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Adapting to Industry 4.0: a case study in a manufacturer SME

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BUSINESS SCHOOL

Department of Marketing, Operations and Management

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Abstract

The digital era is characterized by a transverse transformation across all sectors of society. The Fourth Industrial Revolution, or Industry 4.0 is defined by increases in productivity, harmony between all components of the value chain, and better relationships with customers, through the implementation of new technologies.

This project deals with the preparation of companies for this new reality, using company H as a case study. Company H is a SME in the manufacturing industry, characterized by weak technological advances and intensive human labor. The main objective of the present study is to demonstrate how this company can analyze its current way of doing business and create and develop an innovation strategy that will make it thrive in this new technological era.

To get a better understanding of company H´s current situation, its maturity level was analyzed, and the business model was described. Interviews with the company´s employees were conducted, and it was possible to conclude that company H´s equipment and infrastructures do not represent smart features, processes are mostly performed manually by workers, resources are scarce and data acquisition and processing is not an activity performed by the company.

At the end of this project, it was possible to propose some changes to the company´s current business model that could help in the path of technological innovation.

Keywords: Industry 4.0; maturity level; smart manufacturing; Small and medium-sized Enterprises; Business Model Innovation

JEL classification system: O31; O33

Resumo

A era digital que se caracteriza por uma transformação transversal a todos os setores da sociedade. A quarta revolução industrial, ou indústria 4.0 caracteriza-se pelos aumentos de produtividade, conexão de todos os intervenientes da cadeia de valor, e melhor relacionamento com os clientes, através da adoção de novas tecnologias.

Este projeto procura perceber de que forma a empresa H se pode preparar para esta nova realidade. Esta é uma PME da indústria de manufatura caracterizada pelo fraco avanço tecnológico e intensiva em mão-de-obra humana. O principal objetivo foi clarificar de que forma a empresa H pode analisar o seu negócio para conseguir elaborar uma estratégia para a sua inovação tecnológica.

Para perceber a situação atual da empresa, foi analisada a sua a maturidade tecnológica e descrito o seu modelo de negócio. Para tal, foram realizadas entrevistas a três gestores com elevada responsabilidade e autonomia de decisão. Foi possível inferir que equipamentos e infraestruturas não apresentam funcionalidades *smart*, os processos são maioritariamente realizados pelos trabalhadores de forma manual, os recursos são escassos e a aquisição e tratamento de dados não faz parte das atividades da empresa.

No final, foi possível propor algumas alterações ao modelo da empresa que podem ajudar na sua inovação tecnológica.

Keywords: Indústria 4.0; Nível de maturidade; manufatura inteligente; Pequenas e Médias Empresas ; Inovação do modelo de negócio

JEL classification system: O31; O33

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Acronyms and Abbreviations

AR – Augmented Reality

BM – Business Model

BMC – Business Model Canvas

BMI – Business Model Innovation

BMP – Business Model Patterns

CDO – Chief Digital Officer

CEO – Chief Executive Officer

CPS – Cyber Physical System

HR – Human Resources

I4.0 – Industry 4.0

IoT – Internet of Things

IT – Information Technologies

LPG – Liquefied Petroleum Gas

MN – Multinational

R&D – Research and Development

SAP – System Applications and Products

SM – Smart Manufacturing

SME – Small and Medium Enterprises

SMS – Smart Manufacturing System

SPC – Statistical Process Control

VR – Virtual Reality

1 Introduction

The industrial context is affected by social, economic, environmental, and technological changes. Changes that influence consumers habits. Nowadays, customers are more informed, and consequently, more demanding.

Industry 4.0 as known as the Fourth Industrial Revolution is based on digitalization and the use of new technologies that are changing the industrial sector. Digitalization is changing products and services, processes, or entire business models through the application of digital technology (Nambisan et al., 2017). So, companies need to adapt their business to new realities.

The potential of new of technologies to support business processes is infinite. Its implementation is reflected in terms of productivity, efficiency, and effectiveness in a variety of industries (Burke et al., 2017). Thus, technologies may be considered as the engines of economic growth.

However, Small and Medium Enterprises (SME), are featured by certain conditions which limit their capacity of innovation. The lack of resources is the main barrier that influence the most these companies to evolve (Horvath & Szabó, 2019). In 2020, Pordata published that SME constituted 99,9% of the total of the Portuguese companies. Given the relevance of the SMEs, not considering their restrictions might have adverse effects on the growth of the economy of the country.

The literature available is mostly based on Industry 4.0 technologies, features, enablers and barriers and a few strategies of adoption. But, for those who are interested in embracing it, there is lack of information on how to act. Since Industry 4.0 is not a broadly analyzed subject, this study aims to understand how minor companies could prepare their path of innovation. Its main objective is to understand how a Portuguese manufacturer SME can adapt their business.

To achieve the purpose of this thesis, this work will deal with the following questions:

Q1: How can the manufacturing SME prepare its business model for the digital era?

Q2: How can the manufacturing SME benefit from the use of new technologies?

In practice, this study may help company H guide their innovation process by giving an insight of the components to analyze and the possible strategies to adopt. It is also expected that researchers and managers recognize the importance of the topic and motivate them to work aside to produce value one to each other.

Finally, using this information companies could be able to identify within their own business models, strengths, and weaknesses to exploit and overcome and hence, design a strategy to lead their business innovation to continue competitive in today's world.

This thesis is structured into six chapters. Firstly, it presents the overall research issue and objectives to achieve. In the second, there is an extensive literature review describing the related concepts and models. In the third place, it is explained the methods used to obtain and analyze the information. The fourth chapter is focused in describing the company in study and presented the results obtained with the investigation made. The fifth chapter presents an analysis of the case study carried out based on literature review. The sixth and last chapter, answers the questions of investigation and, shares some recommendations and limitations.

2 Literature Review

2.1 Industry 4.0: contextualization and characterization

2.1.1 Historic evolution

Science has been incessantly evolving since the 17th century when the First Industrial Revolution occurred from 1760 to 1840. The charcoal utility was discovered as a source of energy which was determinant to build the steam machine. The transportation of goods and humans became faster than ever before. Productivity increased enormously because hard activities previously performed by humans could now be performed by machines.

The Second Industrial Revolution started at the end of the 19th century, in 1870 and ended in the early 20th century, around 1914. Also known as “The Technological Revolution”, this era is characterized with the discovery of electricity, bringing telephones and telegraphs. A new wave of globalization started here because people and ideas were starting to be connected more than ever before. It was also the beginning of assembly line production, making production faster and less costly. The mass production of steel and iron allowed the construction of railroads, creating railroad networks and facilitating the transportation of materials and products. These technologies rouse to mass production and standardization.

The Third Industrial Revolution began around 1970 and was defined by the emergence of electronics, telecommunications, and computers. It was the beginning of automation using computers and programs. With it arrived new scientific fields such as Information and Communication Technologies, robotics, nanotechnology, etc. The rise of these new technologies, especially robotics, shifted the production process to a much more automated process, where humans were no longer required. Therefore, Industry 3.0 is associated with the increase of flexibility in production processes according to the demand and consolidated capitalism and globalization.

Currently, we are already experiencing what specialists affirm being the Fourth Industrial Revolution or the so-called Industry 4.0 that is characterized by the connection between the digital and real world (Boettcher, 2015).

Researched authors present different definitions of Industry 4.0 and inherent concepts. Some of the most interesting ones are now referred, once they are complementary and none is more important than the other.

Industry 4.0 intends to change traditional industry into a reconfigurable manufacture system and implement the intelligent factory. This is mandatory when dealing with a small sized production and respond to consumers’ customized demand (Wang et al., 2016).

Industry 4.0 is featured by the recent technological advances. Internet and Information Technologies enable integration of physical objects, humans, production lines and processes beyond organizations’ limits establishing a new value chain which is intelligent, integrated and agile (Schumacher et al, 2016).

Industry 4.0 is a multilateral communication network in real time composed by a huge amount of data and interconnections between cyber-physical systems and people. It has the ability to speed up adaptation and decision-making processes. This leads to an efficiency increase in manufacturing, services and sales, and mainly, to a revolution of the business model (Schuh et al., 2017).

The Fourth Revolution goes beyond digitalization of production and automation of processes. It will completely redefine the way of doing business. It has potential to transform the way products and services are idealized, projected, built, sold and how they compete between each other (Schuh et al., 2017).

Along with the shift from industrial to customized market, services turn out to be the key means to solicit customers. Industrial manufacturers are shifting from selling products to selling product-related services, which requires different business models. Data-driven business models, pay-by- usage/ subscription-based models, technology platform models are examples of new value capture business models based on the new technologies. These models are currently being adopted by some industrial manufacturers. Pirelli, for example, introduced embed sensors in each commercial tire to obtain condition monitoring information. This strategy allowed the company to add a new revenue stream through the sale of data-rich maintenance solutions (Shaefer et al., 2017).

So, new technologies enable the improvement of products/ services quality, offer new possibilities of revenue streams, and facilitate execution of production processes

2.1.2 Related concepts and technologies

Smart Factory

A smart factory goes beyond automation. Citing Burke et al., (2017: 5) "a smart factory is a flexible system that can self-optimize performance across a broader network, self-adapt to and learn from new conditions in real or near-real time, and autonomously run entire production processes". Essentially, a smart factory defines an enterprise that left the traditional models based on human labor and adopted a new way of doing business using a smart manufacturing system.

Smart Manufacturing System and its foundations

However, there is no clear definition of a Smart Manufacturing System (SMS). According to the National Institute of Standards and Technology (NIST) as Kusiak (2018: 509) refers "smart manufacturing is a fully integrated, collaborative manufacturing system that respond in real time to meet changing demands and conditions in the factory, in the supply network and in customer needs. Smart manufacturing integrates current machinery used nowadays with sensors, computing platforms, communication technology, data modelling, simulation and predictive engineering."

SMS is a set of manufacturing practices that use networked data and information and communication technologies to lead manufacturing operations. SMS also allows production planning and control as well as the use information to continuously maintain and improve performance (Mittal et al., 2017). These systems are an entirely connected intake of raw materials to the delivery of finished products to the consumer, which gives them autonomy and efficiency in reacting to unanticipated situations (Qu et al., 2019).

A SMS foundation resides in the integration of information technology and data with different technologies, processes, and resources. It is compound by hardware and software tools associated with technology. New technologies are beneficial for manufacturing firms as they provide advantages such as reduced production costs, improved product quality, reduced delivery times and inventory levels (Mellor et al., 2014). Thus, firms that adopt new technologies and acquire digital capabilities are more prosperous than others who do not (Boothby et al., 2010).

There are particular technologies that are more relevant and with an important role in the Fourth Industrial Revolution. "A few examples of technologies frequently associated with SM are CPS (Cyber-Physical Systems), IoT (Internet of Things), data analytics, AR

(Augmented Reality), VR (Virtual Reality), autonomous and collaborative robots, 3D-printing, IT-based production management, intelligent products, simulation, energy-saving, and real-time communication" (Mittal et al. 2019: 3). McKinsey (2015) grouped them in four clusters according to its features.

Data, computational power, and connectivity. This cluster includes big data, the Internet of Things, and cloud technology. The use of this technology is mainly linked with cost reduction. Using sensors embedded in physical objects, and the interconnection between devices through wireless makes large amounts of data flow to computers to be analyzed enhancing decision making.

Analytics and intelligence (digitalization and automation of knowledge work and advanced analytics). Advances in artificial intelligence and learning machines allied with the increase of information availability is making robots and automated machines more performant. Nowadays, they can do more than simply perform repetitive tasks.

Human-machine interaction. Includes virtual and augmented reality, and touch interfaces for example. People are already familiarized with these technologies. Gesture recognition, virtual and augmented reality is ever more in use. Almost everyone has a personal device with these functions. The human-machine interaction enables performing a given task faster than before.

Digital-to-physical conversion. This cluster includes 3D printing, advanced robotics, energy storage and harvesting. These technologies are becoming more relevant by their decreasing costs and increased quality.

Smart Manufacturing entails the implementation of new technologies. So, it is important to understand the circumstances of technologies being adopted, the extend of technology adopted, as well as, the system, process or activity that needs to be smart (Mittal et al. 2019).

Industry's 4.0 technology applications can be linked to daily activities performed by smart enterprises.

Table 2.1: Industry 4.0 technologies and their applications

Technologies	Applications
CPS (Cyber-physical systems)	Production, logistics & warehouse operations, etc.
IoT (Internet of Things)	Transportation, smart homes, real time communications, etc.
Data analytics	Data management, decision-making, purchasing, sales, etc.
AR (Augmented reality), VR (Virtual reality)	Product development, manufacturing, maintenance, etc.
Autonomous & collaborative robots	Manufacturing, transportation, inspection, etc.
3D-printing	Product development, prototype productions and assessment, etc.

Source: Mittal et al., (2019)

2.1.3 European and National Initiatives

Portugal and the rest of Europe are aware of the benefits prevenient from Industry 4.0 technologies and are making evident efforts to move towards the digitalization of procedures.

Industry 4.0 in Europe

Factories of the future sponsored by *European Factories of the Future Research Association* (EFFRA) promote the competitiveness and sustainability of the European industry. It intends to any type of firms to work together with faculties and research organizations in the development and implementation of advanced manufacturing processes, intelligent manufacturing systems, digital and virtual factories. This requires coordinated efforts of research and innovation. The main focus targets are agile value networks; excellence in manufacturing using advanced processes; develop human competencies; sustainable value networks; connection of manufacturing services (EFFRA, 2016).

Portugal i4.0

The Portuguese Ministry of Economy launched Portugal i4.0 aiming to create conditions for the development of industry and services. This project claims to identify the needs in the Portuguese industrial sector and adopt measures to fit in public and private companies expecting to achieve three main goals:

- Accelerate the adoption of Industry 4.0 concepts and technologies by Portuguese firms;
- Promote Portuguese companies abroad;
- Make Portugal attractive for investments in an Industry 4.0 context.

According to COTEC (2017), the organization responsible for Portugal i4.0 concluded that the priorities are:

- Capacitation of human resources;
- Promote cooperation between development and implementation of disruptive technologies;
- Recognize the role of Startups in technological innovation;
- Finance and support the investment in Industry 4.0 technologies;
- Adapt legal rules to the new reality.

Citing COTEC Portugal (2017) the “development of Portugal i4.0 presumes the creation of a digital platform, constituting the principal instrument of interaction and communication between intervenient in activities in the scope of Industry 4.0 in Portugal”.

Compete 2020

Compete 2020 is a program managed by public organizations. This program aims to improve the Portuguese economy's competitiveness and converge with the growth of the most developed European Union countries. The strategical objectives of this program are: increase technological intensity; empower SME to adopt advanced business models; and, improve transport conditions between Portugal and abroad, to reduce costs and operational time.

2.2 Industry 4.0 and SME

2.2.1 Drivers, barriers, and requirements of Industry 4.0 in SME

Drivers and barriers of I4.0

Although industry 4.0 is on its infancy and there is not a clear and consensual definition of concepts and dimensions affected, academics and practitioners have been really interested in its potential.

After consulting several authors through an extensive literature review Horváth and Szabó (2019) listed a variety of drivers in the introduction of new technologies and the main barriers faced by companies to adopt Industry 4.0 strategies.

Table 2.2: Drivers and barriers of industry 4.0

Drivers	**Barriers**
Growing competition	Human resources and work circumstances
Increased innovation capacity and productivity	Shortage of financial resources
Expectation of customers	Standardization problems
Efforts to save energy and improve sustainability	Concerns about cybersecurity and data ownership issues
Financial and performance factors	Risk of fragility
Support for management activities	Technological integration
Opportunity for business model innovation	Difficulty of coordination across organizational units
	Lack of planning skills and activities
	Organizational resistance

Source: Horváth, D. and Szabó, R., (2019) Within these elements, the growing competition and the expectation of customers are seen as the most relevant drivers. The first one, incentives the companies' necessity to reduce time-to-market adopting innovative technologies with the capacity to answer customers' requirements. The second one, because clients are the ones that establish the market demand. For that reason, producers have to adapt the products' features to the customers' expectations, once their requirements are permanently changing. Decreasing product life cycles is another factor forcing change, as it alters consumer's expectations and needs (Horváth, D. and Szabó, R., 2019).

Regarding the factors that inhibit the industry 4.0 implementation, the need for technological integration is consensually considered as a major barrier. A successful integration of components, tools and methods entails the development of a flexible interface, once the coordination of different languages, technologies, and methods can lead to significant challenges (Zhou et al., 2015). Technology implemented individually creates little impact for an industrial firm, whereas the implementation of a set of technology offers much more possibilities for the future (Alcácer and Cruz-Machado, 2019). For not being usually recognized, even though its huge importance, the management of organizational resistance and cultural acceptance of innovations are other barriers that must be highlighted. According to Machado et al., (16, p.1115; 2019) "investing in technology will not make a company succeed or become more mature in digital transformation, because the digital strategy and purpose should lead the digital transformation."

Drivers and barriers that most influence SME

Horváth and Szabó (2019) conducted a research with several CEOs and CDOs of firms which are providers or/ and users of Industry 4.0 technologies aiming to reveal how they perceive industry 4.0 implementation. Top executives identified some drivers and barriers inherent to the different areas of management and its effects in SME and multinational (MN) companies.

The influence of these factors is not the same in all kinds of enterprises. Different companies require or possess different amounts and type of resources. Thus, some areas of the firm are more affected than others, depending on their dimension.

Concerning the human resources (HR) factors, the increasing labor shortages and reducing human work are decisive drivers. Once these firms are highly dependent on local workers, their offer becomes limited in terms of capabilities and they often struggle to find employees with appropriate competences. So, many SMEs are willing to use Industry 4.0 solution to overcome this problem. The investment in new technologies enables to allocate employees to areas with higher added value and reduce costs with educational training. Besides that, this lack of skilled workforce and the longer learning time turns HR in a substantial barrier for I4.0.

Customer satisfaction is a key for SMEs' success and a crucial driver to pursue digitalization. SMEs try to achieve completely their customers' requirements to guarantee that they will return. This is obtained by enhanced quality, improving productivity and the ability to be flexible. Responding efficiently to individual customer needs quickness, reduces complaints and improves clients' loyalty.

The financial resources, profitability and management reality are SME's mainly inhibitor factors to technological advances. Often, these firms have lack of financial resources and do not expect huge profits, which makes investments in new technologies challenging. Furthermore, the top management of SMEs may not have capacity to identify the opportunities and benefits provided by Industry 4.0 technologies.

SMEs are usually characterized by the lack of a skilled leader with experience and technological competences. Because when there is a CEO committed to a purpose the rest of the organization tend to follow his leadership. So, for SMEs, human resources act as a driver but also barrier to the implementation of new technologies and digitalization of processes.

SME features and requirements to receive Industry 4.0

According to the European Commission (EC, 2003), SME may be defined as organizations that employ less than 250 workers and have an annual turnover that does not exceed EUR 50 million, or an annual balance sheet total lower than EUR 43 million. Due to their dimension, lack of awareness and resources compared to multinational enterprises make the survival of SMEs difficult (Lee, 2010).

SMEs are often family businesses and/or hold by an individual and face numerous risks. The financial constraint is a reality. The lack of collateral or information is a barrier between SMEs and investors. Often, being financially constrained, SMEs do not spend resources in research and development or in upgrading software integration. SME usually have a limited number of products, and hence a shorter and specific network. The existence of standards in an SME is rare, usually they think that will disclose important information that allow them to compete. SMEs' employees are more likely to lack the exposure to mentors, supervised industrial training, workshops and activities that give them more expertise to make them more proactive and confident to perform their jobs (Mittal et al., 2018).

SMEs must pay attention and try to follow the trends, otherwise the gap between them and multinational enterprises will increase and turn the competition impossible. Industry 4.0 technologies simplify and accelerate production processes and decision-making. Due to the advantageous properties offered by automated robots and improved materials these will have an important role in a firm's production efficiency and cost reduction. The technological revolution offers means to achieve advantage in efficiency and competitiveness (Je, 2018).

Companies need to be prepared to change. To implement modern technologies firms are required to possess multiple features. Those that are not present must be developed to facilitate their integration in the business. Some of them were highlighted by a few authors. *Employee participation* is an important industry 4.0 driver. In intelligent factories people work alongside robots and together form a new production system that allows a faster and more accurate information exchange. Employees must be highly trained and skilled in areas that imply communication with robots and are supported by web technologies and intelligent support systems in their daily activities (Hermann et al., 2015). "Innovative production systems have not been designed to replace human operators, but to make them more efficient" (Turkes et al., 2019: 4). Providing *innovative education and training* to employees. This implies, not only, train employees on digital technologies but also, incentive them to develop an innovative mindset motivating them to think how they can improve the product, service or activities performed within the firm (Mittal et al., 2017). *Financial and technical resources* are very important features. Businesses depend on investments and most importantly, on the return on investment (Mittal et al., 2018). *Digitalization* of production and the elimination of boundaries between digital and real worlds. The use of information technologies can prompt an exponential growth of a business (Huxtable and Schaefer, 2016). *Collaborative strategies* such as alliances with universities and research institutes provide knowledge and wisdom regarding a broader area of the business. (Mittal et al., 2018). *Industrial Standards* such as ISO that ensure quality and safety in both products and services internationally traded. The standards help manufacturers increase productivity and innovative efficiency

(Brown, 1998). The *organizational culture* is a fundamental aspect of an enterprise. Top managers have to be flexible and receptive concerning experimentation and implementation of disruptive technologies (van de Vrande et al., 2009).

2.3 Industry 4.0 – Technology implementation process

Nowadays manufacturing firms can benefit a lot from the implementation of Industry 4.0 concepts and technologies. However, huge changes are not easy to make. Therefore, transformations must be well thought and concrete. A clear roadmap must be generated and fully respected to achieve a sucessful Industry 4.0 revolution (Oztemel and Gursev, 2018).

So, aiming to help companies to transit from its current stage to a modern and evolved one. Cordeiro et al. (2017) proposed a set of six steps. Which entails plan a strategy for Industry 4.0, start pilot projects, define required capabilities, specialize at data analysis, increase firm's digitalization and communicate the value chain.

Step 1 - Plan a strategy for Industry 4.0

Firstly, an overall understanding regarding 4.0 must be achieve. The firm must analyse its maturity level and establish the desired future. It is recommeded the use of a maturity model to help this process (Cordeiro et al., 2017). The output of this phase is the future vision of the company. So, external experts and technological partners should have a relevant role in this process. They must identify relevant results and the best practices to tailor the business renovation. Once current maturity is identified and target settled, the company must highlight and analyse the barriers that separate both stages.

Step 2 - Start pilot projects

Once the goals are established , this stage consists in the development and execution of pilot projects. At the end of each project, results must be assessed, registed and disclosed. All the knowledge and information provided by those results must be stored.

It is important that pilot projects are taken at relevant points of the production system in order to spread outcomes to other stages of the system.

For a better execution of projects, the firm should take in consideration the 5C architecture for development of CPS for industrial application proposed by Lee et al. (2015). It serves as a guideline for an efficient integration between computational models and physical components. This architecture is divided into five development levels depending on its attributes, functions and levels of implementation – I. *connection level, II. conversion level, III. cyber level, IV. cognition level* and *V. configuration level.*

Table 2.3: 5c architecture for industry 4.0 technology implementation

5C architecture	Attributes	Functions
V. Configuration level	Self- configure	Allows the system to autoconfigure based on past decision-making (Intelligent production)
IV. Cognition level	Early-aware	Entails the provision of information and simulation to decision-making (Predictive maintenance)
III. Cyber level	Controlable	Control of entire network via CPS (Automated function)
II. Conversion level	Informational	Raw data is transformed into useful information by using data analysis technologies (Information discovery)
I. Connection level	Communicable	Sensors network to data acquisition and wireless communication (Hardware connection)

Source: Lee et al. (2015)

In case of success of a pilot project, it must be efectively implemented, otherwise a top-down analysis should be made to understand the problem between the company and the expected results.

Note that the elaboration of a pilot project must be developed considering the diferent levels of the 5C architecture, which are directly related to the maturity level of the firm. Moreover, the operational complexity of succeeding projects must increase until they reach the most advanced level. The progress within the firm to achieve configuration level involves the adoption of technologies as big data, internet of things, cloud computing, and others.

Step 3 - Define required capabilities

Considering the failed pilot projects, it is important to understand what are the capabilities that the firm does not hold and that might have droven to the project failure. Once those boundaries are eliminated and the company now has the capabilities required to achieve the original goal, the pilot project should be executed again.

Schuh et al. (2017) described the capabilities that every company must possess in order to transform itself into a learning and agile organization through Industry 4.0. It considers four structural areas of resources, information systems, culture and organizational structure. Firms may consult this list to decide the capacities they want to improve.

Table 2.4: Industry 4.0 capabilities for businesses by structural area

Structural area	**I4.0 capabilities**
Resources	• Establish that employee skills profiles include broad-based IT skills; • Technological resources must be implemenented to enable data collection and process data into information to support decision-making; • It requires appropriate interfaces with a structured communication between machinery-employees and machinery-machinery that enable real-time information exchange between stakeholders
Information systems	• Integrate information systems horizontally and vertically • Standardise data interfaces to facilitate information flows between IT systems; • High-quality data are stored centrally and analysed automatically; • Information systems can continuously adapt to changing circumstances;

	• The knowledge acquired through automated data analysis is delivered to employees in a contextualised manner and supports them in their work; • Maintain IT security due to the risk increase of criminal attacks
Organizational structure	**Internal organization:** • Employees must be able to perform their tasks and switch to different teams creating a flexible community guided by task- or goal-oriented teams; • Task- or goal-oriented team leadership is performed by an expert at the specific topic no matter his hierarchical position; • Decentralise the decision-making by using the available information provided by IT systems and/ or involving the most competent stakeholders of the company in this process; • Balance between centralization and decentralization to maximize the effectiveness and efficiency of decision-making process; • Goal systems are required to channel employees' greater autonomy and ensure that they remain focused on the company's overall goal of delivering customer value; • Goal systems should mix monetary and non-monetary incentives as training opportunities and individual freedom; **External collaboration:** • Focus on customer benefits finding its individual contribution and help business partners satisfy the end customer; • Establish exactly what role they should play in the value network; • Assess continuously the firm's competences and adapt to changing circumstances;

	• Manage competences by cooperating within the network by outsourcing certain activities;
Culture	• Entire workforce must be willing to change, open-minded to innovation and able to recognise the value of mistakes; • People should be able to recognise opportunities and/or a need for a change at their own and corporate environment and initiate relevant actions themselves; • These actions should be taken entirely knowledge-based acquired through target observation, data analysis or practical experience; • It is necessary to develop a social collaboration spirit that promotes and helps to accelerate knowledge sharing between employees; • It is important have an open communication channel between people who possess the knowlegde and those who are seeking it; • Managers must value employees and make them part of the decision-making process.

Source: Schuh et al. (2017)

Step 4 - Specialize in data analysis

The integrated and autonomous systems that characterize Industry 4.0 require huge amounts of data. This entails computational system to process data and provide training to worforce. Thus, taking measures towards both aspects allow a better process and selection of relevant information for an effective and quicker decision-making. Data analysis is a major competency to be developed once the information acquired and shared is the fuel to other systems. In that sense, there are four activities that firms must be specialized in as they become more digital.

Table 2.5: Four activities to manage industrial digitalization

Information capturing and recording	• Relevant set of data to prevent information overflow; • Automated, real-time capuring via sensors; • Recording and storing of both, historical and new data in a single information system .
Information transfer	• Digitally transfer information across departments, production sites, value chain steps, and company borders.
Informatiom analysis and synthesis	• Identification of relevant data and analysis (ideally, automated); • Sysnthesis of analysis into relevant insights.
Turning information into outcomes	• Translation of analysis results into recommendations that suggest actions for workers or automatically trigger actions of machines; • Feedback and continuous improvement.

Source: Mckinsey (2015)

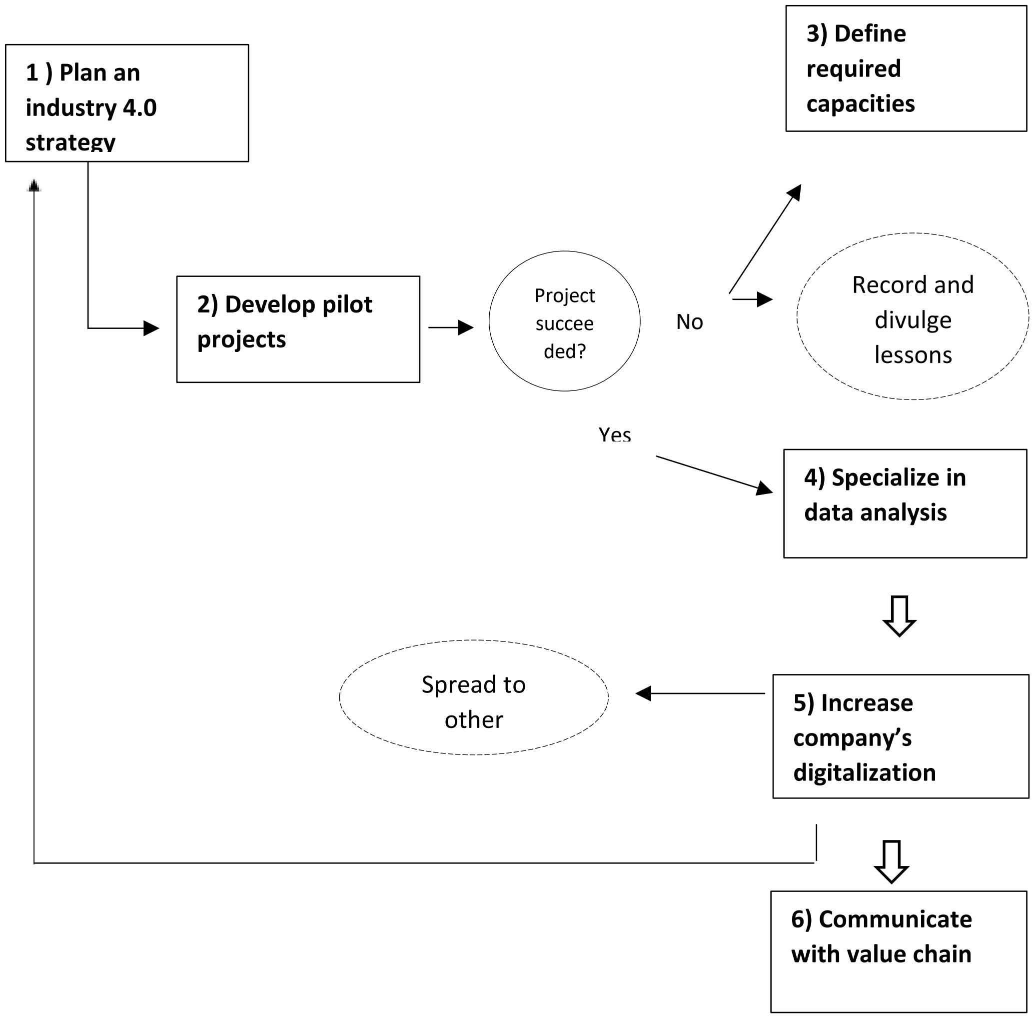
Step 5 - Increase firm's digitalization

As projects are sucessfully implemented and their complexity increases along the 5C architecture attributes, companies also are increasing their maturity level. Thereby, through a continuous and progressive digital adaptation, firms become more prepared to compete in this new reality.

Altough the importance of each dimension depends on the company, sector or industry, a firm should have similar maturity levels through all dimensions. An evenly technological evolution allows that all dimensions are prepared to follow the organization's strategy. A less developed dimension could compromise the role of the others along the production process.

Step 6 – Communicate with the value chain

After completing the company's digital transformation, it is important to expand the process to other players of the value chain. The objective is having available information from the begging of the value chain, raw-materials extration, until the end, delivery to the client. This is attainable with partners who are wiiling to share information or through mergers/ acquisiton.



Source: Cordeiro et al., (2017)

Figure 2.1 - Industry 4.0 implementation process

2.4 Maturity models for Industry 4.0

2.4.1 Maturity models

Maturity models are popular instruments applied in a widespread and range from cognitive science to business and engineering. It rates current activities carried out in terms of maturity and study actions to take them to a higher level through a process of development. They are based on the premise that people, processes, and organizations evolve to more advanced levels (Kohlegger et al., 2009).

A maturity level symbolizes the consolidation of general and specific practices related with a predetermined set of processes. An increase to a higher maturity level can be planned and implemented (Goksen et al., 2015). An evolution to higher maturity levels rises the general performance of an enterprise, or specific objective (De Souza & Gomes, 2015).

There are a variety of maturity models developed by respectable and specialized organizations available for professional or academic purpose. Prepared maturity models have some advantages and disadvantages. These models are ready to be used without having to spend time in their conception and have already been tested by experts. However, they might be too specific to study a determined situation or need and do not reflect the effective dynamic of the organization being studied (Goksen et al., 2015). Some models may be limited by measuring specific aspects. Even though being complex due to different conceptual dimensions and maturity levels, it is possible to combine different models (Donovan et al., 2016).

Considering Industry 4.0 maturity models, these aim to evaluate the stage of technological development within each dimension of an organization. This is, it analyses in which extent organizations are using industry 4.0 concepts and technologies in their benefit.

Reginaldo Carreiro Santos (2018) proposed a descriptive maturity model of assessment industry 4.0 concepts and technologies implementation.

Its applicability in industrial firms enable to assess the current stage of maturity, reveal inhibitors that limit the technological evolution and monitor measures to develop technical and managerial capacities. The author aimed to produce a tool to be used by professors, investigators, students, managers and consultants, including the academic and business public.

Its conception was based on an extensive and detailed research made by the author. Through the comparison of three models which are, the IMPULS-VDMA model elaborated by Lichtblau et al., (2015), “A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises” by Schumacher et al., (2016), and “Industrie 4.0 Maturity Index” by Schuh et al., (2017). In the end, from conceptual changes and added contributions founded by the author resulted his proposed model.

Moreover, the author presents a detailed research where explains the purpose and how the model was elaborated. Defining in a clear manner all the components of the model which facilitates whoever consults the work and want to use it as a tool. This enable investigators to understand precisely how industry 4.0 concepts and technologies are linked, and hence, to know exactly which characteristics is searching within a company or industry when using that tool. For that reasons, the *proposed model of Industry 4.0 maturity assessment* by Santos (2018) was chosen to use during this research.

To better understand the purpose of maturity model in the scope of industry 4.0, the author described the capacities established in each dimension in view of a technological advanced company. So, the more capacities a company is able to develop, higher will be its maturity level. Consider the following dimensions and capacities:

Organizational strategy, structure and culture

- The firm's strategy is a reference for its competitors and the digitalization of processes increases significantly its economic returns;
- Has the flexibility and agility required to adapt its business model and products offer due to market changes;
- Information and operational tecnhologies are its main competitive advantage**;**
- Possesses Human, Financial and Physical Resources to operate and manages indicators to assess operational efficiency;
- Supports the collaboration and share of information through the entire value chain;
- Focuses its strategy based on client's requirements acquired and selected in real-time;
- Bets on R&D to innovate products, processes and in employees' continuous learning

Team works

- Analyses current and required skills to implement operational and strategic I4.0 projects;
- Decentralizes decision-making, giving employees autonomy and resposability which promotes flexibility to deal with problems;

- Use of IT to increase communication, reduce time to take action and antecipate environmental changes.

Smart factories

- Infrastructure and production equipments have digital backups which allows the flow of information between the physical and virtual world in order to monitor and remotely control operations;
- Infrastructure and production equipments are able to communicate between each other and with external systems enabling an agile adaptation imposed by changing quantities or products' diversifiction;
- Possesses simulation systems that permit to gather and analyse real-time information;
- Productions systems based on artificial inteligence capable to recognize products, machines and people. They are very autonomous and able to make decisions, auto-maintain, auto-optimize performance, auto-reconfigure and spot failures;
- Intensive use of mobile and wearable devices on daily routine, as smartphones, tablets, glasses and watches, all equiped with artificial inteligence and conectivity to increase the eficiency and efficacy of operations.

Smart processes

- Use of cloud computing to increase conectivity of equipments and systems and, hence flexibility and reliability of information and operation systems;
- Secure firm's information with andvanced data protection systems;
- Optimization of human resources through intensive use of artifical inteligence machinery in production and distribution processes;
- The firm is a reference in processes' automation by the integration of production chain and digital practices;
- Its main activities are guided by digital models that control and monitor production remotely and in real-time;
- Virtual and augmented reality are present in workplaces delivering real-time and contextualized information;

- The firm is able to answer changes of customized mass production through a permanent analysis of huge amounts of data in real-time.

Smart products and services

- Offers inteligent products and services which are able to recognize their own prodution processes, transportation and use conditions, alerting producers and customers for errors or bad condition of the device;
- Products are capable to auto-optimize by notifying producers if there is a change necessity, who immediately fix or add new features required;
- Products are designed to be completely digitized and communicable with the operations department. They contribute to a significant portion of the revenues;
- The flexiblity and agility in creating and producing products and services allow the firm to respond to the incremental customization trend, offering more segmented and unique units;
- The systems integrated into the products are interoperable with other systems which facilitates information exchange throughout the product's lifecycle.

2.5 Business Models of Industry 4.0

2.5.1 Business Model definition

A Business Model symbolizes the organizational and financial planning of a business. The creation of a business comes with the conception of a unique business model that outlines how value is created, delivered and the capture mechanisms utilized to do so. A business model is used to determine how value is delivered to customers, how they are tempted to pay for this value and ultimately, how the enterprise turns those payments to profit (Teece, 2010).

According to Johnson et al., (2008), a business model (BM) consists of four interlocking elements that, taken together, create and deliver value.

Customer value proposition – this represents the way a company found of creating value to people, meaning, having a solution for a customer's given problem:

Profit formula – this is the blueprint that states how the company creates value for itself while satisfying the customer's needs;

Key resources – these involves all the assets required to deliver the value proposition to customers such as the employees, technology, products, facilities, etc.;

Key processes – these are all operational and managerial processes that allow companies to deliver value in a way they can successfully repeat and increase in scale.

These elements form the building blocks of any BM. The first two define the value for the customer and the company; the last two describe how the value will be delivered to the customer and the company. Major changes to any of these four elements affect the others and the whole (Johnson et al, 2008).

Despite the vast research about BM there is not an established definition or interpretation about the theme. Nevertheless, beyond the variety of definitions and interpretations, it is consensual among all authors that BMs are built on the four building blocks previously described. And, even if using different terminology, the meaning and relation between these elements is the same (Weking et al., 2020), see following table 1.

Table 2.6: Business Models building blocks

Foss and Saebi (2017), Saebi et al. (2017)	*Teece (2010)*	*Johnson, M., et al. (2008)*	*Ostterwalder and Pigneur (2010)*	*Gassmann et al. (2014)*
Market segments	Customers	Customer value proposition	Customer segments	Who is the target customer?
Value proposition	Value		Value proposition	What does the costumer value?
Structure of the value chain	Value creation, value delivery	Key resources, key processes	Key partners, Key activities, Key resources, Customer relationships, Channels	How is the value proposition built and distributed?

Value capture mechanisms	Value capture mechanisms	Profit formula	Revenue streams, Cost structure	Why is the BM financially viable?

Source: Adapted from Weking et al., (2020)

Fundamentally, a BM is a more conceptual framework that enables to understand how a business works in a simplistic way. Beyond the existing variety, some models are more practitioner-oriented, such as the Business Model Canvas (Osterwalder et al., 2010) or the Business Model Navigator (Gassmann et al., 2014).

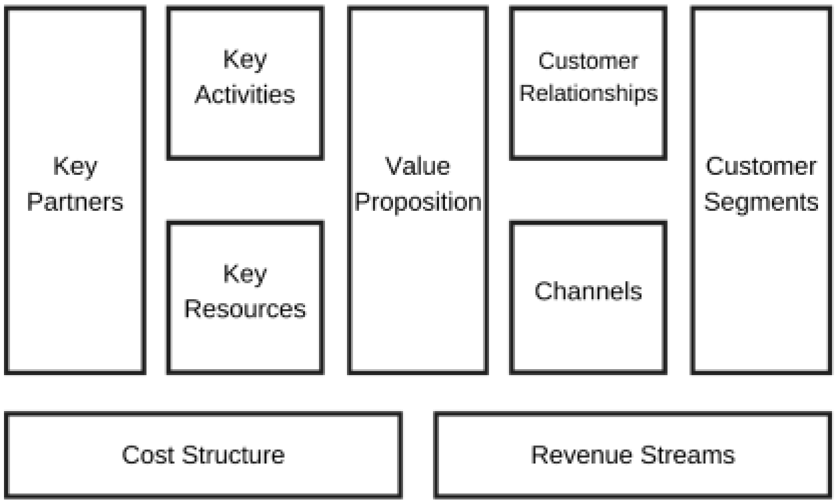
Business Model Canvas

The Business Model Canvas (BMC) is a popular business-modelling tool that has become the standard amongst practitioners in the design or redesign of business models (Michelle, 2020). It was defined by Osterwalder et al., (2010; 12) as "a shared language for describing, visualizing, assessing, and changing business models".

It is used in current literature to analyze business models from a practitioner's perspective. It has proven to be a comprehensive approach to business models, as its nine building blocks assist in generating an integral and nuanced view on business models (Wirtz et al., 2016). Its graphic representation, simplicity and easiness to use has made it focus of many academic studies (Kajanus et al., 2014; García-Gutiérrez & Martínez-Borreguero, (2016); Golnam et al., (2014)). All of these were aimed to evaluate the BMC and to use it as basic tool in the developing of new or reinterpreted business modelling tools concerning a specific situation. Ibarra et al., (2018) in their study called "Business model innovation through Industry 4.0: A review" used the BMC as a tool to develop their research on how companies may reconfigure business models.

Its simplicity, relevance and intuitiveness to understand shows perfectly how a company intends to generate money and facilitate description and discussion of business models. This concept has been a famous tool used in organizations such as IBM, Ericsson, Deloitte, Government Services, etc. (Osterwalder et al., 2010).

To better understand the BMC a brief description of its building blocks is presented. *Customer segments* describe the groups of customers that a company wants to reach and offer value; The *value proposition* provides an overview of a company's bundle of products and services; *Key partners* define the network of suppliers and partners that make the business model work; *Key resources* outline the main assets required to execute the company's business model; *Key activities* describe the most relevant activities to carry out the business. *Customer relationships* explain the types of links that a company establishes between itself and its different customers; *Channels* define the various means that the company utilizes to communicate to its customers segments; *Revenue streams* describes the ways that a company generates income through a variety of revenue flows; *Cost structure* summarizes all the costs incurred in the means employed in the business model (Osterwalder et al., 2010).



Source: Osterwalder et al., 2010

Figure 2.2 – Business Model Canvas

2.5.2 Business Model Innovation

Business model innovation could be defined as the way the company finds to modify the way of doing things, with the purpose of delivering a new value proposition to its customers. Therefore, business model innovation is the upgraded version of the system of activities used to bring out a new value proposition (Souto, 2015).

The new industrial paradigm is altering the ways of doing business, once it is directly influenced by changes in technical and productive systems (Ibarra et al., 2018). To extract value from new technologies, companies must have appropriated business models. The BMs by which companies were founded are likely to be outdated and insufficient to provide new costumer value. Therefore, in response to market changes companies must adapt their BM (Müller, 2018).

Transformations made in business models must be aligned with the nature of the business and with the company's vision of the future. Ibarra et al. (2018) identified three different approaches to guide a BMI. Each one of them is meant to attempt the solving of different issues, however, they are all interconnected.

S*ervice-oriented approach*: this reflects the importance of manufacturing firms to extend their business to services related to their products, the so-called products-service system (PSS). Firms should give up on the traditional sales industry and offer a hybrid solution. As result, suppliers, customers, and other partners are part of the same networked ecosystem.

N*etwork-oriented approach*: the new competitive dynamics motivate companies to expand their vertical and horizontal integration, and act beyond their individual value chain. New members appear and the role of the existing one's changes. This creates new ways of delivering value through wider networks.

U*ser-driven approach*: from this approach, companies need to focus on learning more about their customers (using digital capabilities to obtain information about customers, promoting evidence-based decision-making, developing integral customer experiences, etc.) and become great at building partnerships with new stakeholders.
These approaches provide general directions for possible developments and changes of the business models, which may help managers to choose the right path to follow.

2.5.2.1 Approaches to Business Model Innovation

New and adapted business models are needed to follow the I4.0 impact on the markets and companies. "A 2005 survey by the Economist Intelligence Unit reported that over 50% of executives believe business model innovation will become even more important for success than product or service innovation. A 2008 IBM survey of corporate CEOs echoed these results. Nearly all the CEOs polled reported the need to adapt their business models (Johnson et al., 2008: 60)".

Companies that adopt strategies to transform their BM towards I4.0 aim to achieve an I4.0 BM. There are different opinions on how to achieve them. Ibarra et al., (2018) suggests changes that must be done within the building blocks highlighting some features that must be present in business models. While other authors defend the innovation through business model patterns.

Ibarra et al. (2018) present four theories to conduct a digital transformation in manufacturing companies. Each one is associated to a different level of innovation.

Hence, different changes are described with regard to the value creation (which involves the key activities, resources and partnerships), the value delivery (which includes product and services offered, the distribution, communication and sales channels, customers segments and relationships) and the value capture (that takes into account costs and revenues).

Internal and external process optimization: the introduction of technologies such as Big Data, Cloud Computing, Collaborative Robots or Virtual Reality to optimize value creation by increasing efficiency and performance. This represents a first move of traditional manufacturers without incurring high risks.

Table 2.7: Changes in BM building blocks to achieve internal and external optimization

<table>
<tr><th>Value creation</th><th>Value delivery</th></tr>
<tr><td rowspan="3">✓ Product and resources traceability: more efficient production, logistics, inventory management, quality control, better maintenance
✓ Machine to machine communication: connection of internal processes and suppliers’ processes

✓ Employee training:_working long distance, better communication, knowledge exchange
✓ More transparent management: data-driven decision making</td><td>✓ Flexible offers: individualized mass production, customization</td></tr>
<tr><td>Value capture</td></tr>
<tr><td>✓ More efficient processes and use of resources enable cost reduction</td></tr>
</table>

Source: Ibarra et al., (2018)

Customer interface improvement: this model focuses on the value delivery improvement through the introduction of I4.0 technologies, which enables new ways of interaction in order to get a greater understanding of customers and serve them better. This could be considered an incremental innovation for a traditional business that has already optimized its internal and external processes.

Table 2.8: Changes in BM building blocks to achieve customer interface improvement

<table>
<tr><th>Value creation</th><th>Value delivery</th></tr>
<tr><td rowspan="3">✓ Data collection, monitoring and interpretation
✓ Development of new services
✓ Management of new touchpoints</td><td>✓ Segmentation based on data analysis: greater awareness of customers' needs through marketing and social networks
✓ More direct, long term and efficient relationships
✓ Improved digital sales: coherence between channels, comprehensive customer experience, self-service channels that offer time and cost saving and instant answers</td></tr>
<tr><td>Value capture</td></tr>
<tr><td>✓ Cost saving
✓ New revenue streams: pay-per-use, online payments, etc.</td></tr>
</table>

Source: Ibarra et al., (2018)

New ecosystems and value networks: this model propose a radical innovation on the core business of the firm, providing new ways of value capture. This will modify key activities, channels and customer/partner relationships building blocks. The use of enabling technologies allows information and knowledge sharing, as well as acquiring new skills and resources through the interaction with more agents. This is, moving from limited value chains to interconnected ecosystems.

Table 2.9: Changes in BM building blocks to achieve new ecosystems and value network

Value creation	**Value delivery**
✓ *Real time information* about production, inventories, sales, etc. ✓ Business infrastructures connected to key partners infrastructures	✓ New customer segments ✓ Wider products offer
	Value capture
	✓ Potential increase in value capture due to *cost reduction for all stakeholders*

Source: Ibarra et al., (2018)

New business models: smart products & services: this one proposes a completely disruptive innovation that will change almost every BM building block. This is the creation of a new BM based on the new technologies that allow to offer innovative and smart goods and services. This strategy could be a diversification investment of the firm while the old BM still provides revenue.

Table 2.10: Changes in BM building blocks to achieve new business models

Value creation	**Value delivery**
✓ *New physical, human and intellectual resources are needed*	✓ *Smart products* that constantly collect information ✓ *Innovation is associated services:* predictive maintenance, product upgrades, ordering spare components, etc. ✓ *Co-creation:* customers contribute to the value creation process ✓ *Direct relationship* between the firm and customers
	Value capture
	✓ *New revenue streams:* pay-per-use,_performance-based revenues, etc.

Source: Ibarra et al, (2018)

Business Model Innovation patterns

There are authors defending that a BMI can be achieved by applying Business Model Patterns (BMP). It is a practice-proven approach to systematically and efficiently support BMI (Amshoff et al., 2015). Business Model Patterns capture the core of a frequent BM design problem and the corresponding BM design solution in such an abstract way that it can be applied in BMs of various companies from different industries and markets. Firms can adopt BMPs at different times by applying the abstract pattern to the firm's specific requirements (Weking et al., 2020).

Weking et al. (2020), built on BMP to describe and analyze I4.0 BMs resulting from BMI toward I4.0. The authors identified three main patterns of I4.0 BM which are integration, servitization and expertization, and ten sub-patterns spread through the major ones.

Firstly, the *Integration* BMP is a process-focused BM innovation where the firm's BM is changed with new processes and the integration of other supply chain parts. Thereby, the firm aims to be specialized in a single step of the value chain by covering more activities. The three sub-patterns have in common the fact that the BM building block with most changes is the value chain structure.

- The *crowdsourced innovation* BM, where the firm allows people to join the innovation processes. Firms open their innovation processes by integrating customers or development groups in development processes. Firms move from a closed business to an open one;
- The *production as a service* BM allow customers to design, choose materials and production techniques used to build their products. Basically, firms undertake production from design until shipping as a service for their customers;
- The integration of customers into the value chain characterizes the *mass customization* BM. Smart production enables profitable production of reduced quantities. So, companies are willing to offer customization as an additional option allowing customers to adjust their purchases according to their individual taste.

New production techniques shift mass production toward mass customization. Moreover, this main pattern is characterized by shifts in key elements and target customers, and the online channels allow to directly contact customers and replace distributors.

Secondly, the *Servitization* BMP is a product-focused BM based on new offerings rather than new processes. Companies provide product-service systems instead of tangible products. Its focus remains on repair, maintenance or operating services.

- Implementing a *life-long partnership* BM, firms add continuous revenue streams providing IoT-connected products that enable them to remotely monitor the maintenance or repair failures throughout the products' lifecycle;
- A *product as a service* BM is based on renting products and related services in exchange of a fee instead of selling. Customers pay for products usage not for ownership;
- A *result as a service* BM is characterized by selling the output of a product. Firms sell a full-service package and take responsibility for the operations.

This super-pattern main building block change is in value capture. The addition of continuous revenue streams with subscription-based or life-long service contracts in exchange of solely sporadic sales.

Thirdly, *Expertization* BMP is a hybrid BM in which firms use their internally built expertise in products and processes to provide new consulting services or new platform-based products.

- A firm with a *product* or *process-related consulting* BM wants to help its customers make optimal use of a product or obtain the maximum performance of a process. The firm's own experience developed around a product or process execution enables to deliver value to external parties by sharing its know-how as an advice and/or consulting service.

Both patterns transform the building blocks of value proposition, key elements, and architecture. Value capture, value chain, and target customers are not affected.

- A *product* or *process-related platformization* BM is based on a digital product accompanied with complementary IT services. The firms use their expertise from manufacturing and selling into a new digital product. Cloud-based platforms for trading goods and services among user groups is a well-known example product. Firms can do business online and offline.

The new offerings address both, existing and new customer segments. The value capture building block moves from one-time sales to continuous subscription fees, in which customers do not pay for the ownership of a physical product but for its availability.

The value chain building block shifts from mass production of physical products toward mass customization of digital products.

Changes in BM building blocks

Transforming the current BM into a I4.0 BM entails a deliberate and disruptive change on the current BM key elements (Foss and Saebi, 2016).

Regarding current circumstances of SME manufacturers, the main elements to work on are, firstly, value proposition. Because customers' needs are constantly evolving, the creation of new products and services is required. Secondly, key resources such as production facilities, equipment and employees' capabilities need to be adapted to the new specifications of I4.0. Furthermore, key partners like IT experts are mandatory to perform the changes. Finally, having strong customer relationships will be fundamental when customers are reporting issues. All these are building blocks that mostly require a revision. On one hand, as I4.0 *providers*, SMEs should direct efforts into meeting customer requirements offering individual and specialized products and services expected from I4.0. They should also look into developing IT competencies. New value propositions require new resources, especially creative problem-solvers. On the other hand, as Industry 4.0 *users* they must focus on their key partners: due to their limited resources, partners must be a better solution to develop new capabilities and tools, as well as long-term customer relationships and intensified relationships with the manufacturers and providers of products and services. This will guarantee their availability for the firm's personal usage. So, the perspective of providers involves manufacturing cyber-physical systems and selling them to customers. Users of I4.0 apply cyber-physical systems in production and services (Müller, 2018).

Thus, given SMEs' unique features regarding I4.0, there are changes to make. Redeveloping or extending the existing business models is a major and important step for a company to be able to generate value to customers, in a way that competitors can't.

Whatever are the technologies and purpose of each implemented project always result in operational changes. So, if there are changes in processes it is necessary to adapt the business model. Thus, Gaglio, (2020) developed a framework which gathers the items that characterize the business models in the industry 4.0 context. This was formulated based on strategic transformations made by relevant companies who adopted IT solutions to improve their industrial processes. Key features of modern business models considering industry 4.0 context:

- Customer segment: new technologies serve all market scenarios and multi-sided platforms are adaptable to every market segment
- Value propositions: industry 4.0 technologies are able to create value to customer with better offers and optimize companies' resources
- Channels: internal data collection is preferred once it is easier to store, analyze and use
- Customer relationships: use of direct channels of communication
- Revenue streams: the return from investing in technologies by optimizing resources
- Key resources: technologies used for development of IoT platforms/ solutions and intangible resources as skills, reputation, intellectual property
- Key activities: development of IoT platforms/ solutions internally or externally, data management, use of data collected to support production, management, and maintenance
- Key partnerships: specialized partners that help development, installation and management hardware and software, and the integration of supply chain players
- Cost structure: cost of implementing and maintain IoT platforms/ solutions

2.6 Examples of application of industry 4.0 concepts and technologies

When preparing to implement industry 4.0 solutions companies must develop knowledge and expertise using internal and external sources of information. External sources consist in the best practice examples of other companies and academic literature together with publications of research organizations and branch associations. Internal sources are R&D activities and learning from mistakes (Veile et al., 2019).

SRAMPORT, Transmissões Mecânicas, Lda.

SRAMPORT has been part of the SRAM group, a bicycle components producer. In Portugal, the firm has 127 employees and is specialized in the production of bicycle chains specially to export.

SRAMPORT, since 2004, has been focused on process modernization and technologies adoption. Several projects were already executed to turn production lines automatized. These projects aimed to control and monitor processes by using data collection and analytic tools.

Transformation: digitalization of assembling production lines

SRAMPORT implemented a factory floor system in order to meet traceability and quality control requirements of components and products by batch. Previously, both procedures were recorded manually in SPC (statistical process control) sheets. However, workers need to have information available related to current production stage to simplify and speed up possible interventions.

The traceability of the final product is achieved through production batches, where each one is associated to a set of specific components and produced in a single production line. In each chain batch only one batch of components is used. Thus, whenever the batch of a component is changed results in a new batch chains and associated codes of identification. The quality control of products was performed manually along the production line by operators. This task was executed whenever a determined event occurred such as, change of components batch, a modification in products type, change of personnel shifts, calibrations and/or every 30 minutes.

Nowadays, it is possible to execute a top-down and bottom-up analysis by batch associated in the process, employees have available the control cards in SAP (System Applications and Products) in factory floor, quality department is able to analyze and predict possible deviations, components expenditure is performed in the production line instead by planning department, the quality control became automate through the use of communication devices.

This was achieved through the implementation of cyber-physical systems that resulted in the virtualization of the factory floor. The virtual factory shows in real-time important information related to equipment state and productivities in terms of machine, operator, month, day, etc. Making use of new technologies the company is already able to execute systemically the traceability and quality control of materials and products.

Results:

- Higher efficiency by planning department;
- Real-time inventory;
- Simplified traceability available everywhere in the factory instead of stored paper;
- Automatization of batches changes according to prioritized clients;

- Minimization of errors in terms of calculus, association of batches and reading once devices communicate with computers;
- Cost reduction associated to non-quality products;
- Speed of processes by automatization.

Source: Coelho, P., (2016), *Towards Industry 4.0.* Repositório científico da UC.

Aleluia – Cerâmica, Comércio e Indústria, S.A.

Aleluia Cerâmicas acts in the portuguese ceramic industry. This company is a leader in idealizing, producing, and selling ceramic products such as ceramic floors, porcelains, traditional mosaics and manual painting. Its 430 employees along with more than one hundred distributors enable to export 70% of production to the five continents. After one hundred years in the market this is a technological advanced company.

Transformation: digitalization of factory floor

Aleluia Cerâmicas implemented a project in one of its production lines designated by Vodafone Smart Factory. This solution included data collection in factory floor and supply of industrial indicators of performance aiming to support the industrial management. It required investments in equipment to data collection in factory floor, configuration of platforms and workforce training to use implemented systems.

Vodafone Smart Factory offers high security levels of information, communication between machinery using mobile data, autonomous data collection in the production line and cloud systems. This solution is modular and adapted to the client necessities.

Aleluia Cerâmicas contracted the following functionalities: consumption management (electrical energy, water, and others), link machinery to internet, measures of industrial performance and machinery maintenance.

Previously, most of these processes were in control of employees and recorded manually in paper. The results were differences between stocks and reports, difficulty to measure the efficiency of processes and delays in sharing information. So, the smart factory solution was designed to overcome these issues.

Results:

- More quality information regarding consumption and production;
- Better decision-making based in real-time information;
- Facility to identify the source of problems;

- Real-time indicators of efficiency;
- More complete, efficient, and rigorous control over operations.

Source: Medeiros, A., (2020), *Processo de adoção de tecnologias da indústria 4.0 numa empresa de manufatura: estudo de caso*. Repositório da Universidade de Lisboa.

3 Methodology

3.1 Research design

Given the nature and purpose of this research it was adopted was the case study research method from Robert K. Yin. This is a qualitative approach that seeks to explore and understand complex real-world events within its contemporary context (Yin, 2009).

Due to numerous distinctive situations in real world investigators find more relevant variables than data. Often it is difficult to separate phenomenon and context, so this method relies on multiple sources of evidence that must converge through triangulation methods (Yin, 2009).

This method must be used based on three conditions that consists in the nature of the question, the control that the investigator has over behavioral events and the focus on contemporary events. Which means the most adequate when "how" or "why" questions are being posed, the investigator has little control over events and focus on contemporary events over historical ones (Yin, 2009).

Industry 4.0 as a quite recent field, the case study method enables to provide rich data on contemporary challenges based on the study of the phenomenon (Muller, 2019). So, the author intends to establish a relationship between certain conditions in which it is believed that will lead to a result in a logical mode.

This kind of research has, however, been subject to critics. Its concerns remain over the lack of methodological guidelines and rigor. Mainly, in explanatory case studies results may show the researcher bias whenever an event cannot be directly observed, and inferences are made (Yin, 2009). Other issue is the external validity, meaning that conclusions drawn from a particular case may not be generalized to other settings (Willis, 2014).

3.2 Data collection

To elaborate this study an extensive literature review was conducted based on scientific information mostly obtained on Web of Science. This enabled to discover and understand concepts and theories related to Industry 4.0. It also contributed to elucidate the reasons behind the changes that are recently changing industrial production and consumers behavior.

The data needed to build the case study was mainly collected through informal interviews lead by the investigator to several key employees, usually, managers in each department. Questions were, mainly, open nature in order to obtain the most complete information to characterize the company and describe its business model. It was also used a survey interview in form of a maturity model to evaluate the current readiness of the company H departments to welcome the industry 4.0 concepts and technologies and define the capacities that are more urgent to develop within the company.

The following table presents a resume the interviews and characterize the participants. The interview guides are presented in the annexes.

Table 3.1: Interviews' resume

Participant	**Duration (h/m)**	**Main Contribution**	**Position**	**Functions within the company**	**Background**
P1	00h35m	Show company's vision towards Industry 4.0	Administrator	Establish business strategy for the medium and long-term	Mechanical engineer; Worked in an international organization of certification (e.g.: ISO 9001, ISO 14001); Shareholder and administrator for the last 20 years in company H
P2	00h58 01h14m	Obtain current maturity model of company H Description of the	General Manager	Coordinates and supervise all the areas and performs as Commercial manager	Mechanical engineer; Worked in a variety of firms of the electrical energy, automotive industries;

		business model			Within the company has already acted as technical and quality manager
P3	00h19m	Challenges faced by the lack of technology	Technical Manager	Ensures the conception of the products: responsible for design, materials purchasing, production and infrastructure maintenance	Electro mechanic Engineer; Acted as programmer in the molds industry for five years; In the role of Technical manager since 2020

4 Case study

4.1 Company H characterization

In this study, for privacy and confidentiality reasons, the firm analyzed is anonymized and referred as company H. It is a manufacturing SME in the metalworking industry that occupies around 70 employees. It is specialized in the production and sales of metal tanks intended for the storage of liquid fuels, LPG and compressed air. The products are built in one facility and distributed everywhere that enable ground transportation.

H 's *mission* is to provide efficient solutions that meet its clients' needs in the fuel/gas and water segments, providing high-quality products all over the world. The *vision* is to be a pioneer in high-quality innovative technical solutions in order to satisfy the growing needs of clients, through a business model the aim of which is sustainable development of the environment, the organization and its employees.

4.1.1 Company H maturity levels

Maturity models support companies in estimating their current situation regarding an examined field of action within the different dimensions. It is possible to spot weaknesses, strengths, opportunities, and current capacities of each dimension of the company.

In that sense, an interview was made to the General Manager (P2) of the company to understand the company's present maturity regarding industry 4.0 concepts and technologies. The interview and the interpretation of the results replies were based on the guiding questionnaire and scale present in annex 1.

The evaluated principles are the basis of the transformation process. They constitute relevant items to define strategies and actions to be taken towards industry 4.0. It was attributed a mensurable classification to transformation capacities of each dimension by the respondent (P2). The numerical classification of capacities represents the consolidation of practices and processes that increase the general performance of the firm. It enables to plan, implement, and evaluate to the progress to higher maturity levels. Each maturity level (described from 0 to 5, in annex 1) includes requirements to be identified and complete in the respective level.

Dimension´s maturity level and global maturity level results from a simple average of the capacities and dimensions valuation, respectively, rounded up to one decimal place. This metric attribute the same importance to all factors analyzed. So, it provides a general view of weaknesses and strengths of each dimension.

Company H global maturity level: 1,8

The global maturity of the company was established at 1,8. This value was expected to be lower once most dimensions reveal a low presence of industry 4.0 concepts and technologies. However, dimensions such as smart products and services was classified with higher values than expected.

Table 4.1: Organizational strategy, structure, and culture maturity level and inherent capacities

Dimension	**Level**	**Capacities**	**Level**
Organizational strategy, structure, and culture	**1,7**	Analysis of industry 4.0 in company's competitivity	0
		Strategical management to operationalize Industry 4.0	0
		Investment in Industry 4.0 technologies	1
		Innovation and use of technologies	3
		Available resources to implement projects	3
		Focus on clients' benefit	4
		Central coordination for Industry 4.0	1

The "organizational strategy, structure and culture" low maturity level reflect the company's minimal awareness of the new I4.0 concepts and technologies. Top managers do not include related indicators in the firm's strategy. The innovation and technologies currently used are fitted with the current reality of the business. These results show us that the administration consider competitiveness is influenced by other factors than Industry 4.0, for example, the focus on clients' benefits which is one relevant aspect in the existing market circumstances.

Table 4.2: Smart factories and inherent capacities

Dimension	Level	Capacities	Level
Smart Factories	**1,1**	Digital modeling of equipment and installations	1
		Infrastructure and equipment with embed systems	0
		Integration of information, communication, and production systems	2
		Data collection through sensors	0
		Artificial intelligence and autonomous machinery	0
		Reconfigurable layouts	4
		Portable devices usage	1

The “Smart factories” dimension obtained a low grade. The information systems used to gather, and share information are outdated. There are no signs of high technological equipment such as autonomous machinery, artificial intelligence, mobile devices, sensors, etc. “Reconfigurable layouts” present a high score (4) since production is fully customized. These results confirm the irrelevance given to industry 4.0 concepts and technologies.

Table 4.3: Smart processes maturity level and inherent capacities

Dimension	Level	Capacities	Level
Smart Processes	**1,3**	Use of cloud computing	2
		Data protection and assets security	2
		Autonomous processes	0
		Agile information sharing	1
		Digital modelling and simulation of processes	1
		Visual computation and interfaces to support processes	2
		Relevant data available in real time	1

The “*Smart processes*” dimension reveals a low maturity as expected. Without innovative technologies to support production and management all processes are dependent on employees. Data collection and communication systems are industry 4.0 innovations that are not implemented.

Table 4.4: Work teams maturity level and inherent capacities

Dimension	Level	Capacities	Level
Work teams	**2**	Required and existent abilities	0
		Acquisition of new abilities	1
		Teamwork flexibility and autonomy	3
		Creativity and work enrichment	3
		Openness and response to innovation and changes	3

The “*Work teams*” dimension presents an intermediary maturity level. Autonomy, creativity and flexibility are abilities that are already present. Employees have the skills required to work with existent technologies and systems. However, industry 4.0 technologies require a new set of skills which should be developed because the current openess to innovation and motivation given to employees are not sufficient.

Table 4.5: Smart products and services maturity level and inherent capacities

Dimension	Level	Capacities	Level
Smart products and services	**2,7**	Software embed in products	4
		Data analysis during product utilization	4
		Services based on collected data	0
		Project and digital simulation of products	2
		Products and services segmentation	4
		Agile reconfigurable of products	3
		Product integration with other systems	2

The results delivered by the "*Smart products and services*" dimension were not expected. It was higlhy rated considering the circumstances. Lastly, the "Products and services segmentation" dimension reached level "4" since production is fully customized and may integrate cyber-systems. The firm offers high tecnhological products which may incorporate a variety of smart funcionalities (e.g.: configurable sensors).

4.1.2 Company H business model canvas

The Business Model Canvas is a tool that reproduces how the firm creates, delivers, and captures the value. It shows the key elements used by companies to gain competitive advantage in the market. Company H has always adopted a cost focus strategy as its competitive strategy. Which is characterized by serving a specific market segmented with lowest cost possible. Therefore, the following graphic reflects its current business model and how it aims to reach its short/medium-term goals – "… within three years we want to be Iberic leaders as fuel storage producers, and in five years expand to other markets "(P1).

<table>
<tr>
<td rowspan="2">Key resources

Physical and human resources</td>
<td>Key activities

Production (Design, making, delivery)</td>
<td rowspan="2">Value proposition

Close support management and customized products</td>
<td>Customer relationship

Personal assistance</td>
<td rowspan="2">Customer segments

Segmented market</td>
</tr>
<tr>
<td>Key partners

Diverse suppliers, Transports, Installers</td>
<td>Channels
Telecommunication, trade shows (direct), distributors (indirect)</td>
</tr>
<tr>
<td colspan="3">Costs structure

Fixed costs (maintenance, materials and salaries)</td>
<td colspan="2">Revenue streams

Product sale</td>
</tr>
</table>

Figure 4.1 - Company H current business model

Value proposition:

- ✓ The firm offers customized products to every client and a close management of the trade between both parties.

Key activities:

- ✓ Production is the key activity which entails designing, manufacturing, obtaining international certification and delivering the product.

Key partners:

- ✓ The firm is motivated by the optimization of resources and activities. Hence, it works with a variety of outside partners which are selected depending on the quality-price of the service offered. IT and transportations are outsourced services, for example.

- ✓ Recently, company H has signed some joint ventures contracts with gas station installers.

Key resources:

- ✓ To function the firm needs physical resources as manufacturing facilities, buildings, distribution networks, and materials.
- ✓ It also needs human resources with some specific capabilities, because most machinery requires some experience to operate.

Channels:

- ✓ Customers are reached directly by an in-house sales force via telecommunication (email, phone) or in trade shows where often the company participates to raise awareness and present their value to the customers.
- ✓ Also, indirectly through distribution partners that deliver the products.

Customer segments:

- ✓ The company serves a niche market. Clients are different kinds of firms such as private or public constructors, oil companies or fuel distributors.

Customer relationship:

- ✓ The contact between the firm and its customers is based on the human interaction considered a personal assistance. Customer and the firm's representant have a close relation until the final delivery.

Cost structure:

- ✓ The firm cost structure is based on fixed costs because they remain about the same despite the volume of production. These are mainly maintenance costs, raw materials, energy, salaries, quality, and safety certifications.

Revenue streams:

- ✓ The revenue results from a onetime sale, meaning that the customer pays for the product ownership.

The firm revenue is prevenient from selling carbon and stainless-steel industrial vessels. These are customized vessels to store liquids, gases and atmospheric or under-pressure that can be sold with configurable sensors and digital devices that must be configured as the client requires. Their installation may be above or underground depending on its purpose.

Company H is responsible for product design and assembling. To obtain the final product workers use appropriate cutting and welding machines, which are manually operated, to join large steel pieces together. The workstations are distributed within a single factory.

Production process: clients define the product's features; the designer produces a 3D version of the product; in the meantime, the commercial area makes sure to have the raw materials available; the production process is started; the product is tested by quality department which validate if the product can or cannot be delivered to the client.

In terms of technologies, a few computers and cyber-systems are available for manufacturing and information gathering. To support production and management there are some softwares for data collection and processing, such as Supply Chain Management, Computer-Aided Design, Product Data Management, Production Data Acquisition.

Besides the existence of some technologies, data must be introduced manually into the systems or paper sheets. Machinery does not communicate automatically with those systems.

5 Data analysis and discussion

The analysis of this case is presented in this chapter. In order to reach the initial objective of helping the company prepare their process of innovation, it was necessary to clarify its problems, define the requirements for a possible solution and specify the alternatives. Through the analysis of the company's business model, technological maturity and information given by upper-level managers it was possible to take some insights and understand where company H was concerning industry 4.0.

Company H is a SME where industry 4.0 concepts and technologies are barely present. The digitalization of the factory and processes has not started yet. The company does not own adequate IT systems to acquire, process and share information generated through the value chain. The administrator (P1) considered the expensive prices the main barrier to their implementation and scarce technology available. Another challenging aspect for the company's future is the nonexistence of an organizational strategy to lead the digital transformation as there is no planning to promote the implementation of IT resources and inherent capacities. From the non-adoption of new technologies arise several problems which influence the day to day functioning of the company. The most frequent challenges identified by the Technical Manager (P3):

1. Control of stock;
2. Project management in terms of resources allocation such as, time, materials;
3. Information collection through production processes;
4. Product pricing (are approximations based on past information);
5. Information sharing between departments;
6. Real-time decision making, due to lack of information and shared systems;
7. Manually made procedures associated with high time consumption;
8. Highly dependance on human labor.

So, company H is currently being affected by the lack of technological tools to support its daily activities. Its low technological maturity regarding industry 4.0 concepts and technologies are reflected in the business and most likely is affecting its short-term goals.

Plan a strategy

Having in mind the company's current maturity concerning industry 4.0 concepts and technologies and the future level established it is necessary to project how to reduce the gap between both stages (Oztemel and Gursev, 2018).

An intermediate maturity level of three, seems to be an achievable and realistic maturity goal to be attained for the next few years – "*… I do not see the maturity of this company higher than 3 in the next 5 years."* (P2). At this level, companies are characterized by a partial implementation of processes that improve firm's competitiveness (Santos, 2018). These processes must be well defined and described in procedures, methods, and tools. Furthermore, there is use of cyber-physical systems to control the network, such as integrated information systems horizontally and vertically or standardize data interfaces to facilitate information flows between IT systems.

Firstly, it is necessary to consolidate the global maturity level, 2. This level characterizes companies with established processes to monitor and control that products and services are delivered as planned. There are trained people responsible for process performance and product quality. Industry 4.0 concepts and technologies have been designed to make both processes more efficient (Je, 2018). The consolidation of this stage is achieved by acquiring inexistent capacities within the less developed areas. Which in this case there are mainly, three dimensions that require an immediate evolution, organizational strategy, structure and culture, smart factories, and smart processes. Their maturities must be aligned with the higher ones (works teams and products and services), so that any of them compromise the global digital progress.

Digital transformation is not investing in technology, it must be done with a purpose (Machado et al., 2020). Given the features and challenges described before and according to literature review company H should implement an internal and external process optimization approach. This transformation represents an incremental innovation to optimize the current business model and must be the purpose of the company for the next few years. New technologies such as big, data, cloud computing or additive manufacturing are introduced to increase efficiency and improve performance and hence, optimize value creation. Thus, it is a simple way for traditional manufacturers embrace the industry 4.0 without incurring in high risks (Ibarra et al., 2018). This transformation will have most impact in the value creation for owners, customers, and employees. Industry 4.0 concepts and technologies implemented must result in product and resources traceability (leading to more efficient production, logistics, quality control, inventory management and better maintenance), machine to machine communication (enabling internal and external processes connection), skilled employees (allowing knowledge exchange, faster and greater communication), and a more transparent management (due to data-driven decision making).

Implement pilot projects

Company H need to actualize its infrastructure and production equipment. This involves investment in hardware and software to support production and management activities. As it is possible to confirm in the examples of application, a digitalization of production lines for data collection in factory floor solution, including configuration of platforms and providing training to employees, is able to overcome multiple issues also indicated by company H technical manager (P3). The results achieved by *Aleluia Ceramicas* were more quality information regarding consumption and production, better decision-making based in real-time information, more control, efficient and rigorous control of operations. So, a viable solution to company H could be establishing a partnership with IT experts to implement a project customized to its necessities.

This solution must be oriented to produce digital backups of the physical world, enabling to monitor and remotely control some operations, acquire and process data, integrate management systems between departments. Thereby, managers would have access to real-time information to identify problems, facilitate decision-making, and better resources optimization. Not only, the company itself benefit from the digital innovation having more effective and efficient procedures, but also the remaining value chain. Customers will be offered better product conditions and communication channels. Moreover, customer and partner relationships will be more effective.

Thereby, it is evident that the current one is not adequate to new market conditions. The business model must be reformed once there are strategies and new goals to achieve. There are essential aspects that must be present in industry 4.0 business models. All these elements must be aligned for the success of the company (Gaglio, 2020). Consequently, changes in the business model building blocks will result into an innovated business model for the industry 4.0 era.

<table>
<tr>
<td rowspan="2">Key resources

Physical and human resources

Technologies for IoT solutions (sensors, electronic components, management platforms)

Skilled employees</td>
<td>Key activities

Production (Design, making, delivery)

Data analytics,

Energy efficiency management</td>
<td rowspan="2">Value proposition

Close support management and customized products

Process optimization and efficiency improvement

Productivity increases</td>
<td>Customer relationship

Personal assistance

Improved customer relationship (reduce time to market, more accurate information)</td>
<td rowspan="2">Customer segments

Segmented market</td>
</tr>
<tr>
<td>Key partners

Diverse suppliers, Transports, Installers

IT experts

Software/ hardware suppliers</td>
<td>Channels
Telecommunication, trade shows (direct), distributors (indirect)

Data collected internally</td>
</tr>
<tr>
<td colspan="3">Cost structure

Fixed costs (maintenance, materials and salaries)

Implementation and maintenance costs of new technology</td>
<td colspan="2">Revenue streams

Product sale

Reduction of costs related to wastes and inefficiencies</td>
</tr>
</table>

Figure 5.1 - Proposal of company H's new business model

The main alterations between the current and proposal business model of company H are within key resources, key activities, and key partnerships. New technologies, encompassing all electronic components, sensors, portable devices, platforms, required to develop IoT solutions are mandatory resources aside to employees' capabilities to digital transformation of the business. Data analysis is a crucial activity to be specialized in every company that wants to become more digital. The integrated systems only work with information acquired and shared between each other (Mckinsey, 2015). So, it is mandatory to capture, transfer, analyze, synthetize, and turn relevant data into relevant information to give feedback to workers and machines along all departments. A partnership with IT experts in developing, installing and maintain the technology applied are required once internally there are not available resources to achieve that. Beyond these changes there are new costs related to implementation and maintenance of the equipment, and revenue, in form of cost reduction related to wastes and processes optimization. In terms of value proposition, these changes create the most value for the company translated into process optimization, linked to reduced inefficiencies, human errors and time consumption, improved efficiency and productivity and operation simplification. From a better activity functioning supported by technologies, customer will benefit from improved quality products, reduced time-to-market, faster commutation channels.

Concerning the technological maturity, the implementation of the proposed measures and its consolidation within the business structure will guide the company to establish higher maturity levels within its dimensions.

In terms of the organizational strategy, structure and culture dimension, this thesis may be used as its initial analysis of industry 4.0 context and basis for a strategical management to operationalize its digital transformation. To achieve the proposed third maturity level in the future, the top-managers must be receptive and willing to allocate resources for that purpose, encourage for innovative thinking and provide education to its customers and implement and evaluate results of pilot projects in crucial fields, as suggested. Smart factory and smart processes dimension will be provided with the technological conditions that are inexistent today.

Define required capabilities or specialize in data analysis

After a project implementation, results must be analyzed. For unfavorable outcomes, an additional evaluation must be handled to understand the reasons of failure and find which capabilities should be developed. It is also important to recognize if this trend has room to be developed within the company the way it was planned. When the result is positive, the company must spread it to other fields, training employees and acquiring equipment for data analysis.

6 Conclusions

Currently, the competitiveness of manufacturing companies is highly influenced by digitalization of processes and modernization of infrastructures and machinery. These are important factors to gain competitive advantage in all markets.

This study presented how companies may assess their own business models readiness to the integration of industry 4.0 technologies. It was directed to manufacturer SMEs that are characterized by limited resources and traditional business models converging with the literature review. Their main barriers to digital transformation are the scarce technological and financial resources, and lack of a strategic leadership. Usually, SMEs are not focused on research and development activities or software upgrading. Mainly, due to lack of financial resources or information between SMEs and investors (Mittal et al., 2018). Accordingly, company H does not present a planned strategy to increase its technological maturity. Being its resources restrictions and misinformation, the major reasons given by the administrator.

Q1: *How can the manufacturing SME prepare their business model for the digital era?*

This process must be initiated by assessing the technological level of the several dimensions that constitutes a company (strategical plan, employees, factories, processes and products or services). This research is combined by two frameworks that enabled to assess a company's technological maturity and describe the functioning of the business, a maturity model and business model canvas, respectively. From this scrutiny results an overview of the company's issues and potential opportunities regarding industry 4.0.

Knowing the operational inefficiencies, a strategic plan must be designed to develop the inexistent capacities. This process depends on the maturity levels of each dimensions, those that most require an evolution and the nature of the business. Thus, digital transformation must begin where the company is at the moment and literature has plenty of possible strategies.

The innovation of the business models entails changes in building blocks of the business model. Although being all different there are some functions that characterize the majority of modern business models. Its value proposition focusses on waste reduction, process optimization, operational simplification. The significant reduction of costs related to wastes and inefficiencies is considered an additional revenue stream. Key resources are sensors, electronic components, digital devices, and cloud computing.

Within key activities data analysis has major importance, once it provides the information to predictive and prescriptive maintenance, monitoring, and production optimization. They improve customer relationships by reducing time to market, offering new services, personal assistance, consider clients opinions. The most valued partners are manufacturing hardware, software and IoT platforms developers and data managers.

Q2*: How can the manufacturing SME benefit from the use of new technologies?*

Usually, manufacturing SME are highly dependent on human labor, so they mostly benefit from the adoption of new technologies as users. Investing in technologies to support employees is associated to performance increments and resource optimization. The human-machine interaction enables performing a given task faster with minimized errors. As it was witnessed in the examples presented, literature and the reality are harmonized. The implementation of cyber-physical systems in production lines to collect more quality information regarding consumption and production enable better decision-making based on real-time information, cost reduction, higher efficiency and productivity, better allocation of resources, more control over operations and minimization of human errors. Accordingly, those that consider the implementation of industry 4.0 technologies may expect improvements in production processes, management and decision-making, cost reduction and productivity. However, this requires huge initial investments and open-minded managers for changes knowing that benefits are mostly reflected in the long-term.

Given the current situation, it is recommended that company H elaborate a detailed assessment to all departments and understand in which fields the industry 4.0 concepts and technologies would generate the most value. This study can be used as a guide to execute the analysis.

Lately, if top managers decide to lead the company towards digitalization, contract IT consultants aware of the business nature to lead the implementation, evaluation, and guide further actions. This suggestion may be an effective strategy to overcome the lack of technical resources.

Furthermore, from what we have seen in chapter 1, national public organizations are motivated in creating conditions for the industry development in industry 4.0 context.

There are programs to finance SME innovation projects which are good capital sources for low budget firms.

Limitations and future recommendations

The lack of studies developed around this theme within SME difficulted this research. The fact that was not possible to acquire information regarding the metalworking industry's best practices constitutes a limitation of this study. It would be interesting to compare company H results to its competitors current state and utilize some successful ideas from more evolve ones to improve the business. So, a recommendation for future work is to consider benchmarking as a relevant tool to add reliable value.

Another limitation is the fact that was not possible to follow up a project implementation. For further studies, a recommendation is to implement this planned strategy in a company that is willing to transform their business model through processes digitalization. It would enable to verify the validity of this study and prove the impact of new technologies in SME manufacturers.

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Appendix

Appendix A: Participant 1 interview guide

This interview aims to provide a notion of the company's strategy in the medium/ long-term and understand the vision regarding industry 4.0 from who delineates it.

Do you agree with the maturity levels obtained?

If technological evolution does not make part of your strategy. What is the organization strategy?

How do you want to achieve that?

What are the reasons not to invest in industry 4.0 concepts and technologies? Once these are adequate tools to support production and management.

- Production technologies
- Management technologies

Appendix B: Participant 2 interview guide

The capability maturity models support companies in estimating their current situation regarding an examined field of action within the different dimensions.

The evaluation of the firm's maturity level will be based on the research questionnaire proposed by Santos (2018). The respondent answering to every question and the results must be interpreted considering the Industry 4.0 concepts and technologies present in each department and according the following scale:

Level 0 – low or no implementation level

Level 1 – planning or developing preliminary processes

Level 2 – initiation of implementation processes with residual observed benefits

Level 3 – partial implementation of processes that improve firm's competitiveness

Level 4 – advanced implementation of processes with high economic returns

Level 5 – reference in application of Industry 4.0 concepts and technologies

1. Organizational strategy, structure and culture	1.1 Do you continuously analyze Industry 4.0 impacts for the firm's competitiveness in the mid and long-term?	
	1.2 Are Industry 4.0 concepts integrated as some of the main factors of your competitiveness strategies?	
	1.3 Do you have the appropriated indicators to monitor the evolution of Industry 4.0 actions as objectives and realistic goals?	
	1.4 Do you plan to invest what is necessary in the implementation of Industry 4.0 technologies?	
	1.5 Is your organizational structure oriented towards innovation and the incorporation of new technologies?	
	1.6 Does the board of directors and managers have the required resources to carry out transformational actions?	
	1.7 Does client communication allow meaningful gathering of client information?	
	1.8 Do strategic and operational actions focus on the customer's requirements?	
	1.9 Is the information shared across the different parts of the value chain to improve decision-making?	
	1.10 Is there a central coordination of the Industry 4.0 actions that are in place?	
2. Work teams	2.1. Do you have the technical and managerial abilities required in the implementation of Industry 4.0 actions?	
	2.2. Did you determine the technical and managerial abilities related to Industry 4.0 concepts and technologies?	
	2.3. Do the organizational structure and decision approval system allow the team's flexibility and autonomy?	

	2.4. Do you encourage employee creativity and empowerment towards new challenges and the benefits of the digital transformation?	
	2.5.Can you observe employee openness to innovation and continuous education, with a positive response in a changing context?	
3. Smart factories	3.1. Do the installations and production equipment have digital copies that can virtually reproduce the physical world?	
	3.2. Is the information updated and bidirectional between the physical and digital installations?	
	3.3. Do the infrastructures and installations have the systems required for data processing and communication with other systems?	
	3.4. Is there an integration between the information, communication and operational systems that can respond to interoperability requirements?	
	3.5. Do you acquired data from sensors and actuators in an automatic and real-time way?	
	3.6. Does the equipment function with any sort of artificial intelligence that allow continuous improvement, leading to automatic decision-making?	
	3.7. Are the production layouts re-configurable easily when comes the time to respond to the variation in diversification and volume of the individualized products offer?	
	3.8. Do you use smart mobile devices to optimize operations?	
4. Smart processes	4.1. Is your data stored in a Cloud system?	

	4.2. Do you have in place data protection systems (for employees and actives) against identity thefts and for personal data protection?	
	4.3. Do your production processes operate autonomous and are they supported by machine learning systems?	
	4.4. Are the main business processes shared wisely internally and with other business partners?	
	4.5. Are the main business processes digitalized and incorporated into integrated communication and information systems?	
	4.6. Do key processes have digital performance modeling and simulation capabilities?	
	4.7. Are operations supported by visual computing as virtual and augmented reality systems?	
	4.8. Do visual computing resources deliver contextualized information and interfaces to tasks?	
	4.9. Do you use data mining to process big data volumes systematically and in real-time?	
5. Smart products and services	5.1.Do your products contain intelligent systems?	
	5.2. Are the products equipped with artificial intelligence systems that allow auto-optimization of their characteristics and performance?	
	5.3. Do the embedded systems allow communication with the factory enabling the conditions of use?	
	5.4. Do you offer complementary services to your products that derive from data analysis of the client's preferences and the analysis of the conditions of use?	
	5.5. Do the products have a digitalized project version that can be sent to the factory and other agents of the value chain?	

	5.6. Do you possess the resources and softwares to simulate digitally conditions of use and product performance?	
	5.7. Are the products and services targeted and individualized, in order to respond to the customization of demand?	
	5.8. Does the system and the available resources allow the quick reconfiguration of products' characteristics?	
	5.9. Do the embedded systems in the products integrate with other management and operating systems in the company?	

Appendix C: Participant 3 guide interview

The purpose of this interview is understanding the challenges faced daily that could be solutioned through the implementation of new technologies.

What are the main challenges in your subordinated areas?

How is information recorded?

How do you know…?

- Materials expenditure?
- Stock levels?
- Resources inputted in every product?
- Product phase?

Do you have real-time information?

How does it affect your role as manager? Consequences for the company?