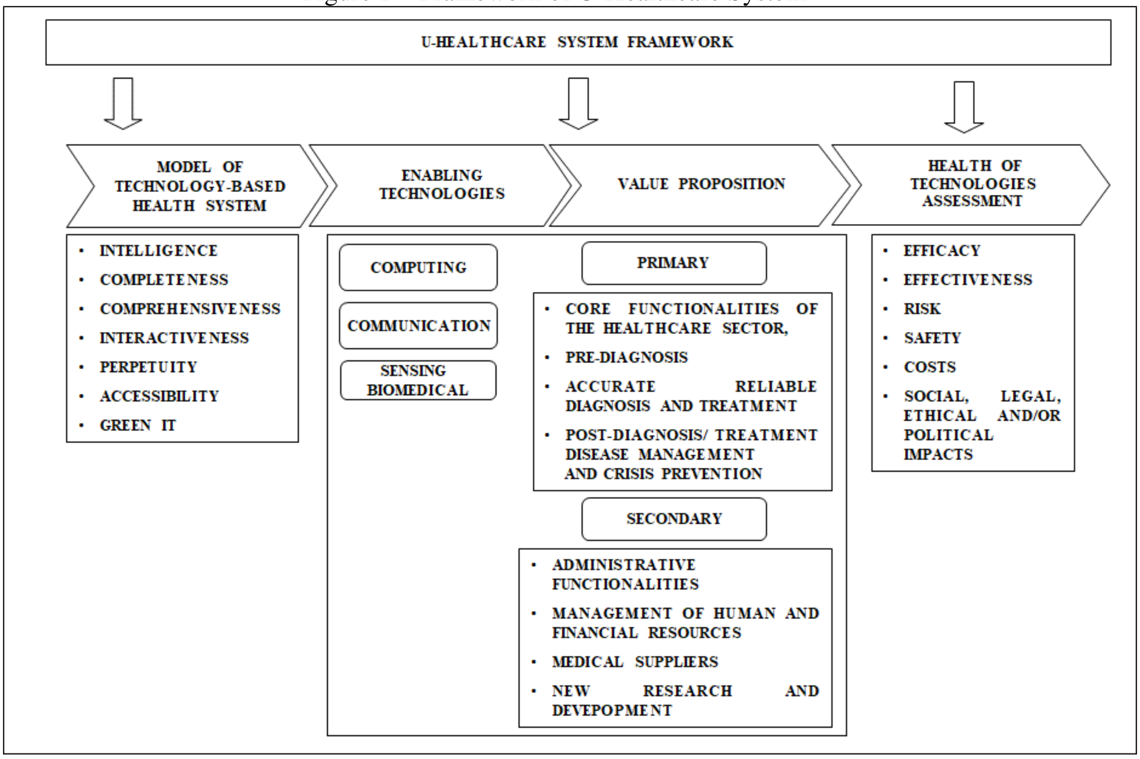
Source: [22, 23]

Figure 1 presents the proposed framework for the U-Healthcare application and the characteristics to establish a model for the development and implementation of this system.

In the first stage, the model proposes a set of health system characteristics related to the functions that the technologies should promote in the system (Intelligence, Completeness, Understanding, Interactivity, Perpetuity, Accessibility, and Green Information Technology). These functions should be complementary to provide the greatest benefit possible and enable U-Healthcare concept. In the second stage, the characteristics relate to the enabling technologies that will compose the equipment structure (hardware) and the entire necessary infrastructure for the operations of U-Healthcare process. At this same stage, it is identified which processes will be affected by the defined technologies and what will be the delivery of value to system users. In addition, whether these will affect the primary processes (directly affect patient care) or secondary processes (assist business management, integration of management information for strategic decision-making, the development of new research and new technologies for health).

In the third stage, the defined technologies will be evaluated by HTA according to the impacts generated. This evaluation is within the following fields: efficacy, effectiveness, risk, security, cost and social, ethical and legal impact. This assessment establishes a vision for decision-making and alignment regarding the actual impacts of the implemented technologies, their cost / benefit relationships, risks and effective results of these technologies.

Figure 1 – Framework of U-Healthcare System



4. Conclusion

The development of a framework for the implementation of a U-Healthcare System can help health organizations to establish a comprehensive vision of the steps that should be taken to plan the transition and define the application of new technologies. The proposed model do not intend to be conclusive, but establishes an integrated view of the factors involved in the planning, execution and control of U-Healthcare application process. It considers the complexities involved in decision-making based on the technologies application to improve population health. The global population profile shows an increase in life expectancy and urban centralization in most part of the world, so decision makers need to evaluate current models of wellness and population health and develop solutions in the short and in the medium term, anticipating operational bottlenecks that reduce the efficiency of the health sector.

As a proposal for future research, perform literature review comparing other frameworks for U-Healthcare implementation, identify its characteristics and compare with case studies where these frameworks were applied. Also as a research proposal, establish a case study with the application of the proposed framework in this work and evaluate the level of adherence of the proposed model.

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DIGITAL TRANSFORMATION 2

Digital Twin – requirements and implementation

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Purpose: To define the main requirements for the implementation of a Digital Twin (DT) and to implement an initial solution at a learning factory.

Design/methodology/approach: To acquire a broad knowledge of DT implementation requirements, this research took into consideration the possible ways a literature review can be developed. The research merges bibliometric studies and content analysis, to take a deep dive on this research topic, as they are complementary methods. With these defined, a use case was implemented at a learning factory located in Brazil to develop an initial DT model.
Findings: Literature review in a sample of 19 articles enabled to state that the most frequent requirements of DT are real-time data, integration, and fidelity. These are crucial requirements for connecting the product model and the real conditions of the product. With the literature requirements defined, it is possible to implement an initial DT model. Initial results show that DT can increase data usage and integration.

Academic limitations/implications: This research has limitation due to the sample analyzed. The database choices, the search strings applied and topic analyzed have a possible bias; hence, important articles can be missed in the process. Besides, the implementation of the DT is still preliminary and some challenges escalating the solution for real case implementation continue to be an open space on literature.

Originality/value: The main value and this paper is the mapping of different requirements for the implementation of a DT, and the initial implementation of a DT at a learning factory.

Keywords: Digital Twin, Industry 4.0, Advanced Manufacturing

1. Introduction

The convergence between physical and virtual spaces has gained wide attention recently [1]. Digital Twin (DT) is defined as a very realistic model of the current state of the process and their behavior in interaction with their environment in the real world [2]. It is used not only for representation purposes but also for predicting the product behavior [3]. A Digital Twin can be described as a virtual, digital equivalent to a physical product [4]; more accurately, the twin is the digital counterpart to a specific copy of a manufactured product, instead of merely representing the product at-large.

However, the definition of a DT and its requirements are not yet fully established [3]. The characteristics a DT model should possess to be widely used in the industry remains an open question in the literature.

Therefore, this research paper aims to narrow this research gap by proposing an initial synthesis of Digital Twin requirements. The paper seeks to answer the question: what are the main requirements for developing a Digital Twin?

2. Methods

For this paper, an initial sample was researched using the ISI Web of Science, aiming to cross-check their results and enhance some documents to be studied. The bibliographic search was performed in January and February 2018. The following search string was used, and no restrictions were considered: ([“Digital Twin” and ("Industry 4.0" or “Requirement*”)] or “Digital Twin”) once DT are deeply related to Industry 4.0. The first search resulted in 52 entries in ISI Web of Science. Therefore, it is not possible define from witch string the paper is originated.

The main exclusion criteria were based on the abstracts and title reading. All these papers had their abstracts read for identifying those that did not fit within the scope of the study, excluding them from the final list, resulting in 20 papers. It was not possible to have access to the full paper of one article, resulting in 19 articles.

3. Results

Digital Twin is a multi-physical, multi-scale, and probabilistic simulation model of a complex product [5]. To be considered a Digital Twin, the model must have some specific characteristics such as: scalability (ability to analyse different scales of information and so permit Real-time data collection from the physical model); interoperability (ability to convert, match and establish equivalence between representation models) and expansibility (ability to integrate models) – providing an Integration between the physical and the digital environment; and fidelity (ability to conform to the physical model) [3]. The different characteristics are highlighted in Table 1, which demonstrates the relations between the parameters (lines) and the citation (columns) and total citation (final column Total). From the 19 articles, it was possible to define different requirements to DT implementation. However, the three most cited requirements derived from seven articles.

Table 1. Literature requirements for Digital Twin

Requirement	[1]	[3]	[6]	[7]	[8]	[9]	[1[illegible]	T
Real-time data								
Integration								
Fidelity								

4. Conclusion

For answering the research question, this paper provides a description and analysis of the Digital Twin requirements in literature. This article contributes to the literature by surveying DT requirements.

An analysis of the most frequent related topics on Digital Twin reveals that real-time data, integration, and fidelity are the DT requirements mostly dealt with and valued by the literature.

Future work may focus on new literature review, real DT case simulations – such as in labs and learning factories –, and pilot implementations.

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Analysing the possibility of dealing with uncertainty in ERP/MRP controlled environment with Demand Driven MRP

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Purpose: This paper proposes providing a research about the uncertainty that the companies managed through ERP (Enterprise Resource Planning)/ MRP (Material Requirements Planning) face nowadays and present and discuss the adoption of Demand Driven MRP (DDMRP) in SME to deal with this scenario in the context of Industry 4.0, digital transformation and in the necessity to be responsiveness in the global competition.

Design/methodology/approach: The methodology used is a literature review to conduct an explanatory research and a discussion comparing MRP and DDMRP in the SME environment.

Findings: The analysis and discussion found ERP/MRP difficulties in dealing with uncertainty and possibilities for improvements with DDMRP in this scenario.

Academic limitations/implications: Assuming that the purpose of this research is the possible adoption of DDMRP by a SME a suggestion for future work is dimension a DDMRP system in a SME that already uses the MRP logic and compare them.

Practical implications: The discussion of this research indicates a possibility for adoption of ERP/MRP systems in SME that is not very widespread in this business offering a new solution for their challenges.

Originality/value: This paper contributes to increase the analysis about the possibilities of DDMRP adoption to deal with uncertainty in SME manufacturing environment, especially considering the advances based on I4.0 technologies.

Keywords: DDMRP, Demand Driven, Uncertainty, ERP in SME.

1. Introduction

ERP (Enterprise Resource Planning) systems are commonly used in large companies; almost all of them have implemented some type of ERP system since it became well known in the 80s. Only recently, since the 21st century, ERP systems are being implemented and used by small and medium enterprises to give an advantage for this category of manufacturers in terms of improving the efficiency of operations [1].

The ERP systems have been gaining importance and popularity as a technological solution because of the complexity of processes and the big increase of global competition in the last decades [2]. In terms of operations management, that is the focus of this work, ERP systems are basically an evolution of the MRP (Material Requirement Planning) and the MRP II (Manufacturing Resource Planning) in more functions, such as, equipment, labor, financial capital, marketing, sales, etc. ERP integrates the management processes and the business processes providing a global vision of the organization.

Nowadays, organizations are under many pressures, e.g., global competition, fast changes in the behavior of the customers, technological innovations, among others, and these pressures create an uncertainty environment that affects the production planning. Koh and Saad [3] defined uncertainty for these cases as an unpredictable event that disturbs the production process in a manufacturing system that is planned by MRP, MRP II or ERP.

In this context of global competition, necessity of increase the efficiency of supply chain management and uncertainty caused by many factors was created the Demand Driven Material Requirements Planning (DDMRP). This recent method focus on manufacturing and distribution flows and it is supposed to deal with uncertainties better than traditional MRP.

This paper has a literature review of the use of MRP and ERP systems under uncertainty, a review of the demand driven supply chains and a review of DDMRP, focusing on the possible adoption of this method for SMEs.

2. Literature Review

ERP and MRP in SMEs

The capacity of ERP systems to manage companies' resources efficiently and effectively by providing an integrated solution for its information processing needs has persuaded not only large organizations, but small and medium sized firms about the importance of these systems as well [4], [5]. One of the main boosters for the emerging trend of implementation of ERP systems by SMEs is the necessity to compete in Business-to-Business and Business-to-Consumer markets. To compete in these markets MRP/ ERP systems play an important role in production planning and scheduling [6].

The cost to implement these systems is high and difficult to justify by a SME. The most important criteria for the decision to implement or not an ERP system by a SME is the total cost, including implementation, purchasing and service & support [1]. Moreover, many advanced features, e.g. material allocation used in conjunction with production planning in ERP have not been explored and SMEs use ERP mainly for its finance and accounting functions [6], [7].

Most of SMEs never think to implement ERP due to high costs and the long time to implementation [7]. Just recently SMEs began adopting ERP systems in their daily operations. SMEs have an important role in economy and ERP systems can be a solution to improve their productivity and overall business performance [8].

To meet these needs of SMEs, lower cost and simpler functions, many midrange and less complex systems have been developed e.g. Alliance/ MFG - Exact Software, MFG/PRO - QAD, WinMan - TTW and All-in-One - SAP. Besides that, many companies combine the software with others production planning and controls techniques, such as Just-in-Time (JIT),Optimised Production Technology (OPT) and finite capacity scheduling to control the flow of materials and manage utilisation of resources. This combination suggests that MRP and ERP are good for planning but are not so good for control and they are susceptible by uncertainty [6].

Uncertainties in ERP controlled Environment

A study with a survey and interviews concluded that ERP systems can create a competitive advantage in delivery for SMEs by promoting more agility to change, but not to uncertainty. SMEs generally use their ERP system to create a plan for production and use it as a guideline. To deal with the uncertainty the small and medium enterprises use a range of buffering or dampening techniques for creating a competitive advantage in delivery [9].

In this study the authors identified seven causes of uncertainty in Make To Stock (MTS) strategy: insecure stores, customer changes delivery lead-times, internal design changes during/after planning, MRP plan overload (infinite scheduling of labour), planned maintenance/repair time exceeded, waiting for labour, and seeking concession. In Make To Order (MTO) strategy there are thirty causes of uncertainty such as, problems related to supplier delivery performance, customer or demand changes, resources (labour, machine and material) availability, design changes, schedule control rules, quality issues, and post-production. And in the Mixed Model (MM) there are five main causes: insecure stores, customer changes delivery lead-times, MRP plan overload (infinite scheduling of labour), waiting for labour, and seeking concession [9].

To tackle uncertainty caused by external demand and external supply was developed a framework to dampen the system nervousness caused by these factors. The framework proposes the use of safety stock, safety capacity, safety lead-times and rescheduling to tackle these problems in the ERP controlled environments [10].

Demand Driven Supply Chain

The Demand Driven Supply Chain can be defined as a network of systems, technologies and business processes that detect and respond to demand signals in real time, through a network of customers, suppliers and employees [11]. This type of supply chain needs to be agile with the ability to respond quickly to changes in demand for both volume and variability of products [12].

Owing to these characteristics, many companies are trying to shift to Demand Driven strategy, they do it by changing from a build-to-forecast to a build-to-order discipline. Demand Driven Supply Chains are the ones that derive information for production and inventory decisions from the real time demand, not the demand forecasted [13].

There are limits to each company reach the build-to-order strategy, but many companies don't access their potential to be demand driven. There is a systematic effort with three elements that can be used to raise the "demand driven" level [13]:

i. Shortening process lead time;
ii. Adopting flow model economics;
iii. Replace forecasts with demand.

DDMRP

"Demand Driven Material Requirements Planning (DDMRP) is a formal multi-echelon planning and execution method to protect and promote the flow of relevant information and materials through the establishment and management of strategically placed decoupling point stock buffers." [14]. DDMRP has six pillars based in conventional methods as shown in figure 1 [14].

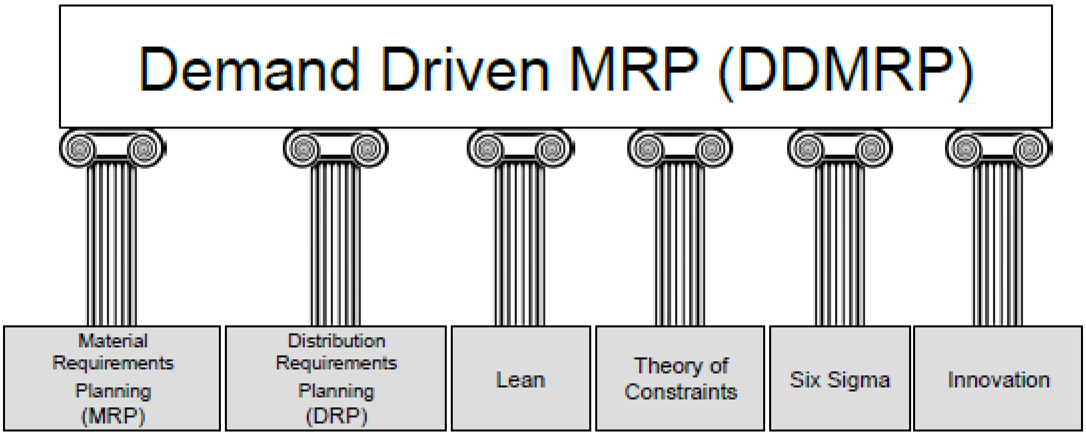

Figure 4: The methodological foundation of DDMRP [14]

DDMRP has five sequential components to be implemented [14]. Figure 2 shows this sequence of components.

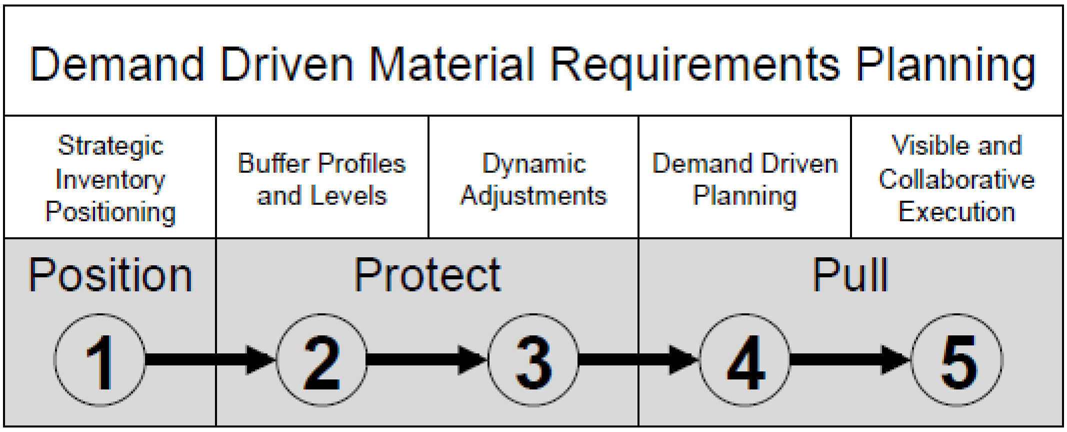

Figure 5 - The five components of DDMRP [14]

The first step is the positioning of strategic inventory, it evaluates if there are benefits to position or not a buffer of articles of the Bill of Materials. The functions of these buffers are launch replenishments and control the dispersion of variability (supply, operational, demand and management). After the buffers are positioned the next step is “Buffer Profiles and Level”. A buffer is replenished according to the “Available Stock Equation” (ASE) that is the inventory position minus qualified spikes. Qualified spikes are large demand orders that need to anticipate production lead time, therefore, made on demand. The ASE is compared to three buffer levels alert: red (safety stock), yellow (average quantity of in process re-plenishment) and green (replenishment size). When ASE enters in yellow zone a replenishment order is done to reach the green level [15].

The next step is the “Dynamic Adjustments”, it refers to the buffers’ level and it is made according to the formulas (1), (2), (3), (4), (5), (6).

$$\text{Green Zone} = \text{Max (Yellow Zone x Lead Time Factor; Lot Size)} \tag{1}$$

$$\text{Yellow Zone} = \text{ADU x ASRLT x PAF} \tag{2}$$

$$\text{Red Zone} = \text{Yellow Zone x Lead Time Factor x } (1 + \text{Variability Factor}) \tag{3}$$

$$\text{Top of Red} = \text{Red Zone} \tag{4}$$

$$\text{Top of Yellow} = \text{Top of Red} + \text{Yellow Zone} \tag{5}$$

$$\text{Top of Green} = \text{Top of Yellow} + \text{Green Zone} \tag{6}$$

Average Daily Usage (ADU) is the result of demand forecasting. ASRLT is the longest unprotected sequence (considering a sum of lead times) in the bill of material of a buffered article. As previously stated, buffers control variability, the unprotected sequences are considered between articles with buffers [15].

PAF (Plan Adjustment Factors) are percentages used to raise or lower ADU. It enables to model and smooth large seasonal variabilities and promotions. Variability Factor is used to protect from uncertainties, it is a part of the Red Zone and represents the safety stock. Lead Time Factor is different for long or short lead time products, when ASRLT is long the Lead time Factor is small. When all DDMRP zones are defined, planners and operators can decide on quantity to replenish (in plan view) and orders to prioritize (in execution view) [15].

Figure 3 shows the buffer zones and purposes.

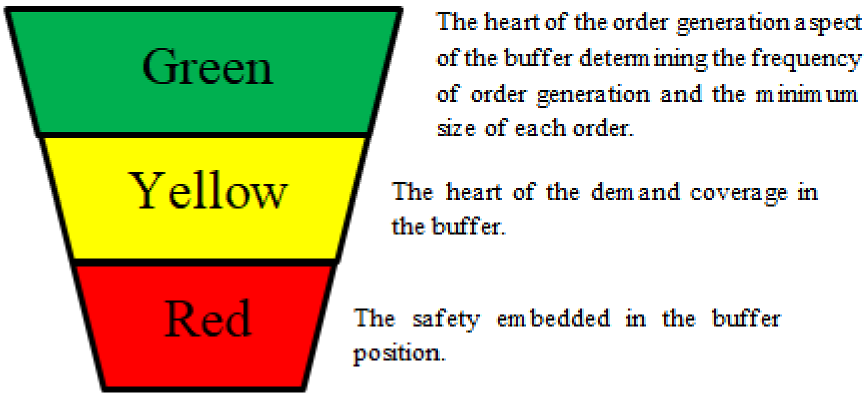

Figure 6 - Buffer zones and purposes [14]

3. Discussion

As shown in the literature review, DDMRP is a recent method created to deal better with uncertainties than the traditional MRP that is a method highly used in companies to manage the production. Over time, with the advancements of Industry 4.0, Internet of things, Big Data and Cloud Computing the possibilities of implementing an ERP system in SME are increasing.

Currently, many ERP providers are offering the possibility to implement the system with servers based outside of company by the use of cloud computing. As discussed before, the main reason of SMEs don't consider implement ERP is the high cost of the system, but with these advances there is a tendency of dropping the prices of these software. Besides that, with simpler options of the system, companies can choose just functions that they need.

Big Data's possibilities increase the potential of sharing information throughout supply chain and this can be used by companies to meet the demand in real time or reach higher levels of responsiveness. Besides that, enterprises can use this information to update the data for DDMRP. Industry 4.0 creates more responsive processes with technological advances, such as, automatizations and 3D Print. This can be used by companies to become more "demand driven" and work together with DDMRP.

Many ERP providers are seeing the potential of this new method and have embedded DDMRP's features and functionalities in their systems, such as: SAP, SabeSoft, LillyWorks, Agilis, IFS, SPX and Eficent.io. Other ones are in process of adaptation.

Some studies were made to test DDMRP comparing to MRP, they used simulation to assess the benefits of DDMRP over MRP. One of them submitted DDMRP to many uncertainty causes and concluded that this method reach the same level of on time deliveries with less working capital and less nervousness [15]. Another study, by simulation, confirmed that DDMRP deals better with variation in demand than MRP and it provides a better inventory management [16]. The last study consulted demonstrated that the lack of buffering control in traditional MRP causes instability and DDMRP manage better this situation than MRP [17].

So, based on the literature review and the simulation cases studied, it is possible to affirm that DDMRP is a potential method to be used by SMEs. As it is known, this kind of company has more difficult to deal with losses caused by instability or uncertainties, commons in Demand Driven Supply Chains, and DDMRP emerged as a possible solution to manage the operations of companies in this supply chain.

4. Conclusion

This study contributes to increase the knowledge of DDMRP and discuss its adoption by SMEs in the context of Industry 4.0. One limitation and suggestion for future works is to do a real case study to evaluate DDMRP in a real company that faces these challenges and compare with traditional MRP, as only simulations were found in the literature a case study would be a great contribution.

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Educational Test Bed: A new teaching approach in the Industry 4.0

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Purpose: With Industry 4.0, the flexibility and integration of the systems have become the main key to this new model. To meet this demand, it is necessary to develop new professionals who adhere to this new model. Thinking about this call, an Educational Test Bed was developed. It is an interdisciplinary course at the Federal University of Technology - Paraná – Ponta Grossa Campus, in the Industry 4.0 area. This course is composed by professors and students from different areas, along with the participation of professionals from it`s region industries. The objective of this project is to disseminate knowledge about Industry 4.0 in several activity areas, by real companies projects, and thereby generate new business models, product and process innovations.

Design/methodology/approach: From a vast literature review, it was possible to realize the need for technology transfer in this area of the Industry 4.0. In this way, this course was implemented at the University, and through a case study, this paper will present the behavior of this Educational Test Bed.

Findings: This project has as a goal to solve real Industry 4.0 problems, thereby, it is possible to gain benefits likewise to the university, the industry and the society. The interation between students of diferent fields, the contact with industry and society, besides the increase in professional development to achieve this new demand, bring a variety of results: Innovative projects; new businesses, products and process; startups; patents; new partnerships; and others.

Practical implications: With the Educational Test Bed, othes subjects will be implemented, and along with that it will be built a distance digital teaching platform.

Originality/value: This paper brings a total interdiciplinary teaching methodology for Univesities, companies and the society. Since the industry 4.0 is a new approach, it is also needed to change the education process. This Educational Test Bed favors the Society, the University and the Industries.

Keywords: Industry 4.0, University, Education, Test Bed, Innovation.

1. Introduction

A new industrial transformation is rising, and with it comes customized products, resources optimization, high performance machinery and flexibility. For this, features like auto reconfigurations and precise decision making, assisting the cyber-physical system, Internet of Things, scanned systems and Big Data are used. The flexibility and the integration of the systems have become the key to this new model called Industry 4.0. To meet this new demand, it is necessary to develop new professionals who adhere to this new model, with critical sense and who can cooperate and interact with other areas of the industry.

Thinking about this call, an Educational Test Bed was developed. It is an interdisciplinary course at the Federal University of Technology - Paraná – Ponta Grossa Campus, in the Industry 4.0 area. This course is composed by professors and students from different areas (Industrial Engineering, Mechanical Engineering, Chemistry Engineering, Eletronic Engineering and Science in Computer), along with the participation of professionals from it`s region industries. The objective of this project is to disseminate knowledge about Industry 4.0 in several activity areas, by real companies projects, and thereby generate new business models, product and process innovations.

This discipline has three interconnected teaching approaches: (1) Flipped Classroom, (2) Problems Based Learning and (3) University-Industry partnership.

Maybe the simplest definition of flipped classroom (or inverted classroom) is given by Lage et al. (2000): "Inverting the classroom means that the events that traditionally happen inside the classroom now happen outside the classroom and vice versa."

Fulton (2012) listed the following advantages of Flipped Classroom: (1) students move at their own pace; (2) doing homework in the classroom gives teachers a better understanding into students' difficulties and learning styles; (3) teachers may more easily customize and update the curriculum and provide it to students 24 hours a day, seven days a week; (4) class time can be used more effectively and creatively; (5) teachers using the method report increases in student achievement, interest, and engagement; (6) learning theory supports new approaches; and (7) the use of technology is flexible and appropriate for "21st century learning."

However, the second teaching methodology used, the Problems Based Learning (PBL), is a strategy where students work to solve problems through previously assembled case studies (Gil, 2006).

These two methodologies complement each other, and make the student feel more motivated. With the aim of better learning in this new area of Industry 4.0, a partnership was made of some companies in the region. This partnership brings benefits not only for the student learning, but also for professionals in the participating companies. In other words, this technology transfer becomes an advantage for both the University and Industry.

2. The Educational Test-Bed

As Industry 4.0 is a new theme, a teaching methodology different from the traditional one was developed and is being applied at the Federal University of Technology - Paraná - Ponta Grossa Campus. Because it is a new discipline, with a new format, it is called the Educational Test Bed.

This course consists of students and professors from the following areas: Industrial Engineering, Mechanical Engineering, Chemistry Engineering, Electronic Engineering and Science in Computer. In addition, it counts with the partnership of the some region companies. This partnership, coupled with the Flipped Classroom and PBL teaching approaches, bring students to real-world industry cases. With these cases, students need to develop a solution using the pillars of Indusria 4.0.

Figure 1 shows this Educational Test Bed being applied in this discipline. Presented in a generic way, it is a model that shows potential to be applied in different courses and disciplines.

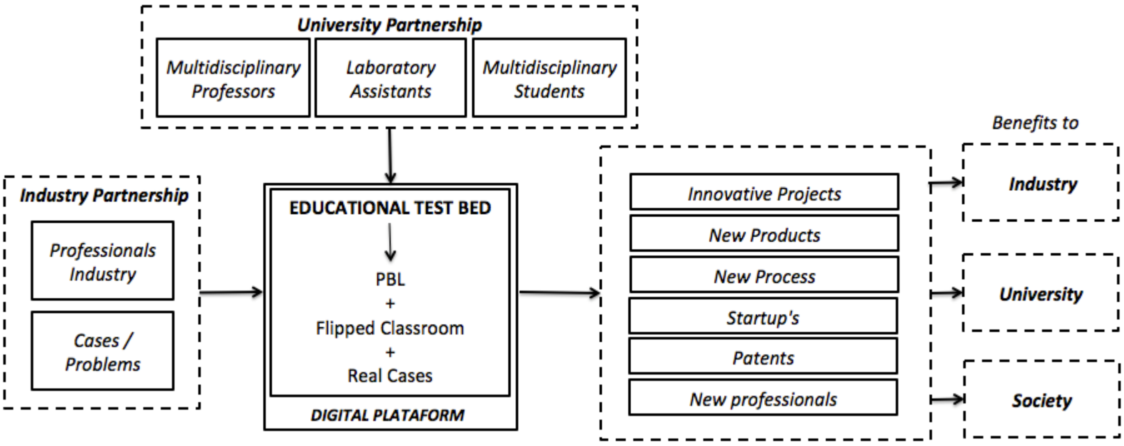

Figure 1: The Educational Test Bed

This Educational Test Bed has the following characteristics: creativity, development for students in projects and real data, work in interdisciplinary teams, learning on the job, real projects from industry/ society, prototyping building, testing, validation ...

In addition, a digital platform is proposed, where companies from different regions can be present in this Test Bed. Students can also learn from their homes, since the materials will all be on this digital platform.

With this partnership between the University and Industry in a discipline in this way, it is possible to get: Innovative Projects, New Products, New Process, Startup's, Patents and New Professionals. With that, benefits are brought to Industries, University and Society.

This Educational Test Bed is a way to teach Industry 4.0 is for students and companies. Thus, new professionals will come up with excellent background.

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APPLICATIONS

Towards automated risk assessment for pedestrian-vehicle safety in manufacturing

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Purpose: Pedestrian-vehicle interface risks in manufacturing work zones result in occupational injuries and fatalities. Risk assessment is currently limited to safety audits and heuristic analysis. A data-driven alternative is desirable since it will capture all risky events and result in more effective countermeasures.

Design/methodology/approach: The camera-based system uses PCA-based shape descriptor as a feature vector for pedestrians and vehicles in the work area. Supervised classification using Support Vector Machines (SVMs) is employed to detect entities and track movements. All interfaces are automatically observed, leading to an estimate of Risk Prioritization Number (RPN). RPN is the industry-standard risk assessment metric.

Findings: Experimental data was collected using a sample work area layout and scale versions of vehicles. Entity interfaces and movements were physically simulated to train and test the machine learning model. High detection accuracy, precision, and recall were observed. The automated estimates were in close agreement with human annotation.

Academic limitations/implications: Onsite validation will be performed in the future. Warning for interfaces will be integrated to make the risk assessment system proactive in preventing risk. Severity and detectability in RPN estimation can be similarly automated using machine learning.

Practical implications: Safety managers in manufacturing supply chains can use this continuous monitoring system to mitigate risk.

Social implications: Safer work areas are key to happier, more productive employees.

Originality/value: Data-driven methods are used for continuous monitoring of work areas for safety. This empowers safety managers and provides researchers with an original direction for applied safety research.

Keywords: Risk assessment, smart factories, FMEA, machine learning, workplace safety

1. Introduction

The manufacturing sector is particularly vulnerable from a safety perspective: it ranked sixth in the US for number of fatal occupational injuries in 2011 [1], and four out of 100 workers in manufacturing were injured at work in 2014 [2]. Manufacturing safety has an economic component as well – an European Union report in 2008 estimated that 143 million work days and over 55 billion euros were lost because of workplace accidents [3]. Material handling – the transportation of materials within a factory – is a significant activity in traditional manufacturing, as well as emerging paradigms such as smart manufacturing [4]. The interaction between material handling equipment – such as forklifts – and humans is responsible for more than half of all material handling accidents [5]. Collaboration or unstructured workspace sharing between humans and material handling equipment is expected to grow with the rapid development of automated mobile equipment [6]. Efforts have been focused towards mitigating steps – such as providing a natural language interface between a forklift and pedestrian [7]. While these approaches are valuable, they do not provide an insight into the type and extent of risk incumbent between pedestrians and vehicles in the manufacturing environment. Risk assessment leads to broader measures which span the factory, such as layout design, scheduling, and warning systems.

The presented work shows the potential of automated risk assessment for pedestrian vehicle interfaces. Quantitative risk assessment methods [8] are chosen because simplify the prioritization of high risk interfaces for mitigative measures. The risk metric evaluated in this work is the Risk Prioritization Number (RPN), which is usually used in combination with Failure Modes Effects Analysis (FMEA) [9]. The conceptual assertion and contribution of the presented work is that risk assessment for pedestrian vehicle interfaces can be reliably automated. Existing techniques rely on subjective decisions or restricted sampling of data [8], justifiable when human involvement is required for data collection and analysis. However, the prevalence of camera networks in manufacturing plants [10] – usually in place for security operations – disposes of the need for human data collection. Machine learning algorithms have been shown to be successful at detecting vehicles [11, 12] as well as pedestrians [13, 14]. Their prudent selection accounts for the second constraint in automated risk assessment – that of analysis of large volumes of data. The incidental contribution of the work is that it makes it possible to provide real-time warning for pedestrian vehicle interfaces because of the continuous nature of the risk monitoring system.

2. Methods

The development of the automated risk assessment system – hereafter referred to as AutoRisk – comprises the following methodological steps: 1. A camera system or network is identified or set up for data collection, 2. The shape of vehicles and pedestrians is characterized using Principal Component Analysis (PCA)-based features, 3. Multiple classification algorithms are tested for pedestrian and vehicle detection, and the best performing algorithm is selected, 4. Pedestrian-vehicle interfaces are inferred using computer vision heuristics, and 5. Risk is assessed using RPN calculations, which prioritize highest risk interfaces for safety practitioners to apply mitigating steps.

Setup

The camera system assumes a top-down view of the work area. This simplifies the shape representation of the pedestrians and vehicles. All potential routes for vehicles in the plant are assumed to be known. The locations of machinery and other stationary objects in the work area are also assumed to be known.

The setup was simulated in a laboratory to provide proof of concept for AutoRisk. A high-mounted camera was installed, and the work area mimicked a heavy manufacturing work area from a recent industrial safety project. Scale models of vehicles were used for simulating the movement of vehicles and training and testing the machine learning algorithms. The three categories of vehicles used in experiments were: 1. "Truck" – an 18-wheeler, 2. "Forklift", and 3. "Car". Two varieties of cars were used to test the robustness of the machine learning algorithm to intra-class variation. The setup is shown in Figure 7.

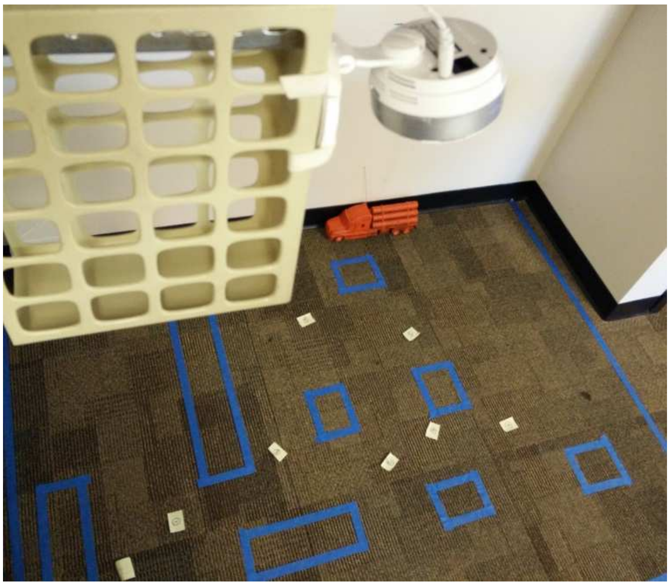

Figure 7: Work area setup. The rectangular outlines represent stationary objects in the work area. The filled rectangular labels simulate potential areas of interest for risk assessment provided by safety managers, typically for listing failure modes in the FMEA context.

PCA-based shape representation

The use of images as direct input to machine learning algorithms requires larger volumes of training data, making it attractive to use PCA to reduce the feature space for classification [15]. The feature vector can then represent the shapes of vehicles and pedestrians.

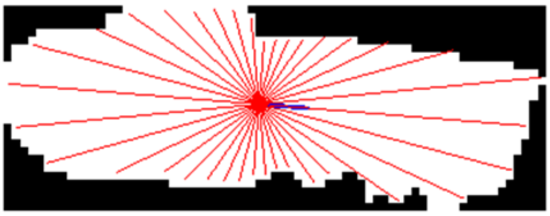

Figure 8: Feature vector generation for the object "truck". The shorter vector indicates the orientation of the principal component.

A region of interest featuring the vehicle or pedestrian is converted to a binary image. The foreground is centered and Singular Value Decomposition (SVD) is applied to find the principal component of the object. The initial feature vector V_{shape} for the object is generated by counting the number of foreground pixels in every one of the P rays radiating from the center to the boundary of the object, starting with the principal component. This is visualized in Figure 8. The vector is normalized, and the object area A_{entity} is added to it and normalized using an arbitrary factor A_{image} to give a final feature vector V_{entity} with $P+1$ elements. This feature vector is rotation invariant because of the use of PCA to guide its initial orientation.

$$V_{shape} = \frac{1}{MAX(s_1, \dots, s_P)}[s_1, \dots, s_P], s_i \in (0, \dots, 1]$$
$$V_{entity} = \left[V_{shape}, \frac{A_{entity}}{0.01 \cdot A_{image}}\right] \quad (1)$$

Classification

Video data for training and validation of the method was collected using the lab setup. Vehicles were maneuvered along traffic lanes to simulate in-plant movement. Approximately 45 minutes of video data which simulated multiple scenarios and vehicle interfaces was generated. Image regions containing individual vehicles were isolated using a semi-automated computer vision technique. This resulted in nearly 200,000 labeled vehicle images. A subset of these images – about 48,000 – were used for classifier development, and the rest were used for validating interface detection.

MATLAB's Machine Learning Toolbox was used to compare multiple classifiers. The cross-validation level k was set to five – that is, data was divided into k subsets, with each used once for training while the remaining $k-1$ sets were used for validation. The best performing classifier for the data was found to be SVM with quadratic kernel [16], which had a cross-validation accuracy of more than 99% and a compelling confusion matrix, as seen in Figure 9.

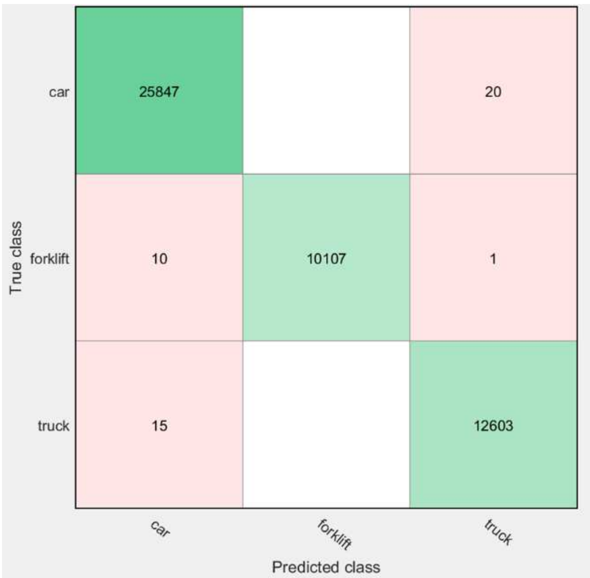

Figure 9: Confusion matrix for SVM with quadratic kernel

Interface detection

Foreground extraction uses a combination of color and background initialization. The trained SVM classifier is given all foreground regions as input – it detects vehicles in the work area in the current version of the work; pedestrian detection is an ongoing developmental feature. The FMEA approach is interested in assigning risk scores to specific events [9]. A FMEA event is defined for this problem as: "the interface between vehicles and pedestrians at a specific traffic intersection".

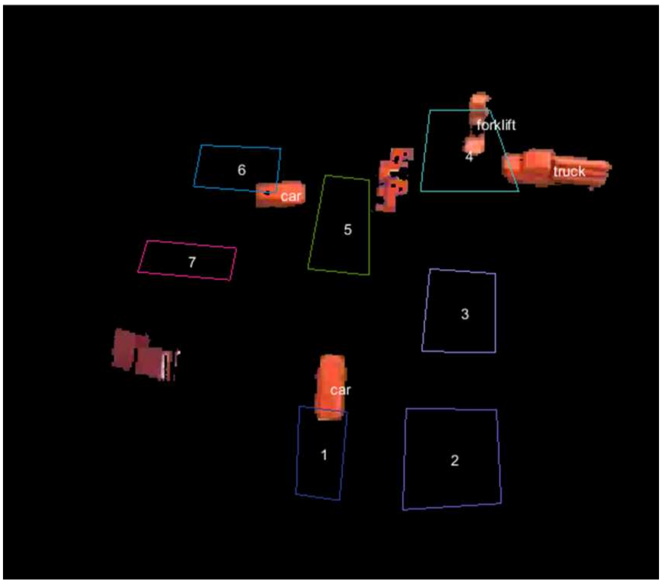

Figure 10: Interface between a forklift and a truck at Intersection 4 in the work area

The computer vision algorithm monitors traffic intersections, shown in Figure 10 using numbers. When the classifier detects two vehicles inside the bounding box for an intersection, a FMEA event is recorded. If more than two vehicles are present, each vehicle-vehicle pair is separately counted as an event. Table 2 shows that AutoRisk is 90.11% accurate when compared with the ground truth obtained by independent human labeling on the same data. This, however, does not account for the fact that humans have to spend much more time labeling the same data and executing the subsequent steps in risk assessment.

Table 2: Interface labeling accuracy for vehicle-pairs. The shaded row shows that the car-forklift interface was most common in the recorded data.

	AutoRisk		**Actual**	
	Count	**Total %**	**Count**	**Total %**
Car-Car	13	14.29	13	14.29
Car-Forklift	35	38.46	40	43.96
Car-Truck	20	21.98	24	26.37
Forklift-Truck	14	15.38	14	15.38
Total	**82**	**90.11**	**91**	**100.00**

Risk assessment

All FMEA events are recorded in Section 0 as $(Vehicle_1, Vehicle_2, Intersection)$ combinations. The RPN metric is a product of three numbers for each event [8]:

$$RPN = P \cdot S \cdot D, \quad (2)$$

Where P is the probability of occurrence of an event, S is its severity, and D is its detectability. The latter two numbers are obtained from work area heuristics which are usually customized for each factory by its safety practitioner. An example detectability heuristic: "Vehicles approaching intersection 6 have poor detectability because of the presence of large equipment and high noise levels", and an example severity heuristic: "Car and larger vehicle collisions are most severe for occupants because of the size mismatch".

A set of multiple severity and detectability heuristics was developed based on the team's experience with a recent safety project. Probability was calculated based on automatic interface monitoring data. Each individual score is scaled between 1 and 10; therefore, the riskiest possible event will get a score not exceeding 1000. Table 3 shows the results of risk assessment, the five highest risk events are highlighted in the table. These values are provided to safety practitioners to develop risk mitigation measures for the work area.

Table 3: RPN estimates of risk. Numbers in brackets are probability scores. The shaded cells are the highest risk events.

Intersection	Car-Car	Car-Forklift	Car-Truck	Forklift-Truck
1	35.0 (1)	567.0 (9)	90.0 (1)	8.0 (1)
2	75.0 (3)	192.0 (4)	576.0 (8)	5.0 (1)
3	90.0 (3)	252.0 (4)	420.0 (6)	10.0 (1)
4	16.0 (1)	480.0 (8)	320.0 (4)	64.0 (8)
5	50.0 (2)	324.0 (6)	630.0 (9)	90.0 (10)
6	24.0 (1)	504.0 (7)	80.0 (1)	16.0 (1)
7	360.0 (10)	810.0 (10)	180.0 (2)	32.0 (1)

3. Conclusions and future work

AutoRisk currently demonstrates the following features: 1. Vehicles are accurately detected even with limited training data, 2. Vehicle interfaces are accurately detected, 3. RPN estimates are consistent with the FMEA format, and 4. It dispenses of the need to sample safety data and instead makes it an activity which may be continuously monitored. These contributions are realized using a combination of computer vision and machine learning techniques. Another significant contribution from an industry practitioner standpoint is that human labor required for risk assessment is saved by the presented approach.

The next steps for AutoRisk research are: 1. Validation using real data from factory floors, 2. Comprehensive trials to compare human and automated system performance in risk assessment, and 3. Extension of presented classification methods to pedestrian detection.

The presented approach has the potential to be deployed in manufacturing plants and will serve as a valuable analytical tool for safety practitioners. It can be integrated with early warning systems to actively control interfaces and prevent accidents. Public data on manufacturing safety and industry regulations can be integrated into the concept to make it a truly autonomous risk assessment approach.

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Application of Manufacturing and Automation techniques oriented to a service-based business using Internet of Things (IoT) and Industry 4.0 concepts. Case Study: Smart Hospital

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Purpose: Apply Manufacture and Automation techniques oriented to a service-based business. Developing and proposing a methodology for the implementation and development of a smart hospital, taking as a foundation a traditional hospital.

Design/methodology/approach: The approach is based on the analysis of the studied healthcare system, focusing on the patient flow. The use of Discrete Event Simulation (DES) models allows a computational model.

Findings: The improvement of the patient flow attendance and service quality, what directly influence the reduction of mortality in the Hospital Emergency Department (HED).

Practical implications: Integration, and improvement of systems using concepts of IoT and Industry 4.0. A case study shows the service quality and reduction of the waiting time for the patients.

Social implications: The reduction of the mortality in the HED, what is directly related to the improvement of the service quality and the reduction of the waiting time for the patients.

Originality/value: The paper shows a different perspective in the IoT and Industry 4.0 area for the integration and validation of its systems using the DES models applied to queue-based systems, taking elements of operations research and statistics.

Keywords: Emergency Department, Smart Hospital, Discrete Event Simulation.

1. Introduction

Nowadays, due to the technological developments, our life quality has been improved, especially in transportation, manufacturing, communications, businesses and related areas. The service-based enterprises hold a close relationship with the healthcare systems because both systems can be modeled as a queue-based system and both offer services, where a healthcare unit can be considered as a critical service-based business, due to the type of service offered. A Hospital Emergency Department (HED) can be considered as a high risk and delicate area, where the nature of services related to the preservation of the users' life.

The HED can be considered as a critical service-based business, where a healthcare system is an example of a service-based business, due to the critical management operation of the system. The HED is an area of primary care, that aims to offer initial treatment of different diseases to patients with high priority who present themselves without a prior appointment, and according to [1]–[3] the HEDs around the world show problems of overcrowding. It is a situation that is presented when the number of patients is superior to the number of available resources, whether medical staff and devices or hospital care areas. This situation leads to a considerable increase in patient waiting time and a reduction of service quality.

The overcrowding is not only a HED problem, it is frequently observed in other service-based businesses. The key factors that generate the problem are mainly the duration of patients' waiting time, agglomerations, patients inflow and outflow, productivity, available physical resources, and others factors [2], [3]. The main consequences are the increased mortality rate and social discrimination in the queues, and the increased mortality rate [4].

The overcrowding in the HED brings economic profits, since the service provided with overcrowding maximizes the use of resources and thus allows a better use of the available assets and personnel, thus maximizing the profit of the providers of health services [5]. It is important to highlight that overcrowding is not a daily problem, and following one, the problem occurs only in 25% of the total operating time of the HED, which increases the difficulty of the problem, due to the unpredictability of patient flow behavior.

The proposed solutions to solve the problem of overcrowding in the HED: the implementation of healthcare politics or the optimization of resources using management operation tools. The management operations view requires the use of simulation and optimization tools, which have increased their use for an administrative view of healthcare management [6]. The different simulation paradigms can identify the complexity of healthcare systems, that are mainly three: Discrete Event Simulation (DES), System Dynamics (SD) and Agent-Based Modeling (ABM). The biggest problems in healthcare systems can be optimized using simulation models, managing to improve problems such as high patient flow, patient scheduling, shift scheduling, testing of new health policies, among others [7].

The use of the IoT and Industry 4.0 concepts in the healthcare is important according to the potentially useful applications in the area [8]. To introduce some concepts, the Internet of Things (IoT) proposes a use, processing, and storage of information in the cloud, that can be accessed and used autonomously by intelligent objects with a connection in the cloud through the internet [9]. The goal of the IoT is the sharing of data and processing of them, to achieve a smart integration of the objects aimed at improving the life quality. By the other side, the concept Industry 4.0 is based on the IoT principle of an intelligent connection of objects, in this case, information technologies (IT) and operational technologies (OT), to facilitate the development of each company's own services and processes. Industry 4.0 can also be called the Industrial IoT following the vision proposed by the company General Electric [10].

The objective of this work is to introduce a potential solution to improve the overcrowding problem in the HED. The methodology requires the use of IoT concepts, DES as a simulation tool, and other secondary concepts, like telemedicine and automatic control. That goal can be achieved through the convergence of the IoT concept and healthcare management. That convergence could be ambiguous, but in a wide view, the healthcare management can be improved using as input data the collected data by the IoT smart objects, bringing an optimization in the use of the available resources.

2. Methodology

The following methodology is based on the data obtained from the HED model presented in [11], where the author developed a DES model and treated it as an optimization problem. In that project, the hospital data and information were summarized the into stochastic data, later reflected on the HED. After the collection of the dataset and the implementation of the DES model in Matlab-SimEvents®, it is possible to reproduce the simulation and verify the improvement of the system.

The DES allows reading the different management data of the system, and that information can be compared with some of the information obtained by the IoT system, following each patient in the HED, information like queue length in each station, the average waiting time of patients, and so on. That data is enough to observe the system as the IoT would look at it, with an administrative management perspective, allowing the implementation of an online control for the current system requirements. The identification and improvement of the principal bottlenecks in the system, and the simulation allows the detection of the main system bottlenecks and with that knowledge is possible to propose a feasible solution to solve that problem.

The proposed solution is based on telemedicine and principles of control theory, to control the flow of patients. Also, the additional investment in hospital personnel and the use of a service of telemedicine requires a little investment, compared with the hospital quality improvement. The implementation of the HED using DES is based on the data and simulation presented in [11], follows the stochastic data presented in Figure 1 and Table 1, that shows the inputs of patients correspond to a receptionist arrival and an ambulance arrival.

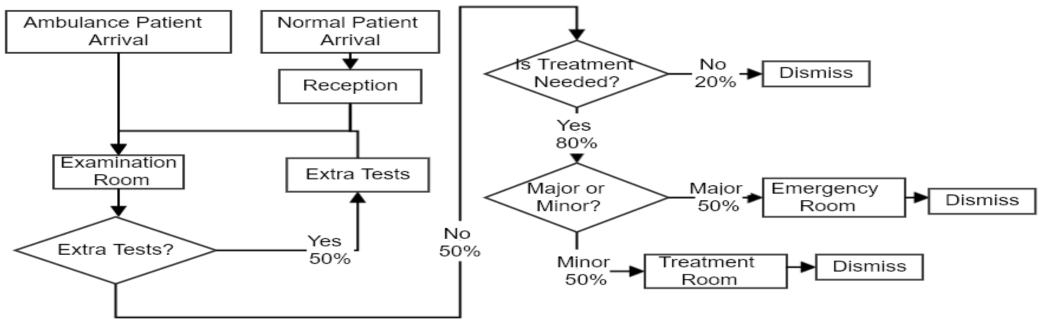

Figure 1: HED high-level process and Service time distribution at each stage of the process [11]

Table 1: Constant Values for Each Staff Server of the Fig. 3.

Stage	Distribution (Minutes)
Reception	Uniform (5,10)
Lab Tests	Triangular (10,20,30)
Examination Room	Uniform (10,20)
Reexamination Room	Uniform (7,12)
Sala De Treatment Room	Uniform (20,30)
Emergency Room	Uniform (60,120)

The receptionist arrival corresponds to a non-homogenous Poisson process with an estimate of $\lambda(t)$ given in Figure 2, and the ambulance arrival process is given by a Poisson process with a rate of 2 per hour. The implementation of the simulation was made using Simulink®, as is presented in Figure 3, and the constants of the system that corresponds to the staff servers are presented in Table 2.

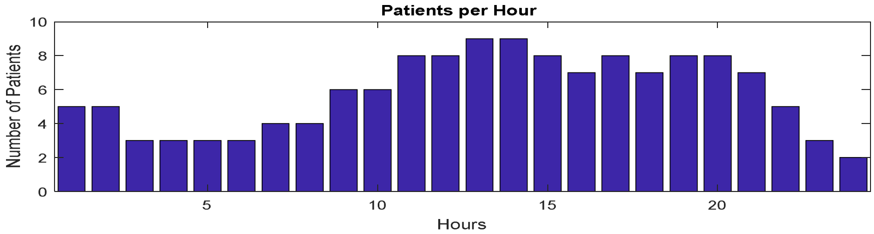

Figure 2: Plot of the estimated rate function $\lambda(t)$ in patients per hour for the arrival process

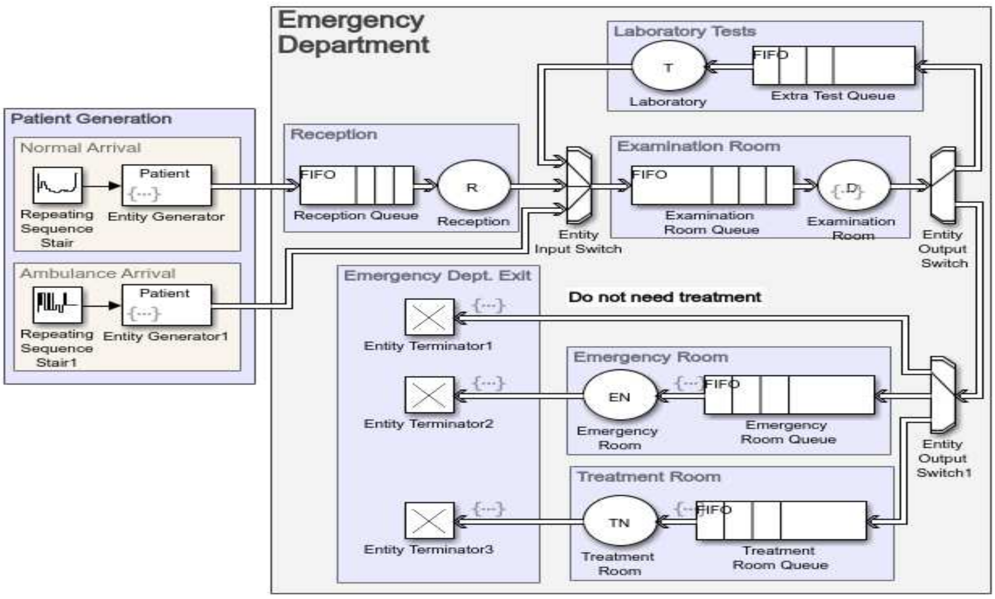

Figure 3: Implementation of the HED in the DES using SimEvents® in Matlab 2017a

Table 2: Constant Values for Each Staff Server of the Fig. 3.

Staff Server	Abbreviation	Current Value
Reception	R	2
Doctor	D	2
Laboratory Technician	T	3
TR Nurse (Treatment Room)	TN	1
ER Nurse (Emergency Room)	EN	9

The results obtained by the system, after 1000 simulations, can be observed in Table 3, where appears the main statistical information of the system behavior, can be observed that the utilization of the Examination Room is 96±1%, what is too high. The queue length and the waiting time of patients there are high, the queue length an average of 17.83±5.55 patients and the waiting time an average of 84,67±25,62 minutes, showing it as the main bottleneck in the system.

Table 3: Information about the main processes of the system presented in the Fig. 3 (1000 simulations).

Result	Value	Standard Deviation
Expected Patient Time in System (h)	3,68	0,7
Expected Number Out (patients per hour)	4,66	0,27
Average Waiting Time (min): Reception	0	0
Average Waiting Time (min): Laboratory	0,54	0,3
Average Waiting Time (min): Doctor	**84,67**	**25,62**
Average Waiting Time (min): Emergency Room	0,03	0,16
Average Waiting Time (min): Treatment Room	19,7	11,11
Average Queue Length: Reception	0	0
Average Queue Length: Laboratory	0,05	0,03
Average Queue Length: Doctor	**17,83**	**5,55**
Average Queue Length: Emergency Room	0	0,01
Average Queue Length: Treatment Room	0,61	0,41
Utilization (%): Reception	28,0	1,0
Utilization (%): Laboratory	5,0	5,0
Utilization (%): Doctor	**96,0**	**1,0**
Utilization (%): Emergency Room	34,0	4,0
Utilization (%): Treatment Room	64,0	9,0

The proposed solution is based on the telemedicine concept, specifically the use of telepresence for the Examination Room, with the utilization of concepts as IoT, that concept, and use can be highly used with the inclusion of the new technologies in the society [12], [13], and an alternative Examination Room based on telepresence, what will allow that some doctors in a remote center be able to diagnose the patients, consequently will remove the detected bottleneck of the system. The Smart Hospital concept is primarily based on the implementation of the telediagnosis room in the DES is introduced as a finite resource that depends on the queue length.

The selected reference queue length is 5 patients in the waiting line, the reason of that choice is that the current number of doctors in the physical room is 2 and the tele-doctors is 2, so a waiting line of 5 leaves only 1 person waiting in line. The remote diagnosis center can maximumly assign 2 tele-doctors per turn, each turn is assigned each 13.25 minutes, what is the average time a doctor diagnoses a patient. The number of patients is measured by the connection of one or various smart objects, in an IoT network. The connected devices will provide the current queue length values in real-time.

For the control of the required number of doctors was used a concept of automatic control, the implementation of a PID (Proportional, Integral, and Derivative) controller what is highly used in industrial processes and others[14]. The controller was tuned heuristically by the response of the system, because of the nature of the system, that follows a stochastic model, and has a limited and rounded output (the number of doctors is an integer positive number). The minimum number obtained can be 0 and the maximum is 2, it is a constraint for the number of tele-doctors.

3. Results and Discussion

The implementation of the Smart Hospital is based in the traditional HED, just adding a PID controller to requiring the telepresence doctor service. After the implementation of the Telediagnosis center, it was possible to identify the creation of a new bottleneck in the Treatment Room (TR), so a treatment nurse was added to improve this new issue. The PID controller to control the number of required doctors allowed to improve the results given by [11], that was also presented in Table 3 and was adjusted with the parameters: *P=0.3, I=0.001* and *D= 0.0005.*

The Table 4 shows the comparative study after 1000 simulations and presents the differences between the traditional hospital and the Smart Hospital proposal, where is possible to see the improvements of the hospital in different ways, between the most remarkable results, are the reduction of the user time in the system by 1.18 hours, the increased number of output patients by 1.42 patients more per hour, the reduction by 61.55 minutes of the average waiting time for the doctors are the most remarkable changes in the system. In contrast, some results were negatively affected, but the decreased behavior is not significant to affect the system or to reduce the quality of the obtained results. Therefore, the patients will see a significant improvement in the HED, reducing the mortality rate according to [4].

Table 4: Comparison of the key performances of a traditional hospital and a Smart Hospital proposal for HED.

Result	Hospital	Smart Hospital	Standard Deviation	Difference
Expected Time in System (h)	3,68	2,5	0,18	**1,18**
Expected Number Out (patients per hour)	4,66	6,08	0,3	**-1,42**
Average Waiting Time (min): Reception	0	0	0	0
Average Waiting Time (min): Laboratory	0,54	5,9	4,58	-5,36
Average Waiting Time (min): Doctor	84,67	23,12	1,77	**61,55**
Average Waiting Time (min): Emergency Room	0,03	0,44	1,1	-0,41
Average Waiting Time (min): Treatment Room	19,7	3,81	2,22	**15,89**
Average Queue Length: Reception	0	0	0	0
Average Queue Length: Laboratory	0,05	0,69	0,62	-0,64
Average Queue Length: Doctor	17,83	5,09	0,59	**12,74**
Average Queue Length: Emergency Room	0	0,02	0,07	-0,02
Average Queue Length: Treatment Room	0,61	0,16	0,1	**0,45**

The comparison between the used resources by each case is presented in Table 5, where is possible to see the modifications between the systems and understand the additional required staff to improve the HED quality according to the Table 4. On observing that is possible to infer that the Smart Hospital system added 1 TR Nurse and the equivalent of a 0.6737± 0.1566 tele-doctors (in a day). That increase in the staff number has improved the HED system as is presented in Table 5. Those improvements affect directly the system performance by reduction of the user time in the system by 1.18 hours and the increased number output patients by 1.42 patients more per hour.

Table 5: Comparison of the Staff Number in 24 hours of service.

Staff Server	Abbreviation	Hospital	Smart Hospital
Reception	R	2	2
Doctor	D	2	2
Telepresence Doctor (Dynamically Controlled)	**-**	**-**	**0.6737± 0.1566**
Laboratory Technician	T	3	3
TR Nurse (Treatment Room)	TN	1	**2**
ER Nurse (Emergency Room)	EN	9	9

4. Conclusion and further developments

The IoT concept can be used with different objectives, for example in the improvement of any service-based system. The implementation of an HED and uses of connected things to obtain online data for improve the management of a service-based system, and the use of IoT concepts in a simulation environment, as it was presented in this work, it allows an easy and cheap possibility to prototype and make viability tests of real IoT based solutions for service-based systems.

The improvement of the HED was successful, using not many additional resources and a concept as telemedicine and IoT, the system improved by around 30% in the expected number of output patients and patient expected time in the system. Those significant changes were obtained by an addition of 10% of staff, according to the presented results, and finally, it was possible to present a work were the IoT, IIoT, the DES, and other current technological concepts converged in the result of an optimized environment, what leads to a futuristic and not so distant reality, where the smart connected devices allow an improvement of the human life quality.

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Supporting supply chain digitization through lean startups: a cases study from the household appliances industry

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Purpose: Nowadays, manufacturing processes digitization is challenging the supply chain management area. This phenomenon comes from the fourth industrial revolution, known as Industry 4.0. The primary technology drivers are the internet of things, big data, artificial intelligence, cloud computing and machine learning, among others. These technologies provide new forms of monitoring and controlling products in real time by the customer, both at the shop floor and during product delivery. The areas of inbound and outbound logistics are being challenged to absorb and adopt such technologies, in a feasible and reliable manner, as fast as possible. This work presents a framework to catalyze the move from traditional logistics to a more vertically and horizontally integrated value chain through the establishment of an innovation culture based on lean startups that accelerate organizational transformation.

Design/methodology/approach: Cases and examples of lean startups for the implementation of digital technologies-oriented solutions in supply chains are presented and discussed with an example of a Brazilian household appliances manufacturer..

Findings: Additive manufacturing, augmented reality, exoskeletons, data science-oriented digital kanbans, machine telemetry and drones are some enablers that must be implemented to lift a company's supply chain to a 4.0-oriented ecosystem. The path of digitization is full of obstacles that can take an industry, when acting alone, towards insufficient results and postpone the achievement of its goals, and these obstacles are discussed.

Originality/value: This paper shows that a more collaborative and dynamic strategy, based on small and agile enterprises such as startups that can help organizations rapidly implement the cited enablers, becomes a determinant factor for success.

Keywords: lean startups, supply chain digitization, collaboration, organizational transformation.

1. Introduction

Nowadays, the fourth industrial revolution, known as Industry 4.0, is a challenge to managers and decision makers in industries of all sorts and sizes, not only because it completely changes the paradigm of production, from the isolated use of computers and automation (the so called 3rd revolution) to the emergence of interconnected cyber-physical production systems (the 4th revolution), but also because the path for evolving from the third to the fourth revolution is not well paved [1]. Although much has been researched and said about the technology drivers of Industry 4.0, such as the Internet of Things (IoT), Big

Data, cloud computing, artificial intelligence and machine learning, among others, there is no sequential, clearly established way to implement them [2].

This behavior is evident when we look at Industry 4.0 from a learning-curve point of view. First, the different pieces that compose an Industry 4.0-solution, such as technology drivers and the hardware and software that implement them must be comprehended (including their potential to generate results and the benefits and barriers to their application). Only then an understanding of how to integrate these pieces to can be developed. The other way around merely creates confusion, wastes resources and underachieves the full potential of the drivers [3]. Following this reasoning, it can be inferred that different industries are in different stages of maturity concerning the implementation of Industry 4.0 [4]. This article provides first thoughts about how to connect the pieces of the Industry 4.0 jigsaw puzzle more effectively.

To start understanding how these pieces may be brought together, this paper considers the Industry 4.0 transformation process as a change process [5] towards a continuous cycle for production management, inspired in traditional management cycles such as PDCA or PDSA [6], divided into 3 phases: informational, decisional and action-oriented that feedbacks to the informational phase, as depicted in Figure 1.

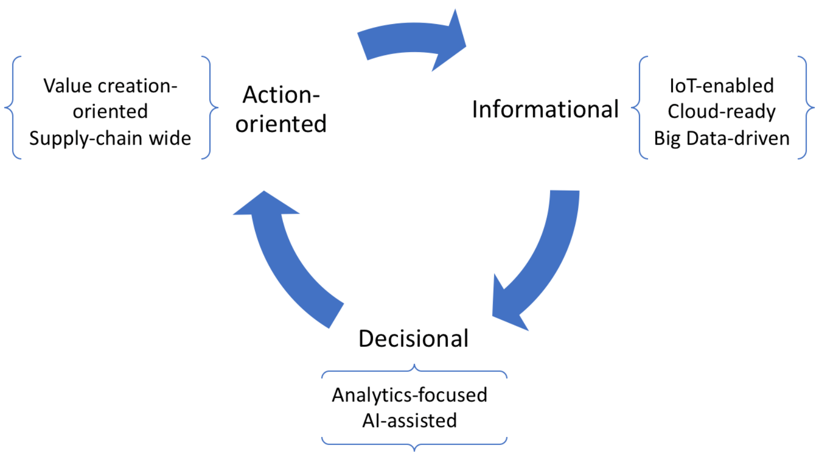

Figure 1: Continuous cycle for production management from an Industry 4.0 perspective.

The informational phase starts with the gathering of information, using the integration of industrial decision-support systems, an evolution of the old Enterprise Resource Planning (ERP) systems paradigm, with data stored in the cloud by a myriad of applications that support different production functions such as maintenance, scheduling, quality and inventory, among others. These systems must be fed by reliable information coming from IoT-enabled electronic sensors and other data acquisition devices installed on the shop floor. All this information forms a vast mass of data that because of its volume, variety and velocity both in storing and accessing can be considered Big Data.

In the decisional phase, this Big Data must be intelligently processed to be transformed from its raw form to usable decision-making information, using Data Analytics techniques. Data Analytics encompasses the necessary knowledge to develop predictive, prescriptive and descriptive decision-support systems, an evolution of the operations research optimization-simulation theory. Once usable decision-making information has been generated, it can be used in the management of the production floor. This phase also includes the application of man-machine decision-making interfaces with the use of artificial intelligence, helping in the creation of smarter management systems, in contrast to the standalone human-centric systems of today. When decisions are made, the decisional phase ends and the action-oriented phase is opened.

In the action-oriented phase, decisions taken in the previous phase are transformed into actions affecting the production process. Actions may be oriented, for instance, to address issues related to production sequence and process, final product quantity and distribution, raw material quantity and supply source, among other factors. Also, using data from quality control and scheduling, actions may address maintenance issues such as the appropriate moment to stop an equipment or the detection of iminent failurer. Such a smart production system focuses not only on itself, but on the whole supply chain. This closes the action-oriented phase and inherently generates new data to feedback to the informational phase, closing the continuous cycle.

As we can see from this short description, the transformation process from the use of computers and automation (3rd revolution) to cyber-physical production systems (4th revolution) is complex and involves not only the application of technology, but a paradigm-shift, in which humans are required to understand the role of technology as well as their role as decision-makers. It requires an innovation-based organization, an efficient production system and an orientation to value creation.

This paper aims at providing an example of how a household appliances manufacturer has been embracing this change process. The authors of this paper have been actively involved in this transformation, helping facilitate the process through training, consulting and mentoring. Several managers of the company have been interviewed, as well as middle-level managers and operational-level staff either involved in carrying out the described actions or impacted by them. Next section discusses the chosen path – to develop Industry 4.0 capacities through the creation of internal lean startups to take advantage of their flexibility and agility – and the way through which this path was paved. The final section presents some conclusions and insights from this case.

2. Case Description

The reality of the household appliances industry in Brazil includes: (i) big manufacturers that already have ERP systems and data collecting procedures and are moving from the third to the fourth industrial revolution; and (ii) small suppliers that are experiencing the second industrial revolution, improving their mass production facilities. From their experience with a big household appliances manufacturer, the authors propose a three-stage framework to catalyze change in the first group. The company under consideration has the objective of moving from traditional logistics to a more vertically and horizontally integrated value chain. Authors proposed, through their framework, the establishment of an innovation culture based on lean startups, accelerating organizational transformation, as it is their understanding that, as the path of digitization is full of obstacles, it can take an organization, when acting alone, towards insufficient results and postpone the achievement of its goals. Figure 2 represents the three-stage framework proposed by this work.

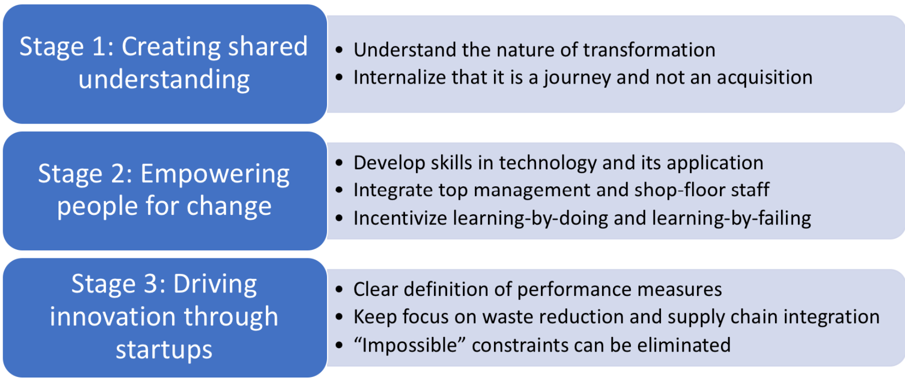

Figure 2: Three-stage framework to drive digital transformation through lean startups.

2.1. First Stage: Creating shared understanding

Initially, the organization under study thought that Industry 4.0 technologies were plug-and-play technologies that could be rapidly deployed, so that the transformation to a more integrated and intelligent production system could be easily accomplished. In other words, leadership thought that digital transformation could be achieved by the acquisition of technology packages from third-party vendors and installation of these packages on the shop floor. However, after some trials and tests that did not deliver the expected results, it was seen that this was a mistake. Hence, the first conclusion is that the Industry 4.0 is not a plug-and-play set of technologies, and transformation towards Industry 4.0 must be developed by the company through the involvement of its own resources.

The company then started to create a shared understanding of what Industry 4.0 is and the necessity to involve everyone in the organization in the improvement of operations towards a more integrated and intelligent production system. Top level management and shop floor personnel participated in talks, videos and information were delivered for everyone to watch and acquaint themselves with the new technologies and demands imposed by integration and intelligence. This led to the creation of a common view towards both the necessity to improve the production system and to what Industry 4.0 was and drove the organization into the next stage by considering how transformation should be carried out.

2.2. Second Stage: Empowering people for change

The necessity of technical solutions customization and fast deployment of these solutions triggered a vital insight: digital transformation would only be possible by empowering people to work with more flexibility and agility through startups, aligned and assisted by business management. Some of the applications considered for development were machine-to-machine connectivity, exoskeletons to carry heavier loads, smartphones to visualize online information and the integration of the whole value chain to support the real-time sensing of the status of products and processes.

This digital innovation journey demands new employee skills to be able to cope with these emerging Industry 4.0 technologies, leading the company to an environment in which its competitiveness remains healthy. The second conclusion, hence, is that the company must run a specialized learning program to develop capacities necessary for its people to move from operating a standard shop floor to a connected and intelligent one. Above all, integrating top management and shop floor staff through internal startups and asking for external help when necessary, so that deployed solutions are aligned and value-focused.

Consequently, a personalized program with eight learning modules was designed to develop the technology skills of people from top management and shop floor. They are: (i) Industry 4.0 fundamentals; (ii) collaborative engineering; (iii) robots and sensors; (iv) industrial Internet of Things (IIoT); (v) Big Data; (vi) supply chain 4.0; (vii) maintenance 4.0; and (viii) leadership 4.0. Besides that, the group was divided into small multifunctional teams, with people from different levels and areas, with each team responsible for defining, conducting and implementing a startup on the shop floor, with freedom to work and overcome barriers as needed. All teams are supported by coaches and must go through proof of concept and minimum viable product steps before final implementation of a solution.

2.3. Third stage: Driving innovation through startups

The created startups function outside of the organizational structure and apply lean startup mechanisms to quickly evaluate and pivot ideas as needed. The direction of all startups is guided by eight key performance drivers that create clear accountability on the final results: (i) safety; (ii) time to market; (iii) sustainable resources; (iv) equipment utilization (OEE); (v) minimum inventories; (vi) supply on demand; (vii) total quality; and (viii) intelligent labor. Startups have to embrace at least one of the value drivers and progressively deliver enhancements that transform production. There are fifteen startups in this case distributed in four main areas: 6 in logistics and supply chain, 4 in manufacturing digitalization, 3 in maintenance and 2 in environment, health, and safety. The number of startups in supply chain shows the importance of this area regarding Industry 4.0. This is the third and final conclusion from this case: step one in starting the transition to a smart factory is to transform supply chain management.

A critical point in this scenario is the concern to keep strong the lean philosophy, already adopted by the organization, applying these new technologies to emphasize waste reduction and integration of the value chain. It is assumed that constraints that were taken as impossible before have to be eliminated, because they might be overcome by the application of Industry 4.0 technologies. Accordingly, all projects are considered lean startups since they have to deliver results aligned with the lean organizational culture. The interaction between these startups and the shop floor is essential, and it is what keeps the development of both startups and the shop-floor alive. This is achieved by emphasizing communication of what is being done throughout the company.

3. Conclusions

After analyzing this case in the household appliances industry with the creation of lean startups that transform supply chain operations in the shop floor, it is possible to highlight some important aspects. On the one hand, startup team agility allows considerable gains in small deliveries to be achieved, what contribute to the company short-term results. It also keeps the whole innovation strategy strong. The startup methodology is essential to quickly pivot when faced with an obstacle, such as the use of methods and techniques such as Scrum, sprints and pitches. On the other hand, the main challenge of the entire group is to find out what exactly to do with all available technologies and how to make sure that technology matches organizational culture.

Finally, the digital innovation journey cannot be accomplished by acquiring a plug and play set of technologies. It must be developed by the organization, from the inside to the outside. Nevertheless, lean startup teams are strongly recommended to help the organization travel this path safely and to adopt, as fast as possible, Industry 4.0 technologies that face market demands and deliver a better experience to the final customer.

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