NOVA IMS Information Management School

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Industry 4.0 for SME

Gonçalo Rosário de Carvalho

Dissertation

presented as partial requirement for obtaining the master's degree Program in Data Science and Advanced Analytics

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação
Universidade Nova de Lisboa

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INDUSTRY 4.0 FOR SME

by

Gonçalo Rosário de Carvalho

Dissertation presented as partial requirement for obtaining the master's degree in Advanced Analytics, with a Specialization in Business Analytics

Supervisor: Vítor Santos, Phd

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledge the Rules of Conduct and Code of Honor from the NOVA Information Management School.

DEDICATION

I want to start by thanking professor Vitor Santos for the guidance and motivation along this path that started in June 2021.

I also thank and appreciate the experts, Henrique São Mamede, Rui Gonçalves e Tiago Correia, that were interviewed during the phase of validation of the model. Not only for the availability but especially for the commitment and criticism shown during interviews.

Likewise, I would also like to thank KPMG Portugal, the company that I work for, for the support and flexibility given during the process.

Finally, I want to thank my parents not only for their support in the last year but also for the last 23 years of care, guidance and education. I could not have become the person I'm today without you both in my life.

Lastly, I would also like to thank my brother, guide, inspiration, and motivator for all the support, tips, and advice provided, especially when it was not requested, during the last five years that helped me define and achieve meaningful goals for my life.

ABSTRACT

Industry 4.0 has been growing within companies and impacting the economy and society, but this has been a more complex challenge for some types of companies. Due to the costs and complexity associated with Industry 4.0 technologies, small and medium enterprises face difficulties in adopting them.

This thesis proposes to create a model that gives guidance and simplifies how to implement Industry 4.0 in SMEs with a low-cost perspective. It is intended that this model can be used as a blueprint to design and implement an Industry 4.0 project within a manufactory SME.

To create the model, a literature review of the different fields regarding Industry 4.0 were conducted to understand the most suited technologies to leverage within the manufacturing industry and the different use cases where these would be applicable. After the model was built, expert interviews were conducted, and based on the received feedback, the model was tweaked, improved, and validated.

KEYWORDS

Industry 4.0; SMEs; Digital Transformation; Low-Cost;

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LIST OF ABBREVIATIONS AND ACRONYMS

AI- Artificial Intelligence

CPS- Cyber physical systems

DSR- Design Science Research

DT- Digital transformation

Iaas- Infrastructure as a service

IoS- Internet of Services

KPI- Key performance indicator

LR- Literature Review

ML- Machine Learning

Pass- Platform as a service

RPA- Robotic Process Automation

Saas- Software as a service

SLR- Systematic literature review

SME- Small and Medium Enterprises

1. Introduction

1.1. Context

Some economists claim that small and medium enterprises are the backbone of the economy, so it is essential to focus on studies about the growth of those kinds of companies and the influences they could have in creating and studying new techniques and technologies.

Improving the productivity of SMEs is, therefore, a worthwhile endeavor. Indeed, SMEs can spur a country's growth for two reasons. First, integrating proven practices and technologies is faster and safer than testing new ones, and SMEs have a significant adoption gap to close. In the same way, emerging markets can grow faster than high-income markets by adopting tested technologies, and SMEs can grow faster than large companies by adopting the proven technologies and practices of larger enterprises. Second, start-ups, a critical subsegment of SMEs, have become essential sources of innovation. Because they are unhindered by legacy systems and outdated strategies, new market entrants often can rethink established practices and cut through traditional industry boundaries. Halving the global productivity gap between SMEs and large companies would amount to about $15 trillion in corresponding value-added or roughly 7 percent of global GDP. Governments worldwide can and are helping close this gap through different approaches tailored to meet SMEs' most pressing needs (Albaz et al., 2020).

Industry 4.0, also called IoT or smart manufacturing, marries physical production and operations with smart digital technology, machine learning, and big data to create a more holistic and better-connected ecosystem for companies focusing on manufacturing and supply chain management. This makes it easier for companies to collaborate and share data among customers, manufacturers, suppliers, and other parties in the supply chain. It improves productivity and competitiveness, enables the transition to a digital economy, and provides economic growth and sustainability opportunities.

Industry 4.0 is based on a concept that is as striking as it is fascinating: Cyber-Physical Systems (a fusion of the physical and the virtual worlds) (CPS), the Internet of Things (IoT), and the Internet of Services (IoS) will collectively have a disruptive impact on every aspect of manufacturing companies. The fourth industrial revolution, unlike all others, is being predicted, allowing companies to take specific actions before it happens.

Manufacturers can define their target manufacturing model and then plan a transformation roadmap. Despite the significant hype around the topic, people have yet to learn what the exact consequences are for manufacturing operations or when these will happen, although there is a clear notion that the later movers will most likely be forced out of the market (Alamda-Lobo, 2015).

A (Deloitte, 2014) study, which analyzed the position of Swiss companies concerning this new production paradigm, revealed that many companies believe that the digital transformation promoted by Industry 4.0 will increase their competitiveness. Despite this, most still feel unprepared when implementing projects in this area.

In today´s complex and fast pacing environment, businesses must efficiently orchestrate their processes to remain competitive. Industry 4.0 allowed companies to automate all their processes from production to product delivery to their clients. This new way of work opens a new world of opportunities to improve the companies. Unfortunately, not everything is good points, and at this moment implement, this kind of strategy and technology brings a lot of problems and issues.

1.2. Motivation

Companies, from all sizes, are increasingly trying to automate their traditional manufacturing and industrial practices, however this is a rather complex process.

The fear of digital transformation hinders especially smaller companies from growing their business and, consequently, their profits. There are various reasons for fear of this kind of change. One of them is their costs, so creating low-cost IoT solutions and applications that allow smaller companies to adapt those solutions to their business quickly is a good exploration area due to the impact it can bring to these companies.

Limited access to finance, lack of a database, low research and development (R&D) expenditures, undeveloped sales channels, and a low level of financial inclusion are some of the reasons behind the slow adoption of Industry 4.0 of SMEs (Yoshino, 2016).

Similarly, because of their knowledge and exposure to many new technologies, younger generations are increasingly being relied upon to suggest digital solutions to transform their family's business operations or to develop new technology products or service offerings that can accelerate the business into the future (KPMG, 2012).

The adaptation of these technologies and techniques it is not accessible. On the contrary, nowadays, changes and adaptations cost a lot of money to companies that sometimes need help to ask for a loan to invest in that way. Looking for ways to overcome these challenges became the underlaying motivation for this project: to create a model to implement Industry 4.0 to small and medium companies that help them with a small investment create value and allow them to compete with more profitable companies.

Another challenge that companies among their workforce face is the gap in technical skills. Are all employees able to keep up? The need for employees to acquire different or all-new skills to excel in these changing roles (Solutions, 2020), in the article, it is evident that this is a fascinating point that needs to be worked on during this implementation. Nevertheless, the question is, what is the better form to make this improve?

1.3. Objectives

To help mitigate these problems, the research aims to define a model/strategy for implementing an Industry 4.0 approach in SMEs. To achieve this goal, the following intermediate objectives were defined:

- Understand and explain the biggest hindrances to implementing Industry 4.0 in companies.
- Choose a company (Medium or Small) or a general business to analyze.
- Identify the processes that could improve their performance when applying Industry 4.0 solutions.

- Evaluate how those possible changes will affect the company's performance.
- Create a model to apply Industry 4.0 concepts in SMEs specific case.
- Implementation/simulation of the solutions in the previous processes.
- Evaluate the results.
- Identify and propose improvements to the model.

1.4. STUDY RELEVANCE AND IMPORTANCE

If the defined goal is achieved, this project could benefit many companies. The goal is that after the project has been concluded a company that fits in some pre-requisites could easily apply that model. With their information the company should define what kind of improvements can be made and how that improves will affect the company without a high budget.

In the Industry 4.0 environment, producers should better understand the patterns of consumption and, based on that, be able to adjust the product to the specified requirements of the end-users (Miśkiewicz & Wolniak, 2020). A better understanding of these patterns allied in the different departments of a company could quickly improve their productivity and, consequently, their profits.

To finalize, the last goal that this project will bring to society is the demystification of the impossibility of small and medium companies with low financial resources, which will develop with the help of these new technologies. These changes should be well planned and based on facts and experiences about other companies that will bring the possibility to train and test the model, the different application areas, and the different trade-offs between cost, importance, and difficulty of implementation of each solution.

2. Methodology

2.1. Design Science Research Methodology

The methodology used in the project will be the Design Science Research Methodology (DSR). Design science, as the other side of the IS research cycle, creates and evaluates IT artifacts intended to solve identified organizational problems. Such artifacts are represented in a structured form that may vary from software, formal logic, and rigorous mathematics (Hevner et al., 2004). It involves a rigorous process to design artifacts to solve observed problems, to make research contributions, to evaluate the designs, and to communicate the results to appropriate audiences. Such artifacts may include constructs, models, methods, and instantiations (Peffers et al., 2007). The output of design science research is virtual artefacts (software and systems) that alter the real world in beneficial ways. So, the goal is to develop an artifact that will consist of a model to apply Industry 4.0 concepts in any SMEs specific case. In IS, Design Science Research involves the construction of a wide range of socio-technical artifacts such as decision support systems, modeling tools, governance strategies, methods for IS evaluation, and IS change interventions (Gregor & Hevner, 2013).

This methodology has a variety of suggested sequence of steps to present new solutions for observed problems and provide a better understanding of the world. This study will follow five steps:

- Problem Identification
- Objective Definition
- Design & Development
- Evaluation
- Communication

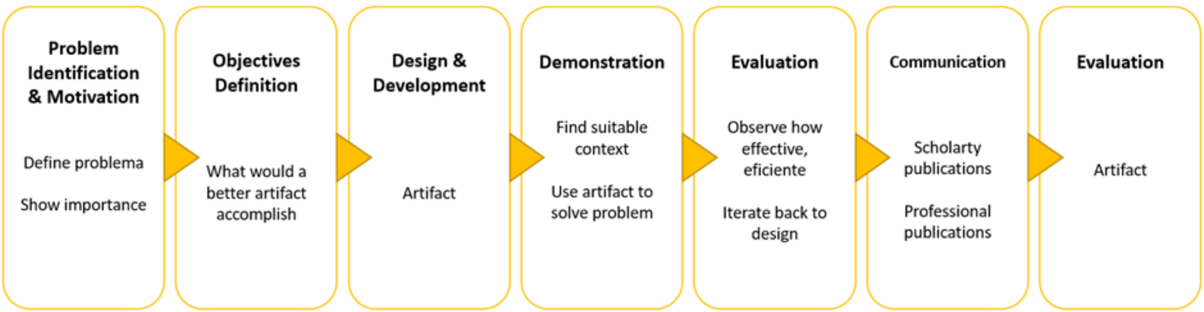

Figure 1- Design Science Research Model. *Adapted from* Design Science Research Model (Peffers 2017)

Therefore, the proposed model will constitute an artifact due to its tangible quality and potential to address this investigation's problem. The chosen methodology will unlock helpful information to the technology world by exposing the utility of the proposed artifact.

Hevner defends that before applying the DSR methodology, an environment study must be done. In this approach, it is crucial to understand the research opportunities and problems, the vision and imagination, and the research questions we want to answer with the study.

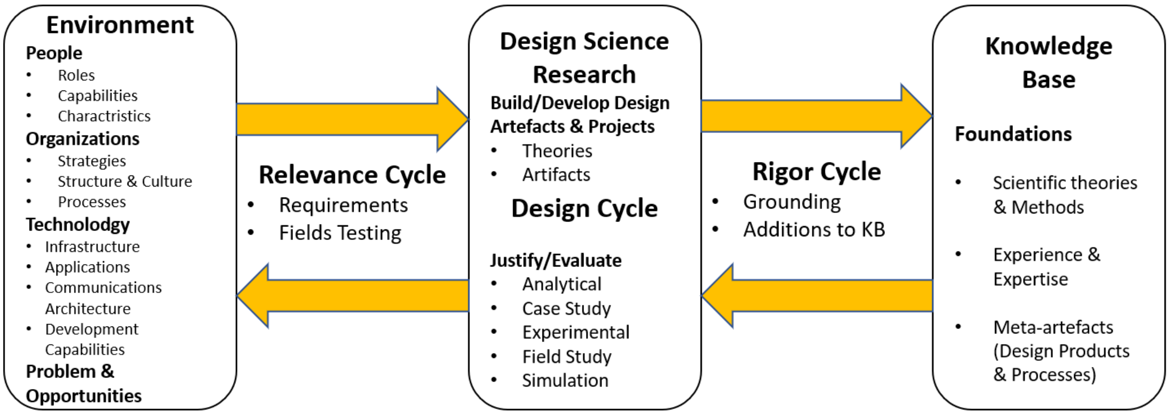

Figure 2- DSR Model Hevner perspective. *Adapted from* DSR Model (Hevner et al., 2004)

The objective of DSR is to develop technology-based solutions to important and relevant business problems (Hevner et al., 2004)

2.2. Research Strategy

In this sub-chapter it will be explained how the DSR will fit in my study and should be done in each step.

2.2.1. Problem Identification

In this step, a literature review will be performed to overview the state of the art of fields such as Industry 4.0, IoT, and the economy of Small and Medium Enterprises (SME). Beyond this, it will be done an overview of what has already been done in this typology of companies related to industry 4.0.

To do so, one researched and investigated the literature on scientific journals, papers, national & international news, and available conferences, as well as other channels that contained information that was considered pertinent for this research.

2.2.2. Objective Definition

In this step, it will be defined what should be expected from the model to help mitigate the problems identified in the first step. This information will be essential to the Design & Development step because here will present the needs of the model.

2.2.3. Understand the Context

Following (Hevner et al., 2004), the environment defines the problem space within which the phenomena of interest exist. Understanding the environment in which the artifact operates is essential in DSR because artifact performance is related to that environment.

So, before delving deep into the scientific background of industry 4.0 and its technologies, it is vital to understand the environment of small and medium enterprises. To achieve that goal will be performed a research to understand how an SME is characterized. How many SMEs do we have in Portugal and Europe, and how they are distributed in the different activities sectors. To finalize the context chapter, try understanding the most significant threats, challenges, and opportunities facing the 21st-century SME.

2.2.4. Understand Scientific background

The knowledge base is comprised of foundations and methodologies. Foundational theories are derived from prior research and result from reference disciplines, frameworks, instruments, constructs, models, methods, and instantiations used in the development/build phase of a DSR study (Cater-Steel et al., 2019).

To gain this prior knowledge, a research will be done to understand what Industry 4.0 is and go deep into all that is part of this industry. Their history, areas, assumptions, and technologies will be explored with possible detail and precision to understand which ones could be used in the future model. Furthermore, it will be performed a systematic literature review on Industry 4.0 & SME using the Prisma methodology.

2.2.5. Design & Development

In this stage, the objective is to develop the artifact. The artifact design looks at how the system should behave and what the system looks like. These two aspects are highly design oriented, and consequently, we have used the design science paradigm in our research (Miah et al., 2014).

How it will work, what kind of data is needed, and what type of expertise is required, these are the principal points that will be analyzed and studied in this sub-chapter because, from a user's perspective, knowledge about the possible functions of an artifact is not provided exclusively by beliefs about its physical characteristics; it is primarily offered by know-how related to its use (Houkes, 2006).

2.2.6. Demonstration

Once a Strategic Model has been defined, it is crucial to demonstrate its use. To this end, a use case will be used to experiment and simulate the value of the artifacts created.

2.2.7. Evaluation

To evaluate and guarantee the relevance of the model and expert analysis will be conducted and will lead to conclusions about the artifacts' effectiveness and an understanding of its limitations, implications, and future work (Peffers et al., 2007).

2.2.8. Communication

The last stage aims at communicating the results of this research and of the appliance of the artefact. To do this a master thesis will be written and will be available to a technical and non-technical audience to understand how effective this solution is and gather more feedback on its performance (Hevner et al., 2004).

3. Small and medium-sized enterprises (SME)

3.1. Characterization

Small and Medium-Sized Enterprises (SMEs) nowadays constitute a significant business sector worldwide, covering a broad spectrum of industries. The number of SMEs far exceeds the number of big organizations. SMEs contribute enormously to the GDP and even more to most countries' employment growth. They usually present entrepreneurial dynamism, flexibility, and higher motivation, while large firms are more robust in economies of scale and scope and financial and technological resources (Steinhäuser et al., 2021).

There are several ways and factors to define companies. In the EU this definition is presented in the EU recommendation 2003/361.

From that many factors for the EU, the main factors to define an enterprise as an SME are staff numbers (the 'staff headcount criterion') remains undoubtedly one of the most important and must be observed as the main criterion and turnover criterion should be combined with that of the balance sheet total, a criterion which reflects the overall wealth of a business, with the possibility of either of these two criteria being exceeded the staff headcount or either turnover or balance sheet total (Commission, 2003).

Following the article 2 of COMMISSION RECOMMENDATION of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises:

1. The category of micro, small and medium-sized enterprises (SMEs) is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million.
2. Within the SME category, a small enterprise is defined as an enterprise which employs fewer than 50 persons and whose annual turnover and/or annual balance sheet total does not exceed EUR 10 million.
3. Within the SME category, a microenterprise is defined as an enterprise which employs fewer than 10 persons and whose annual turnover and/or annual balance sheet total does not exceed EUR 2 million.

3.2. Distribution of corporations by sector of activity

Pordata is a database on Portugal with official and certified statistics about the country and Europe, divided into a wide range of themes such as population, education, and health, among others. This is available to all citizens, it is free, with accurate and unbiased information. All its information comes from official entities, such as the National Institute of Statistics or Eurostat. The total of sources used is now close to 60. All data are presented on an annual basis and, whenever possible, date back to 1960.

To understand how the SMEs are distributed in Portugal and Europe, it was used the Pordata data referent to the 2019 year.

3.2.1. In Portugal

In Portugal, there are 1333649 SMEs, that fit the rule above. From that, the sector with more companies is Wholesale and retail, which represents around 16% of all SMEs in Portugal, followed by Agriculture, animal production, hunting, forestry, and fishing, which represent approximately 10%, respectively, and then Hospitality and catering that represents 9%.

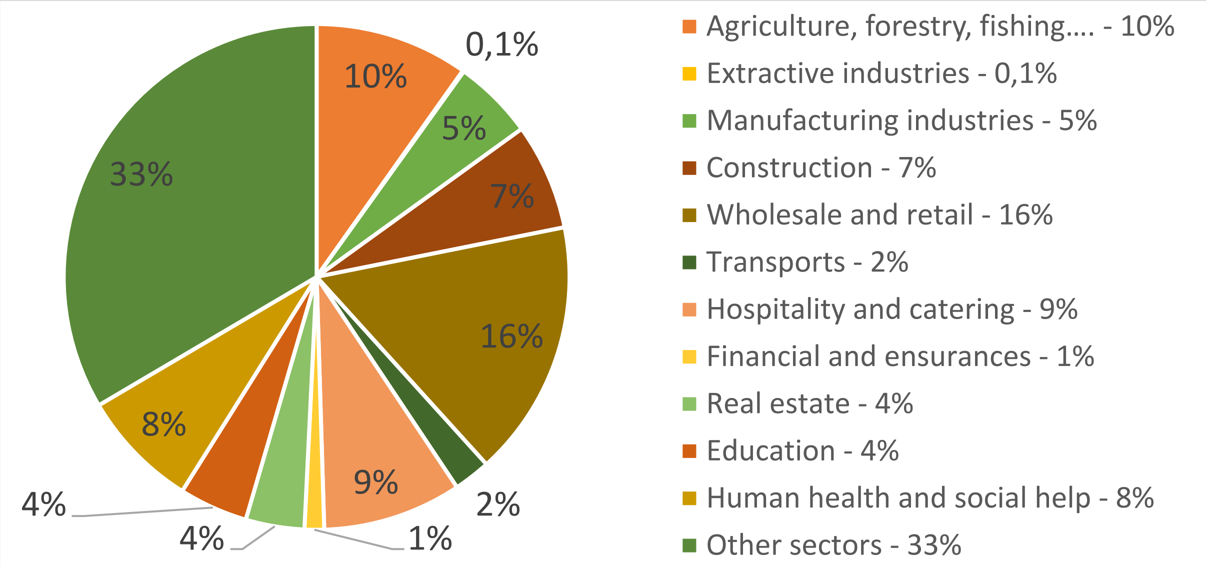

Figure 3-Distribution of Portuguese SMEs by area. *Source:* Pordata, 2019

In the pie chart above it is possible to see the distribution of the 13 business areas. One crucial point is that 33% of the companies enter the field "other companies," which means that companies are not represented in the other 12 areas.

3.2.2. In Europe

In Europe, two-thirds of all new jobs are created by SMEs and more than 99% of all enterprises are SMEs (Commission, 2003) (European Commission, n.d.), that correspond to around 12.5M enterprises divided in eight different categories, these categories are:

- Manufacturing industries,
- Construction,
- Wholesale and retail trade,
- Transport and storage,
- Accommodation and catering,
- Real estate activities,
- Consulting, scientific, and technical activities,
- Administrative and support services activities,

In the chart bellow it is possible to understand that the 3 categories that group more companies are Wholesale and retail trade (25%), Manufacturing industries (21%), and Construction (15%).

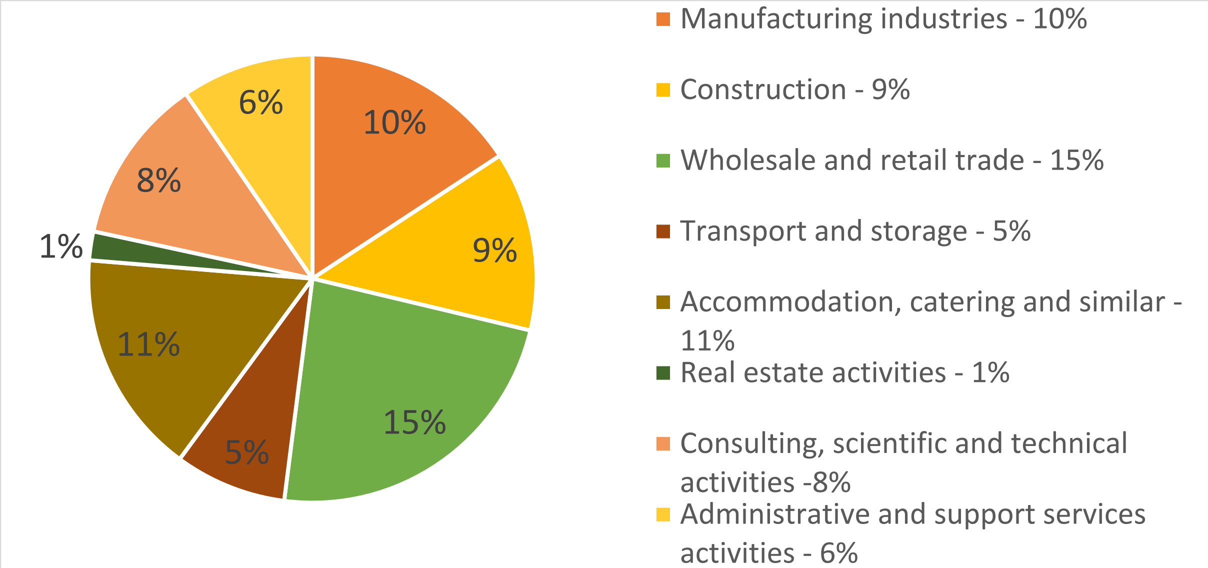

Figure 4- Distribution of European SMEs by area. *Source:* Pordata, 2019

Making a country analysis, it is easy to observe that Germany, Italy, Spain, and France are the countries with more SMEs, with particular attention to Germany, which had almost double SMEs compared to the second country with more SMEs (Italy).

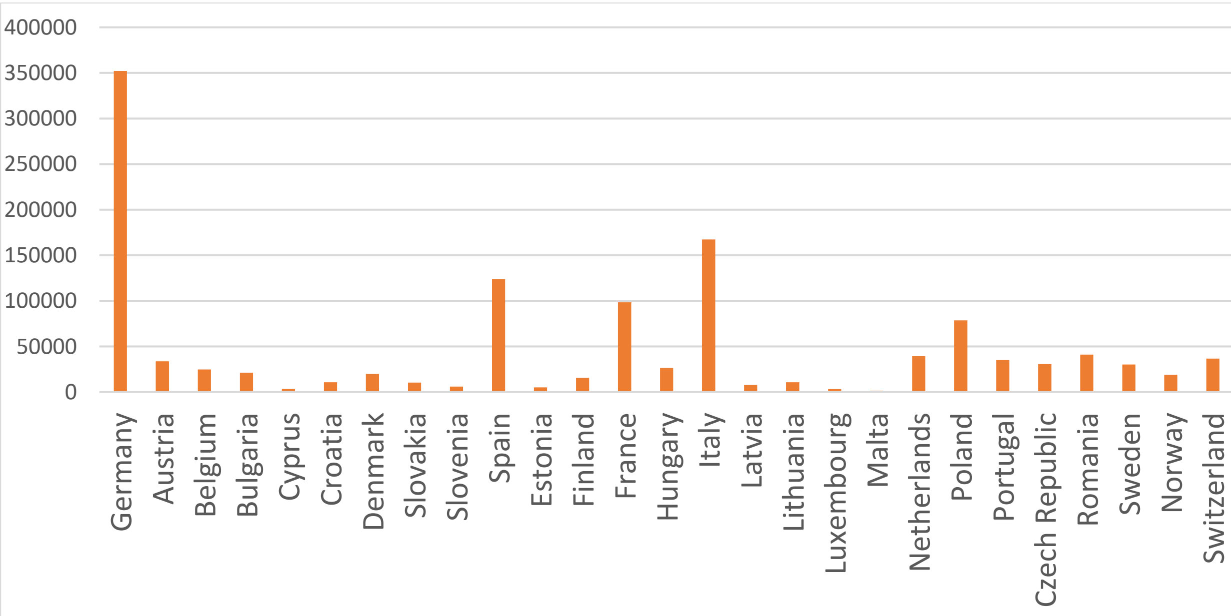

Figure 5- Number of European SMEs per country. *Source:* Pordata, 2019

3.3. The Information Systems role by sector

Before analyzing the role of the IS in the different sectors and companies, it is essential to define what are IS. Over time different authors presented different definitions for various applications, so it is important to choose the ones that best fit this study.

For (Mills, 1977), an information system is a system whose primary purpose is to manage and provide access to a database of information composed of three principal abilities: organization, storing, and structuring the data in a way that could respond to the company's needs.

(Bruegge, 1994) defends that IS are not only IT systems but are social systems. They are developed by people (developers) for people (customers). Social factors determine the success of a software project – technology is secondary. There are many examples of technically inferior systems that work and benefit customers. The inverse is not valid. A system with no benefit (perceived or real) to the customer will be abandoned no matter how technically brilliant it is.

In another perspective (Laudon & Laudon, 2003) define IS as a set of interrelated components that collect, process, store, and distribute information to support the taking of decisions, coordination, control, analysis, and visualization in an organization.

Information systems can be beneficial. Nowadays Information systems can be used in the field of accounting, as this is the primary source of a company's financial information (Barna & Ionescu, 2021).

3.4. TREATS, CHALLENGES AND OPPORTUNITIES

Nowadays, the business environment is very dynamic and constantly changing for that reason, organizations must implement IT systems to help them to carry out their planned activities more easily (Barna & Ionescu, 2021).

SMEs suffer from inherent challenges induced by social, economic, geographical, or cultural grounds or other reasons beyond their control.

SMEs usually present entrepreneurial dynamism, flexibility, and higher motivation, while large firms are more robust in economies of scale, scope, and financial and technological resources.

4. Literature review

This master thesis' section aims to assemble, synthesize, and provide an overview of the themes and concepts that will support the research being performed based on the already existing scientific literature. By combining and assimilating findings and perspectives from many empirical findings, one will address the research question defined and uncover subjects in which more extensive research is required, generating added value to the fields under the scope of this research(Almada-Lobo, 2015).

4.1. History & characterization

The general concept of Industry 4.0 was first introduced by the German government program to introduce a paradigm shift toward a digital future in industrial production and to increase the competitiveness of the manufacturing industry (Bigliardi et al., 2019).

The manufacturing industry changed in the 1970s, and these changes led to the entry of information technology into the industry (Kagermann & Wahlster, 2011), these changes took a long time to be implemented, and the main shift and final stability that led to the formation of the new concept called "Industry 4.0" took place in 2011 (Rad, 2021). Industry 4.0 dictates the end of traditional centralized applications for production control. Its vision of ecosystems of smart factories with intelligent and autonomous shop-floor entities is inherently decentralized. (Almada-Lobo, 2015).

All industrial revolutions have common features that allow defining them as revolutions, not simple evolutional changes in the industry. A generalized model of the Industrial Revolution, which emphasizes its peculiarities, is presented graphically in figure number 6.

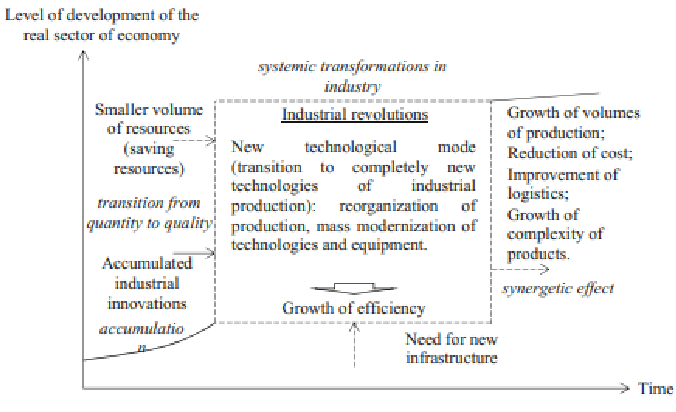

Figure 6- Generalized model of the industrial revolution. *Source:* (Popkova et al., 2019)

The result of the industrial revolution is a transition to a new level of development (new quality of growth) of the real sector of the economy. The essence and critical parameters of the three previous and the Fourth Industrial Revolutions, according to the offered generalized model of the Industrial Revolution, are shown in Table 1 (Popkova et al., 2019).

Table 1- The essence and key parameters of three previous and the Fourth Industrial revolution. *Source:* (Popkova et al., 2019)

Parameters	The industrial revolution			
	First	Second	Third	Fourth
Time frame	18th–early 19th century	Late 19th–early 20th century	Second half of the 20th century	21st century
Accumulated industrial innovations	Production of cast iron, steam engines, and textile industry	Production of high-quality steel, distribution of railroads, electricity, and chemicals	Renewable sources of energy, digital technologies, network organization of business processes	Internet of things, robototronics
Type of technological mode	Industrial production	Conveyor production	Global production on the basis of digital technologies	Fully automatized production
Required new infrastructure	Industrial equipment	Conveyor equipment, railroads	Digital equipment, global infrastructure	High-speed Internet, robotized equipment
Essence of systemic transformations in industry	Formation of industrial production	Formation of conveyor production	Formation of global production on the basis of digital technologies	Formation of fully automatized production
Efficient changes in logistics	Steam transport	Railroad transport	Buildings that generate electric energy, electric, hybrid, and other transport means	Exoskeleton, manipulators, Robototronics
Efficient changes in products	Cast iron products	Steel products	Computer products	New construction materials

Unlike the other industrial revolutions, the 4th industrial revolution is being predicted, therefore allowing companies to take specific actions before it happens (Almada-Lobo, 2015) and avoiding some mistakes in their application.

4.2. AREAS

Industry 4.0 is based on a concept that is as striking as it is fascinating: Cyber-Physical Systems (a fusion of the physical and the virtual worlds) CPS, the Internet of Things, and the Internet of Services will collectively have a disruptive impact on every aspect of manufacturing companies (Almada-Lobo, 2015).

Following (Cochran & Rauch, 2021) there are nine core technologies that are imperative to the Industry 4.0 and they are:

1) Advanced robotics,
2) Additive manufacturing;
3) Virtual and augmented reality;
4) Simulation;
5) Vertical/horizontal data integration;

6) Industrial internet of things;
7) Cloud;
8) Cyber-security;
9) Big data;
10) Data analytics.

4.3. RELATED TECHNOLOGIES

Several techniques are used in this 4th industrial revolution. This sub-chapter will analyze the state of the art of technologies that are used, like Robotic process automation, intelligent process automation, process mining, digital twins, and IoT, among others.

4.3.1. Process Automation

Some of the biggest challenges that SMEs should focus it is cost savings improved productivity, and reduced manual tasks. There is a vast need to automate processes to care for repetitive work. The importance of automation in the process industries has increased dramatically in recent years. In highly industrialized countries, process automation serves to enhance product quality, master the whole range of products, improve process safety and plant availability, and efficiently utilize resources (Jämsä-Jounela, 2007).

4.3.1.1. Robotic Process Automation (RPA)

Nowadays, information management processes have become a burden for many organizations due to repetitive workflows. This is a big job that can't go wrong, and the amount of data is increasing as the organization grows but by human nature, Data entry errors are always possible. And vast amounts of data and time constraints on working cause stress, resulting in more mistakes and less joy at work. As a result, employees work worse or resign, eventually becoming a problem for the organization. Such problems are a problem that many organizations must face often. These problems can be reduced and solved by Robotic Process Automation (RPA) technology (Reungyu & Waiyanet, 2022).

Robotic Process Automation (RPA) is a software or program that helps businesses build robots (Bots) to perform assigned tasks efficiently (Reungyu & Waiyanet, 2022) instead of people by combining Rule Engine, Image Recognition, Machine Learning, and AI to automate work reduce errors more efficient and work 24 hours a day (A, 2018). With this technology, it is possible to automate data entry, transfer, and verification tasks, mainly when they involve multiple applications.

(Waiyanet & Madonkha, 2022) presented the following benedicts for the RPA use:

- Reduce errors in the work caused by humans (Human Error)
- Reduce costs, reduce costs because they can work 24 hours a day.
- Improve work efficiency by increasing Output and reducing Error.
- Makes repetitive tasks no longer boring.

Back-office jobs are typically tedious and repetitive. When assigned to people, they become weary or bored after a while, increasing the chance of error and lengthening processing times. Still, robots do not suffer from these problems. This change of paradigm in a company could lead not only to an increase in productivity but to a nondecreasing of during time. (3) made a study where was compared giving back-office work to robots and people. The study found that using RPA to supplement current teams increased the number of cases serviced by the organization by up to 20%. To exploit this technology, organizations need to identify routines prone to automation (Leno et al., 2020).

4.3.1.2. Intelligence Process Automation

Artificial intelligence disseminates in business dynamically. ICT, e-commerce, marketing, HR, accountants, car industry, smart house – in almost every branch, it can help to gain a competitive advantage based on fast and efficient analysis of vast amounts of data and rapid decision making (Jabłonska & Pólkowski, 2017). Organizations need to handle the huge amount of data available within ICT systems and exchanged on the Internet to operate efficiently (Stalidis et al., 2015).

AI implementations in business require enormous investments, which can be why smaller companies need help using this kind of system.

As customers continue to move online, businesses on all scales are competing to create the most effective online customer experience possible, this create the necessity to answer to these customers the faster as the company can and to do that there were created Chatbots.

A chatbot is defined as artificial intelligence (AI) enabled service agent that conducts “natural” conversations with consumers to provide individual information (Wuenderlich & Paluch, 2017). After some investment, these technologies can save companies a lot of money, time, and resources. There are different characteristics for chatbots, and following (Wuenderlich & Paluch, 2017) the four chatbot features deemed necessary for SMEs: are responsive chatbots, simple actions step to trigger customer action; humanized conversations; and personalized recommendations.

The uses of AI don’t finish with the customers. Still, they continue to all the productivity in a company where we can retrieve a lot of internal data and create value with that data upgrading their internal processes.

4.3.2. Internet of Things (IoT)

The Internet of Things (IoT) consists of many smart devices capable of data collection, storage, processing, and communication. The adoption of the IoT has brought about tremendous innovation opportunities in industries, homes, the environment, and businesses (Diro et al., 2021) . This concept rests on managing processes through connectivity, mobility, and data analysis generated by sensors, bringing the natural world closer to the virtual. In this sense, the IoT is a combination of several technologies, which allows the simple identification of objects and the accomplishment of daily tasks through the intense use of smartphones, laptops, GPS, and networks (Lopes & Moori, 2021).

Nowadays, the goal is to create a world “Smartization” which refers to introducing intelligence to traditional systems to achieve sustainable, efficient, and convenient services. IoT services are instrumental in achieving this goal by working collaboratively to enable intelligent services for the people. Such systems include smart cities, smart homes, and smart health (Bouguettaya et al., 2021). In recent years, data-driven intelligence has revolutionized how enterprises run their business using informed data-driven decision-making or web 2.0 applications that provide a rich human-computer experience to their users (Bouguettaya et al., 2021).

In recent years, data-driven IoT services move the digitization process from the artifacts in the Internet era to "everything" in the IoT world—our cities, hospitals, transport systems, and human beings. The IoT is a key enabling pillar of digitizing "everything" since "things" in the systems have embedded capability to collect data, capturing the systems' holistic view. They are increasingly supplying information about the physical environment (for example, infrastructure, assets, homes, and cars). The advancements of existing computing paradigms such as data science, deep learning, and cloud computing and emerging technologies such as Edge computing, 5G networks, and blockchain create opportunities for innovative IoT services. These different paradigms or technologies have been explored in the context of IoT applications and platforms and are equally crucial for IoT services (Bouguettaya et al., 2021).

4.3.3. Cyber physics

The production process generates massive amounts of data that are generally transmitted to a cloud system and then remotely processed Digitalization and its impact on technological development leads to the shift from classical, mechanics-centered systems to mechatronic systems and on to intelligent, cyber-physical systems (Kobayashi et al., 2021). For (Ungvarsky, 2019) prominent applications of CPS include:

— Industrial control systems (ICS).
— Smart grid.
— Intelligent transportation systems (ITS).
— Aerial systems CPSs have evolved to be complex, heterogeneous, and integrated to provide rich functionalities

CPS's typically consist of five components: The physical space contains physical elements of CPSs, e.g., engines, tanks, and wheels. Actuators receive control commands (denoted as A2) from control systems and change the run Ning parameters of physical devices (A1). Sensors measure the running status of devices ((S1) and report to the control systems (S2). Control systems obtain sensor measurement (S2) and send control commands to actuators(A2), which follow the predefined control logic. We define communication between sensors (actuators) and control systems as level 0 communication (denoted as C0). The content of Co communication traffic is sensor measurement (S2) and control commands (A2) (Ungvarsky, 2019).

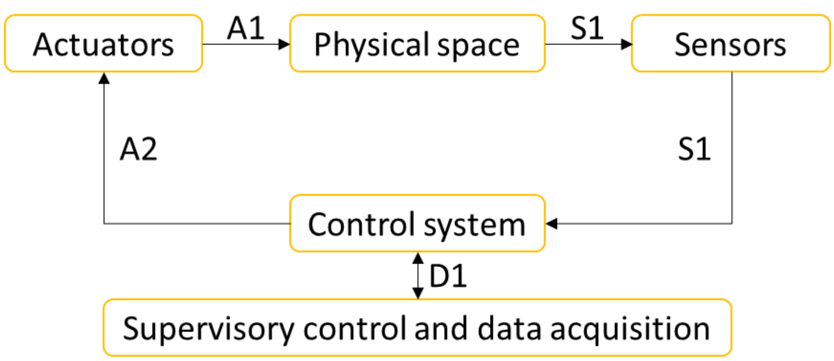

Figure 7- Cyber Phisycal System Example - Adapted from (Ungvarsky, 2019)

4.3.4. Digital Twin

A digital twin is a computerized virtual representation of a physical object, system, or service. It is used to test, monitor, repair, and predict the future behavior of the physical object it duplicates (Yao & Tech, 2021). Digital Twins are part of the vision of Industry 4.0 to represent, control, predict, and optimize the behavior of Cyber-Physical Production Systems (CPPSs) (Bolender et al., 2021). Digital twins can also be connected to a physical object to help technicians collect real-time data generated by the physical object. The concept has existed since the early days of computers but is becoming increasingly important in the twenty-first century as more sophisticated computers are developed as duplicates (Yao & Tech, 2021). The study from (Bolender et al., 2021) confirmed that DT autonomously detects unintended system behavior and produces solutions based on similar cases provided by the case base.

The Digital Twin in the industrial revolution 4.0 is at the forefront, facilitated by advanced data analytics and IoT technology (Bolender et al., 2021). With the development of artificial intelligence, big data, cyber-physical systems, and other technologies, the digital twin has been highly concerned by the academic community and carried out in-depth research (Liu et al., 2021). (Tao, Fei & Qi, Qinglin, 2019) said that the digital twin has great potential to create a new paradigm in the manufacturing industry.

The digital twin application in machining and manufacturing effectively breaks through the bottleneck of product machining quality and accuracy (Liu et al., 2021).

4.3.5. Process Mining

Process Mining is a technique applied to different kinds of companies. That started as a state policy to innovate manufacturing in Germany, Industry 4.0 has become an essential field for both research and practice (Bolender et al., 2021), business process management and business process development utilize Event Logs as the basis for process mining, providing greater visibility into business processes, effective workflow, and corporate data (Montianrat et al., 2020), the company's business processes and the actions taken by its employees are chronologically captured in the event log for analysis (Chiu et al., 2019).

This is a technique that may strive for immediate insights based on streams of events that are continuously generated by diverse information systems in the company (Awad et al., 2020), this provides a new approach to gathering evidence by automatically analyzing the entire population of event logs recorded and enables users to analyze a company's business processes using event logs. Event logs provide an audit trail that captures every user's actions and every business process (Chiu et al., 2019).

Event logs record the execution of a process. Registering a single instance of a function (a.k.a. case) is a trace, a finite sequence of events. An event, in turn, is a manifestation of the execution of activity of the process. An event records essential information about the performance of the activity, such as the case and the time it was executed (Awad et al., 2020).

As seen in table 2 and table 3, event logs can consist of different features describing the context of the events recorded. The minimum required features include a case ID, the description of an activity and a timestamp. The case ID is a unique identifier referring to a single instance, such as a booking number for a flight. The activity describes an action that has been performed, such as check-in or boarding. The timestamp tells the specific time the activity has been performed. Based on this input, process mining generates a process model that reproduces the observed process flows. Note that the above features only represent the minimum information required. More data can be mined, such as the resource with which the process was performed or the cost of the process (Lorenz et al., 2021). This data can be transformed into process performance metrics or key performance indicators (KPIs) (Sitova & Pecerska, 2020). The dynamic discovery of actual process flows in factories enables the identification of capacity constraints, process variability, and waste (Lorenz et al., 2021).

Table 2- Information Stored in Event Logs- Adapted from (Lorenz et al., 2021)

Information Stored in an Event Log	
Information Stored in an Event Log	**Example**
Process instance	A unique purchase order number
Activity	An employee signature on a purchase order
Resources	An employee who performs an activity
Timestamp	The year, month, date, and time of an activity

Table 3 - Sample of an Event Log- Adapted from (Lorenz et al., 2021)

Sample of an Event Log				
	Process Instance	**Activity**	**Resources**	**Timestamp**
Event Log	1	Create purchase order	Peter	2019-02-25 09:12 p.m.

In addition to understanding the information stored in an event log, it is also essential to know the "variant." A variant in process mining is a group of process instances with an identical path (Chiu et al., 2019). In traditional postmortem process mining, the order of events is derived from their timestamps (Awad et al., 2020).

Another advantage of process mining is that after understanding the different variations, the analyst or the algorithm can discover the process deviations and identify factors that negatively affect productivity (Lorenz et al., 2021).

Improving system flow can be achieved by reducing three fundamental roadblocks: (i) bottlenecks, (ii) process variation, and (iii) non-value-adding activities. Existing online algorithms for process mining, whether for discovery, conformance checking, or prediction, assume that an event stream is ordered, i.e., the arrival order corresponds to the event time order (Awad et al., 2020). In contrast to manual process mapping, process mining allows for analyzing process flows dynamically and identifying non-value-adding activities in an automated manner (Montianrat et al., 2020).

Recently, the application scenarios of process mining have been greatly extended. This includes scenarios where streams of event data from diverse information systems are used to provide near-real-time operational insights and decision support (Awad et al., 2020).

4.3.6. Predictive Anomaly Detection Algorithms

To enhance production efficiency and reliability, statistical Artificial Intelligence (AI) technologies such as machine learning and data mining are used to detect and predict potential anomalies within manufacturing processes (Cao et al., 2022).

Anomaly detection plays a significant role in preventive maintenance by detecting machine failures and inefficiencies, and industrial IoT is one of the beneficiaries of anomaly detection tools (Diro et al., 2021) In most scenarios, it is vital to detect anomalies and process them accordingly in real-time (Yu et al., 2022).

Considering the anomalies as the data that deviates from the known standard patterns, most traditional methods focus on detecting such data (Yu et al., 2022). This process is key to determining the exact boundary between normal and abnormal operations (Guo, 2022).

(Egorova, 2022) defends that using Data Mining algorithms, an anomaly detection model can be built directly from data collected during the operation of onboard systems and not based on failure diagnosis methods or human experience.

For (Diro et al., 2021) the development of anomaly detection schemes in the IoT environment is challenging due to 5 factors:

- Scarcity of IoT resources;
- Profiling normal behaviors;
- The dimensionality of data;
- Context information;
- The lack of resilient machine learning models

The detection and timely assessment of abnormalities in the operation of the industrial ecosystem allows the detection of incidents and the corresponding identification of correlations and causal relationships with security incidents (Guo, 2022).

Most existing industrial anomaly detection methods first collect sensor data from single or multi-source time series, then the collected sensor data are compared with all known anomalous patterns (Yu et al., 2022) The availability of data and the determination of the type of deviant behavior should also be specified before the model development (Guo, 2022).

For (Egorova, 2022) an anomaly detection algorithm should have the following properties:

- Identify the state xt as normal or abnormal before receiving a subsequent xt+1;
- Continuously learn without the requirement to store the entire stream ;
- Work in automatic mode without a teacher (no data labels or manual parameter settings) ;
- Adapt to a dynamic environment as the data flow is non-stationary;
- Minimize false positives (be insensitive to outliers) and false omissions (errors of the second kind, when an anomaly is accepted as a norm) ;
- Detect anomalies as early as possible for the fastest possible forecasting.

To select the appropriate anomaly detection technique, several factors must be weighed. The most important is the nature of the data produced, i.e., binary, continuous in time, or discrete values and their relationship (Guo, 2022), the algorithm must consider too the current and the previous states to decide whether the system behavior is abnormal, as well as perform any data updates and model adjustments (Egorova, 2022).

There are different techniques and different results from different case studies, in the following paragraphs it will be resumed some results obtained from the LR in different experiences.

(Burggrafa et al., 2021) compares the of different types of algorithms: Multilayer Perceptrons (MLPs), Support Vector Machines (SVM), as well as Decision Trees and identified which one was more suitable for industrial applications, on the task of quality prediction. They predicted with 98% certainty the product quality by implementing a Decision Tree model with a 6-variables vector as input. However, our decision for industrial applications would be the MLP with 88% accuracy, to guarantee that all passed parts are OK and avoid labeling NOK pieces as OK.

(Egorova, 2022) start constructing of an algorithm using the Hierarchical Temporal Memory to use in analyzing of telemetric information received from sensors of the on-board measurement system is considered. Deep neural networks being the advanced machine learning algorithms are used to detect anomalies more often because of dynamically developing technologies in the field of artificial intelligence. Deep learning is a complex of broad family of machine

learning methods based on imitation of operative human brain to process the data. Deep learning algorithms are highly effective in different recognition systems such as machine vision and diagnostics. The hierarchical temporal memory algorithm (HTM) learns from changeable input data, this technology is based on the recognition of a large set of temporal, spatial and spatio-temporal patterns and their sequences.

(Guo, 2022) presented an hybrid system of deep machine learning architecture that was used to predict anomalies in the operation of industrial equipment. The Bayesian online changepoint detection algorithm was used to detect anomalies, in fata from an industrial plant that performs cold rolling on metals. The time-domain features extraction process for feature extraction, and the long-short term memory neural network to predict the values of the magnitudes that reflect the correct or not the operation of the equipment.

(Han et al., 2021) resort to the fact that system logs record notable events to use that logs to detecting anomaly as fast as possible to improve the quality of service significantly. Log-based Anomaly Detection Framework usually contains four parts: Log collection, Log parsing, Feature extraction, Anomaly detection. In modern systems, logs are generated in real time and should be collected in a centralized place under log collection component Then Log parsing component converts the unstructured messages into a map of structured event templates. After this, Feature extraction component forms the feature matrix. At last, Anomaly detection component checks whether a given feature vector is an anomaly or not. The advances presented by the authors for this type of solutions are that it doesn't require specific parameter training phase, it can adapt to system fluctuation, its performance doesn't rely on specific algorithms and plenty of learning methods (e.g., SVM, KNN, DT) fit the framework. Fourthly, it uses feedback of IT operators to adjust parameters rather than the labels of training data sets.

To conclude this sub-chapter of LR it's is important to mention that, building effective and efficient anomaly detection modules is a challenging task as machine learning has the following drawbacks:

- First, machine learning models, specifically with classical algorithms, are shallow to extract features that can truly represent underlying data to discriminate anomaly events from normal ones.
- Second, running machine learning models can consume extensive resources, making it challenging to deploy such models on resource-constrained devices.
- Third, it requires massive data for training machine learning models to archive high accuracy an anomaly detection. Therefore, machine learning models may not capture all of the cyber-attacks or suspicious events due to training data. This means that machine learning suffers from both false positives and false negatives in some circumstances.

4.4. SYSTEMATIC LITERATURE REVIEW ON INDUSTRY 4.0 & SME

4.4.1. Method

The previous overview of concepts defined the scope of this investigation and specified suitable keywords for the scientific matter request.

Hence, a systematic review was performed to understand the most recent developments in Industry 4.0 regarding SMEs literature, applications, and technologies. For that, the Systematic Literature

Review (SLR) approach is used to explore the main goal of the research. This method helps to filter out contradictory or similar findings on a specific topic from many sources. The process of the SLR consists of several steps.

Research questions were formulated to conduct this process:

- **RQ 1:** What are the most relevant Industry 4.0 applications for SMEs?
- **RQ 2:** What technologies from Industry 4.0 are currently being used in SMEs?
- **RQ 3:** What technologies could be recommended to a apply Industry 4.0 in SMEs?

Answering these questions required a selection of the most relevant studies. Therefore, keywords were carefully chosen, aiming to revise the available literature and proceed to a responsible selection of articles.

Terms such as "Industry 4.0" and "4th Industrial Revolution" were treated as synonyms, as well as "Industry 4.0" and "4th Industrial Revolution. Even though concepts such as IoT and RPA (Robot process automation) were explored in the overview stage, they were not included as keywords, given their diversified nature and the risk of widen the scope of this study.

Boolean queries were designed to include, at least, one of the above expressions in the abstracts, titles, or keywords of the searched articles. This condition guaranteed the collection of relevant data related to our domain. Only scientific documents were considered before November 10th, 2020, and between 2016 and 2021, attempting to cover the latest developments in the Industry 4.0 field.

The query string was prepared as followed: ("SMEs" OR "Small and medium enterprises") AND ("Cyber-Physics") AND ("Digital Twins) AND ("Process Automation") AND ("Process Mining") AND ("Low-Cost").

After text the query it was obvious that this query was too much restrictive because most part of the articles don't include all the subjects in the query, for that reason the query was changed to a simple one: "("SMEs" OR "Small and medium enterprises") AND "Industry 4.0" AND "Low-Cost" The resources considered to this research are reflected in Table 3. Given Scopus and Web of Science to be general databases, a technical resource such as IEEE Xplore was selected to give a more specific contribution.

Table 4 - Systematic Reviews' Resources and Domains

Resources	Domain
Scopus	https://www.scopus.com/
IEEE	https://www.ieee.org/
Web of Science	https://www.webofknowledge.com/

Aiming to select the most relevant articles for this study, inclusion and exclusion criteria were defined as mentioned in Table 5.

Table 5 - Systematic Reviews’ Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Evidence of Industry 4.0 technologies and applications to SMEs	Publications before 2016
	Language different than English
	Articles that review/overview
	Non-Academic Papers (e.g., magazine’s reports, newspapers)
	Articles’s abstracts that are clear outside the scope

Some articles were removed by attending the exclusion criteria and by being duplicated or unable to be accessed. The remained articles’ abstracts were analyzed and removed if not relevant to this study. Even though it is essential to understand the risks behind technological developments, the authors agreed to combine efforts among the most used Industry 4.0 technologies and not necessarily its drawbacks.

The final step is analyzing the remaining articles, which should be the most relevant to this study.

Only three information resources were accessed to revise the essential information in Industry 4.0 literature, whereas only English articles were selected. Therefore, despite the extensive and careful search, some articles may not have been analyzed given the application of such filters.

4.4.2. Results

The previous section announced the tools that will be used in further analysis and selection, based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method (Moher et al., 2009).

The initial search on the three mentioned databases retrieved 425 articles (Identification Phase). This step and others were organized into a flowchart (Figure 8).

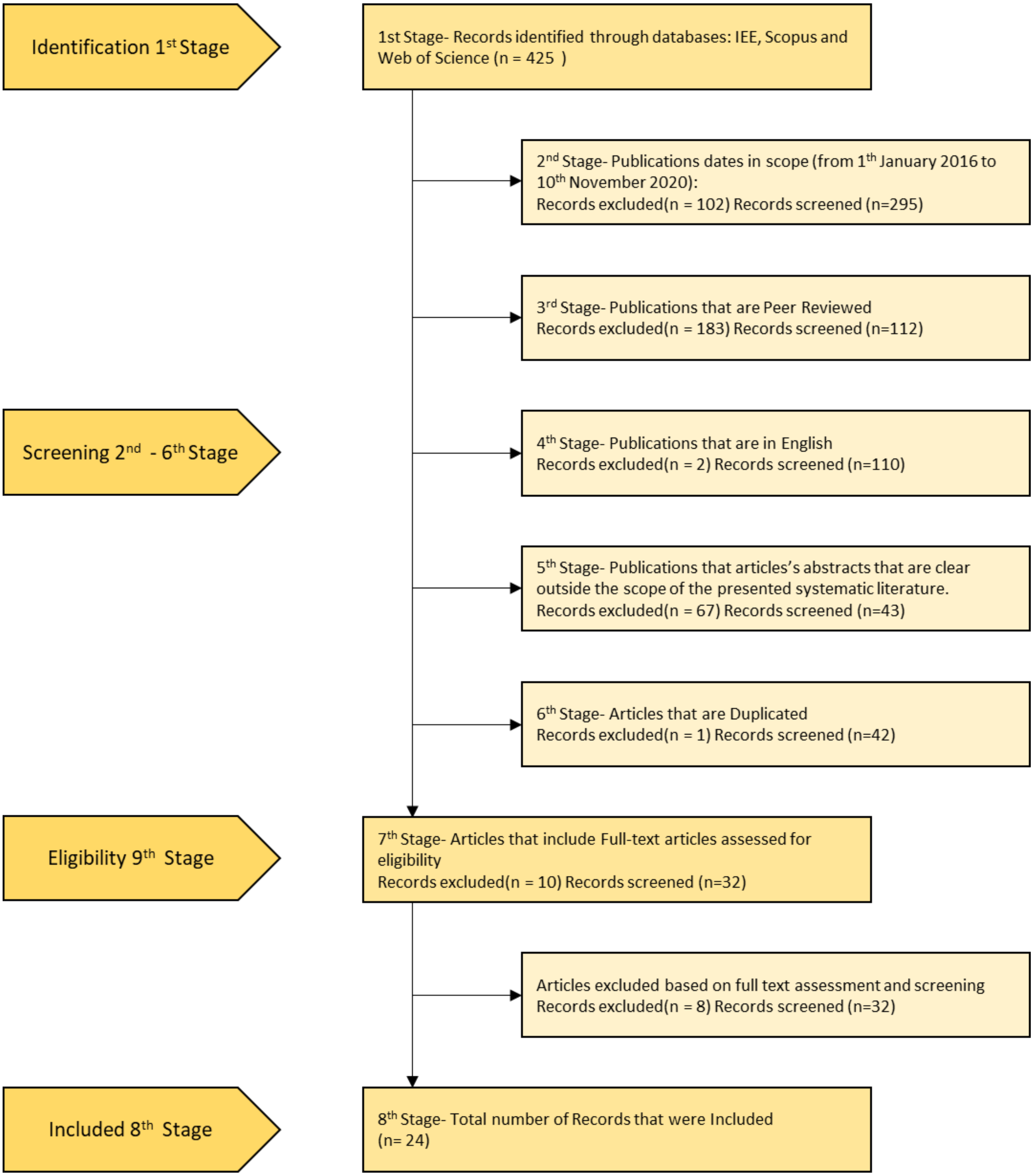

Figure 8- Prisma Flowchart

After the removal the articles that are out of date scope in Step 1 (n=102), that are not Peer Reviewed in Step 2 (n=183), and that are not in English in Step 3 (n=2), the remained articles (n=110) were analyzed. Hence, in Step 5, a total of 45 articles were excluded by their non-relevant abstracts.

A total of 42 full-text articles were eligible to be assessed for this investigation. However, some were excluded after discovering that the text was not in open access, 10 articles were excluded.

Hence, this method retrieved 32 articles to be included in this study. After a carefully analyzing each article 8 articles were excluded because they were much specific for some areas and did not have value for this study.

After analyzing all articles, Table 6 was created to synthesize the main themes and technologies in the article. In table 7 there is a count of the number of articles that talk about each theme /technology.

Table 6- Themes addressed in each article

Article	Industry 4.0: Defenition	Lacks of studies	A catalogue of digital solution areas for SME	Big Data	Use of IOT/Sensors	Emplyees/staff	Difficulties	Digital Twins	Cloud	Digital transformation	Smart Manufacturing Industry/smart factory concept	BPM	Data colection, analisys and vizualization
olution areas for prioritising the needs of		X	X										X
Supply Chain 4.0 in manufacturing organisations of developing				X									X
ctors of IoT Adoption for Sustainability in Supply Chain Management					X	X							X
Digital Twins for Small and Medium-Sized Enterprises					X		X	X	X				X
-Layer Smart Factory Architecture with Special Focus on eering Education						X							X
gical-Oriented Definition Based on Bibliometric Analysis and	X												
and Environmental Sustainability: A Review and Research Agenda	X	X		X	X					X			X
es usage: motives and enablers						X	X						X
on for Reading Digital Measurement and Inputting Condition turing Industry					X				X		X		X
implementation of Industry 4.0 methods: Toolbox, Assessment and nces for Industry 4.0											X		X
ory for SMEs: Concept, Application					X	X			X		X		X
X, DISRUPTIVE, BUT INEVITABLE				X	X		X	X	X				X
nart factories: using science mapping to understand the strategic es and future trends				X	X	X			X	X	X	X	X
artin Pech			X		X			X	X				X
yun Jung , In-Gyu Choi and Sung-Hoon Ahn			X	X	X			X	X		X		X
eng Ting , Yo-Ming Chen , Don-Lin Yang , Hsi-Min Chen and Josh Jia-					X				X				X
IARKO DJAPAN, PETAR TODOROVIC, MILAN ERIĆ, MILADIN I MACUZIC			X		X								
ara, Satish T.S. Bukkapatnam & Fugee Tsung					X								
nio Giovannini , Pasquale Merlac , Michela Chimienti and Hervé			X		X	X							
nd Tamer Eren						X	X						
								X	X	X	X		X
krishna and Sunpreet Singh					X				X	X	X		X
l A. Sebastián and Cristina González-Gaya		X	X		X				X				X
andarup Mukherjee, Duncan McFarlane, Yedige Tlegenov, Ajith K. yner and Alan Thorne			X	X	X		X		X	X	X		X

Table 7 - Number of article per Theme/Tecnolodgie

Themes/Tecnolodgies	Number of articles
Industry 4.0: Defenition	2
Lacks of studies	3
A catalogue of digital solution areas for SME	7
Big Data	6
Use of IOT/Sensors	16
Emplyees/staff	7
Difficulties	5
Digital Twins	5
Cloud	12
Digital transformation	5
Smart Manufacturing Industry/Smart factory concept	8
BPM	1
Data colection, analisys and vizualization	19

From the retrieved articles, it is possible to conclude that businesses are rapidly growing to integrate Industry 4.0 concepts (Sevinç et al., 2018) and they are integrating that proactively instead of reactively (Cater et al., 2021). Several authors have identified a gap in digitalization research in small and medium-sized manufacturing enterprises (SMEs). Most studies and developments focus on larger companies, disregarding SME-specific digitalization challenges such as knowledge, resource, and technology-awareness limitations (Schonfug et al., 2021). A recent study by (Orzes et al., 2019) identified 37 SME specific challenges in the 6 categories:

— Economic/Financial
— Cultural
— Competence/Resource
— Legal
— Technical
— Implementation process

The adoption behavior of SMEs is slightly different compared to enterprises with more opportunities and resources (Sevinç et al., 2018). Digital transformation can provide a competitive edge for many manufacturers. Many smaller companies may be unable to embrace this opportunity and may be left behind c. Understanding the contribution of the Industry 4.0 transition to competitiveness and the production of financial solutions will make it easier for company officials to make positive decisions (Sevinç et al., 2018). A key element to supporting digital adoption in SMEs is to identify the areas of the operations mons in need of solutions. A solution in this context is a system that facilitates a (current or new) activity in a company (Schonfug et al., 2021).

For (Hawkridge et al., 2021), a simple and first approach to I40, one option is to use applications where system visibility can improve operator decision-making. Second, the cost of typical monitoring systems cannot be justified for important yet inexpensive assets. Third, for the quick deployment of proof-of-concept, prototype systems when the return on investment is yet to be determined. There is a potential fourth application in the form of temporary installations. Some practical examples of this include:

- Machine utilization monitoring –help identify operational or capacity issues that are leading to bottlenecks.
- Monitoring key process variables –improve process visibility and facilitate continuous improvement.
- Monitoring environmental conditions – humidity, temperature, vibration, emissions and/or noise which can influence quality, have an environmental impact, and/or affect working conditions. Energy and/or material usage monitoring – to better attribute or estimate direct costs for parts or products.

After presenting these 3 steps, he said that for a low-cost monitoring system to be helpful to a manufacturer, it needs to solve practical issues that they experience during day-to-day operations.

The simplest models include, at a minimum, a single Data Collection Service Module, and a User Interface Service Module. In this primary case, the system acquires data and presents it live to a user (Hawkridge et al., 2021).

To an easy development effort and integration issues, it is necessary to leverage the large communities surrounding many low-cost platforms and the wealth of libraries and tutorials they provide. Furthermore, new entrants to the workforce are increasingly more likely to have skills such as basic electronics, software configuration, and programming required for integrating some of the essential technologies covered in this section. This trend is primarily attributed to the modern school curriculum, which provides self-explanatory and almost pre-packaged technical solutions that can be easily installed or replicated and customized for a specific task. These digital transformations in production will create a real-time, dynamic, self-organizing infrastructure. This infrastructure allows enterprises to analyze customer expectations and reach their targets (Sevinç et al., 2018).

(Schonfug et al., 2021) propose to increase the accessibility of digital solutions to SMEs by providing a catalog of critical operational challenges that SMEs can address through technology adoption. In line with the definition of digital manufacturing, these challenges should relate to production processes and all business processes in a manufacturing company. The majority of solution areas are in Data Capture and Visualization (37 %) and Data Analysis and Decision (42%). This could reflect that many SME manufacturers are still in the early stages of digitalization (Pech and Vrochta, 2020).

To finalize (Cater et al., 2021) says that companies' intentions to use I40 technologies are significantly influenced by the expected increase in efficiency and competitive advantage and not by external normative pressures from suppliers or customers or even by mimetic pressures from competitors.

When we talk about industry 4.0, there is an exact match to IoT. Many authors and studies refer to the importance of the use of this technology and, even more specifically, when we talk about a low-budget way to introduce industry 4.0 to companies. (Pimsakul et al., 2021) refers that the incorporation of information and communication technologies resulting from IoT adoption has made production systems and supply chain processes more intelligent and sustainable (Pimsakul et al., 2021). The Internet of Things (IoT), also known as the Industrial Internet of Things (IoT), is considered one of the crucial pillars of Industry 4.0. IoT also represents one of the most disruptive technologies. It can be defined as a network of hardware, software, devices, databases, objects, sensors, and systems, all working at the service of supply chain partners (Pimsakul et al., 2021). Since the I4.0 principles are about automation and M2M (machine-to-machine) interaction, the knowledge formalization framework should be able to represent the sensor's capabilities and take action on the machine's actuators (Dassisti et al., 2019).

As the production and manufacturing processes have evolved and become increasingly digital, the concept of a DT, which is a virtual representation of the as-designed, as-planned, as-built, and as-maintained physical product, is critical to support product development (Yasin et al., 2021).

Achieving sustainable business opportunities requires a balance of economic, environmental, and social performance. Sustainable supply chain in IoT adoption should be addressed in an integrated approach from its three perspectives: economic benefits, environmental conditions, and social needs, also known as the triple bottom line (TBL) of sustainability (Pimsakul et al., 2021).

One of the first steps that (Yasin et al., 2021) should be taken is to determine what data were to be collected based on their relevance to the productivity or the goal of the complete system. The aggregating data from different sensors, different sources, and of different types can easily lead to errors in DT modeling, PLM, and real-world decision-making. As such, it was paramount to understand the parameter being measured and the format this data would take to avoid these errors. The approach taken by this article and the author was to utilize various software with a preference for low-cost, low-code, and open-source options where possible. This has been accomplished using OPC UA protocol, 3DExperience, Modelica, Nodered and MySQL.

(Pimsakul et al., 2021) made an extensive literature review where he identifies the major key contributors in I4.0/IoT Adoption, I4.0/IoT Adoption and Sustainability, I4.0/IoT Adoption and Enabling Factors, and I4.0/IoT Adoption and Enabling Factors and Sustainability that keys are presented in table 8.

Table 8 - Major Key contributors to I4.0/Iot adoption- Adapted from (Pimsakul et al., 2021)

Study Focuses	**Key Contributions**
I4.0/IoT Adoption	— IoT definition and taxonomies. — IoT platform and IoT evolution. — IoT applications and key enabling technologies. — IoT adoption in manufacturing organizations and various supply chain processes such as warehouse and inventory management. — IoT applications in retail, healthcare, and agricultural industries.
I4.0/IoT Adoption and Sustainability	— I4.0 and IoT adoption and the impact or improvement in economic, social, and environmental sustainability.

I4.0/IoT Adoption and Enabling Factors	— IoT adoption and its critical success factors, enabling factors, or critical barriers. — IoT adoption and its potential benefits and challenges.
I4.0/IoT Adoption and Enabling Factors and Sustainability	— Enabling factors of IoT adoption for sustainability in supply chain management.

All the enabling factors of IoT adoption were validated as relevant and essential for the successful adoption of sustainability in supply chain management. Most interviewees ranked system integration and IoT infrastructure as the essential enabling factors among the five selected factors. Observations from the interviews also confirm that IoT adoption significantly supports three dimensions of supply chain sustainability: economic, environmental, and social. Based on technological perspectives (i.e., system integration and IoT infrastructure), IoT systems can mainly provide efficient real-time data analysis, better communication, and a faster and more accurate decision-making capability. Further economic and environmental sustainability developments obtained from IoT adoption include strategic operating and maintenance plans and recycling material utilization (Pimsakul et al., 2021).

Table 9 shows another perspective from (Yang et al., 2019) with a list of major IoT platforms and their characteristics. IoT platforms provide the software infrastructure to enable physical "Things" and cyber-world applications to communicate and integrate. Examples of popular platforms include GE Predix, ThingWorx, IBM Watson, Azure, C3 IoT, and AWS. These industrial platforms include a variety of architectural mechanisms, including cloud computing, embedded systems, augmented reality integration, data management, software applications, machine learning, and analytical services (Yang et al., 2019).

Table 9- Major IoT platforms and their characteristics - Adapted from (Yang et al., 2019)

Platform	Features
Predix	Supports over 60 regulatory frameworks worldwide Pivotal Cloud Foundry Enable industrial-scale Analytics for Asset Performance Management Cloud platform to build apps for industry
ThingWorx	IoT Analytics Augmented Reality Integration Machine-to-Machine remote monitoring and service Machine learning and tradeoff Analytics: helps the us
Watson IoT	— Machine learning and tradeoff Analytics: helps the users to make decisions — Visual recognition, Rasberry Pi support — Real-Time Insights - Contextualize and analyze real-time IoT data
Azure IOT	— Easily integrate Azure IoT Suite with your systems and applications, including — Salesforce, SAP, Oracle Database, and Microsoft Dynamics — Services: computing, mobile services, data management, and Messaging — Enables devices to analyze untapped data automatically

AWS Iot	— An IoT platform for enterprise application development — Supports HTTP, WebSockets, and MQTT — Rules Engine can route messages to AWS endpoints — Create a virtual model of each device
Google IoT Cloud	— Cloud-based platform — Modular services: computing, app, query, cloud functions, cloud database — Use Google's core infrastructure — Committed to open source
Machineshop	— Middleware — Provides a rich set of different level services — Easy integration using industry-standard RESTful APIs — Edge computing platform
Cisco IoT Cloud	— Platform as a service (PaaS) — REST APIs for send and get data streams — Better for tiny IoT prototypes or M2M applications — Access to 3rd party APIs
Oracle Cloud	— Pre-integrated: Oracle SaaS Auto-Association & Auto-Discovery — Rich Connectivity: Cloud & On-premise connectors — Recommendations: Built-in recommendation engine for guidance — Error Detection & Repair: Alters & Guided Error Handling

The following figure shows trend comparisons of popularity levels of "cloud manufacturing", "industrial internet of things", and "cyber-physical systems" from 07/01/2011 to 08/01/2017. The popularity score represents search interest relative to the highest point on the chart for the given time in the world. Figure 9 shows Google trend comparisons of the popularity levels of "cloud manufacturing", "industrial internet of things", and "cyber-physical systems" from 07/01/2011 to 08/01/2017 (Yang et al., 2019).

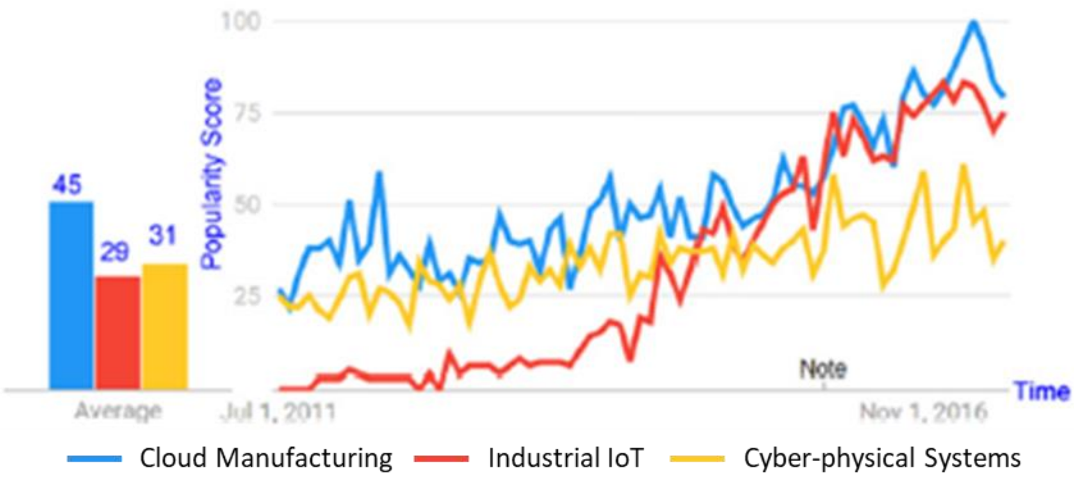

Figure 9 - Trend comparisons of search interest to "Cloud Manufacturing", "Industrail Iot" and "Cyber-physical systems" – Adapted from (Yang et al., 2019).

The study done by (Cater et al., 2021) reveals the importance of employees' competencies as an enabler of I4 technology usage, which implies that a complementary investment in training is needed to enable employees to work with new technologies and fully utilize their potential. Without considering the experience and preferences of involved employees on the shop floor, a well-planned digitalization solution is likely to fail. Including respective workers in developing user interfaces at the earliest possible stage helps to successfully implement and sustain the change in the working environment (Ralph et al., 2021). (Liebrecht et al., 2021) argues that losing employees and their know-how unplanned is a several challenge especially for smaller companies.

One crucial step in the roadmap presented by (Liebrecht et al., 2021) is the implementation of basic methods such as the "Digital skill matrix" or the "Development of competence profiles," which enable a competence "based employee-allocation." As industry 4.0 significantly changes employees' work environment, the method "Education and Training" "is also one of the first steps in the roadmap and serves as a relevant basis for the following industry 4.0 implementation.

(Pimsakul et al., 2021) made a set of interviews to investigate the enabling factors of IoT adoption from a sustainability perspective in industry 4.0. The investigation ensures that IoT systems require technological knowledge, workforce skills, and investment costs. He referred that technologies are constantly improving and quickly evolving. The managerial implications for company management are as follows: Needs to reinvent HR function, training program curriculum, and university-industry or industry–industry collaboration.

Closely linking products and machines increases efficiency, reduces costs, and saves resources. Intelligent surveillance and transparent procedures provide businesses with a constant overview of the business process, which enables them to respond quickly and with the flexibility to changes in the market (Cater et al., 2021).

Another perspective from (Sevinç et al., 2018) says that a firm's transition to automation processes reduces the dependence on people, cost, and efficiency. However, it can be seen in the literature that it is an undesirable process for enterprises to use electronic environments and operations in these environments.

(Narwane et al., 2021) try to explore how big data can be relevant to the supply chain, he defends that big data provides analytics tools for decision-making and business intelligence and that supply chain 4.0 and big data are necessary for organizations to handle volatile, dynamic, and global value networks. In their study (Feroz et al., 2021) Identified that big data, furthermore, can play a crucial role in understanding the opportunities and challenges associated with climate change by measuring carbon emissions and employing techniques to reduce the footprint on the environment. This can be very important in the major companies that are always trying to be more sustainable because that sustainability can be an essential factor in profit improvement.

According to SAS (2013), the number of organizations that use BDA is relatively low. This stresses the need to study BDA adoption and its impact on firm performance. (Narwane et al., 2021) suggest an 11 factors framework of organizational and top management, sustainable procurement and sourcing, environmental, information and product delivery, operational, technical, knowledge, and collaborative planning have a significant effect on big data adoption. The proposed framework considers 11 factors: Organizational and top management support performance (OTMSP)

— Information and product delivery performance (IPDP)
— Sustainable procurement and sourcing performance (SPSP)
— Collaborative planning performance (CPP)
— Sustainable manufacturing performance (SMP)
— Closed-loop supply-chain performance (CLSCP)-
— Operational performance (OP)
— Technical and knowledge capability (TKC)
— Environmental performance (EP)
— Supply Chain 4.0 business performance (SBP)
— Big data analytics (BDA)

The results of the hypotheses formulated before and after a statistical and ANN (Artificial Network network) analysis reveal eight factors that positively influence BDA adoption. At the same time, we obtained confirmation that BDA has a meditation effect on Supply Chain 4.0 performances. These factors are: Organizational and top management support performance (OTMSP), information and product delivery performance (IPDP), sustainable procurement and sourcing performance (SPSP), collaborative planning performance (CPP), operational performance (OP), technical and knowledge capability (TKC), and environmental performance (EP) positively influence big data analytics (BDA). In addition, BDA positively influences Supply Chain 4.0 business performance (SBP). However, two of the hypotheses, sustainable manufacturing performance (SMP) and closed-loop supply-chain performance (CLSCP), do not positively influence BDA (Narwane et al., 2021).

The different authors described several difficulties in the adoption of industry 4.0 by the SME, one of the main difficulties, and the origin of this master thesis is the high costs. (Yasin et al., 2021) said that the high cost of investment based on technology and the neglect of its return prevent firms from being convinced. The availability of finance impacts this relationship oppositely. From a different perspective (Cater et al., 2021) argues that the relationship between intentions to use and actual use is strengthened in companies with lower finance availability. However, this relationship is not significant after a certain point (high availability of finance), this relationship is not significant This means that companies with enough financial resources do not see finance as a critical enabler of their actual use of I4 technologies. Understanding the contribution of the Industry 4.0 transition to competitiveness and the production of financial solutions will make it easier for company officials to make positive decisions (Sevinç et al., 2018). Another point presented in the literature was the constrain of developing low-cost monitoring solutions. That can be explained by the limited performance of inexpensive hardware and software, poor robustness of non-industrial components, potential integration issues with existing systems, and increased development effort (Hawkridge et al., 2021).

Another area for improvement in this adoption is the shareholders' mindset. The companies still need help to integrate information technologies, the internet of objects, in short, the concept of Industry 4.0. Even if the business owners realize the importance of the study's results, they ignore this awareness and continue their traditional processes. The transition of a firm to automation processes reduces the dependence on people and reduces the cost and increases efficiency. However, it can be seen in the literature that it is an undesirable process for enterprises to use electronic environments and operations in these environments (Yasin et al., 2021).

Based on the study of the literature review carried out, namely the characterization, distribution, threats, challenges, and opportunities of SMEs and then the history, characterization, and different areas and related technologies of Industry 4.0, a reference model for the use of industry 4.0 techniques and technologies in SMEs is presented.

5. A model proposal for application of Industry 4.0 in SMEs in a low-cost way

How can a small or medium enterprise with a low budget and resources use/apply industry 4.0 concepts and technologies to increase productivity, quality, and, consequently, its business revenues? The literature review outcomes shown in the previous section lead to the construction of the following artifact. This artifact aims to be a helper to the problem presented in the previous paragraph.

Figure 10 represents the principal components of the artifact.

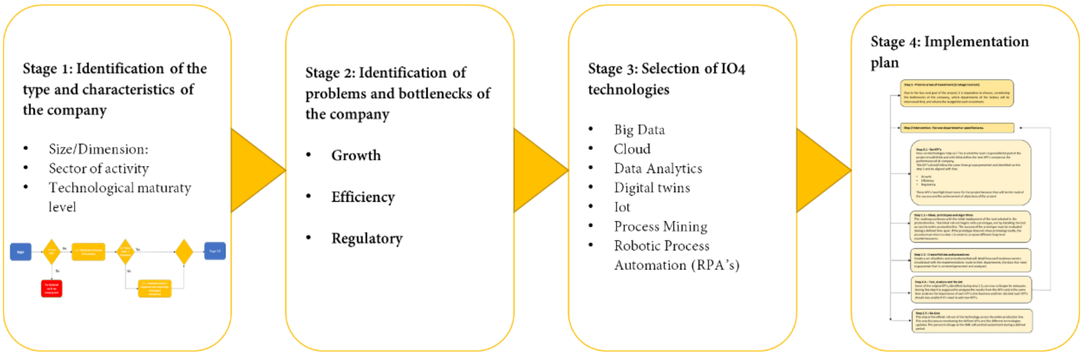

Figure 10- Model overview

The process proposed in the artifact it is composed of four stages. Each stage will provide steps and guidance to help the company implement Industry 4.0 from the planning until the execution. The four stages are:

- Stage 1: Identification of the type and characteristics of the company.
- Stage 2: Identification of problems and bottlenecks of the company
- Stage 3: Selection of IO4 technologies
- Stage 4: Implementation plan.

5.1.1. Stage 1: Identification of the type and characteristics of the company

In this stage, the objective is to follow the path represented in the process flowchart below and have a clear notion of the company in question that can apply this model and the unique characteristics that must be considered during the application.

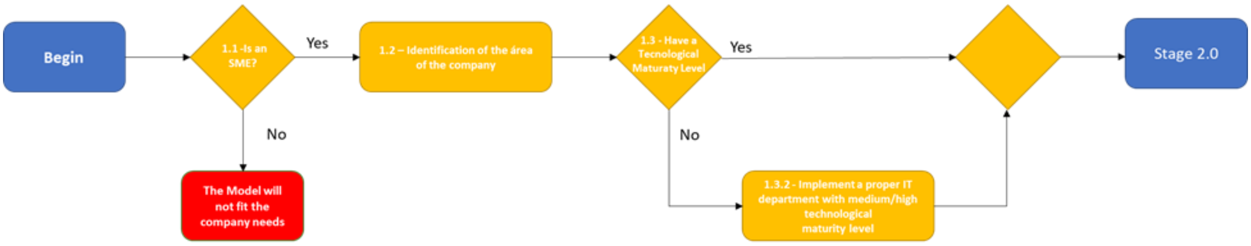

Figure 11- Step1 overview

In step 1.1, the responsible for the model implementation should collect some information about the company as the number of employers, the annual turnover, and the balance sheet. Inside the SMEs, there are three categories of companies: micro-sized enterprises, small-sized enterprises, and medium-sized enterprises, the following table presents the differences between them. If the previously collected information does not fit in any of the options, the company in question is not an SME, so the model in question will not be a good option, although it can be used.

Table 10- SMEs reference values.

	Micro sized enterprises	Small sized enterprises	Medium sized enterprises
Number of employers	Less 10	Between 10 and 50	Between 50 and 250
Min. Annual Turnover	-	2M€	10M€
Max. Annual Turnover	2M€	10M	50M€
Min. Balance sheet	-	2M€	10M€
Max. Balance sheet	2M€	10M€	43M€

Industry 4.0 technologies are much connected to an industrial environment, so it is crucial to understand if there is an opportunity in the company to apply this set of concepts. The existence of a factory environment can materialize this opportunity.

In step 1.3 the responsible should, using table 10, identify the technological maturity level of the company and, with that questionnaire, understand if the company is ready or not for this kind of innovation.

Table 11 was constructed based on (Mehedintu & Soava, 2022) framework. That framework consists of a 16-questions questionnaire, of which only eight question groups were used because those 8 questions are the ones that evaluate the digital resilience of the companies.

Table 11- Questionnaire to evaluate the companies maturity level. Adapted from (Mehedintu & Soava, 2022)

	Group	Options	Answer (Yes/No)
1	Security investments	The company ensures Internet of Things security	
		The company uses solutions application security	
		The company ensures network security	
		The company uses solutions cloud security	
2	Cloud migration	The company uses software as a service (SaaS)	
		The company uses platform as a service (PaaS)	
		The company uses infrastructure as a service (IaaS)	
		The company uses a hybrid model	
3	Digital transformation investments	The company uses tools for interaction through the website, e-commerce, and m-commerce	
		The company uses mobile applications in business processes—Apps	
		The company uses social networks in the digital transformation of business—Social media	
		The company uses conversational interfaces—Chatbots	

4	Digital adaptation	The company implements IT projects to support vulnerable processes discovered in times of crisis	
		The co pany develops IT projects in support of the new operational requirements generated by the implementation of technology 4.0/pandemic crisis	
5	Digital acceleration	The company develops IT projects that model business innovation	
		The company develops IT projects to increase market share	
6	Digital core	The company adopts industry 4.0 technologies in the automation process	
		Has the company achieved digitizing the business	
		The digitalization of business has led to its globalization	
7	Digital innovation	The company introduces digital products	
		The company uses customer touch points and gives enhanced sales pitches	
8	Digital resilience	The company has established a strategy for developing the digital business model	
		The company has improved customer experience: customer journeys, channels, and touchpoints	
		The company uses platforms and infrastructure for digital processing of the data and information	

The objective of this questionnaire is not a "pass" or "not pass" output. It is expected that the project responsible, and the company board in general, are aware about:

- The point where company is;
- If the company should start their investment in IO 4.0;
- What kind of implementations should be implemented in the company (Ex: Security systems, Cloud services, staff training…);
- the final goal that the company could achieve with a correct implementation.

After the evaluation of the previous points, the company should be ready to jump to the stage 2.

5.1.2. Stage 2: Identification of problems and bottlenecks of the company

After the company's characterization and before choosing the technologies that will help to conduct this new paradigm in the company, it is crucial to understand the bottlenecks that are being faced and will be overtaken by the project.

To facilitate the structuring of thought, three sub-categories were created to catalog the company's bottlenecks.

- Growth- Every problems/goals that led to an improvement in the invoicing as the number of sales, cash flow…
- Efficiency- Every problems/goals that represent cost and that could to their reduction and improvements as, electricity consumption, time to produce an item…
- Regulatory- Nowadays, more and more regulatory obligations exist and must be reported, so there are many challenges related to their compliance and reporting.

This makes it necessary for each company to create a team composed of the Digital Transformation project owner and people from the different departments to identify the principal bottlenecks hindering the overall efficiency of the company. The search for bottlenecks consists of evaluating Key

Performance Indicators (KPIs) defined by this team throughout different production departments. This evaluation will answer the following questions: "Why do we need to act?" and "Where are we now?".

The goal is for the project owner to use these KPIs during the implementation process to understand better the company and what should be modified and improved using I4.0.

5.1.3. Stage 3: Selection of IO4 technologies

In this stage, the goal is, after identifying the problems and bottlenecks of the company, to choose the best technologies that can be applied based on the area of work and the bottlenecks of the SME.

The Literature Review identified some technologies/concepts that should be applied in an SME independently of their area. In this stage, the technologies will be connected to the areas where they could bring value to SMEs.

The following tool will help the responsible for the project to decide which technologies should apply to the business due to the area of the company.

Before introducing the tool, the technologies that will be allocated to each business area will be presented as some examples of their use.

- **Big Data:**
  Big data provides analytics tools for decision-making, and business intelligence is necessary for organizations to handle volatile, dynamic, and global value networks. The utilization of these technologies will open the door to the application of simple data analytics and the option to use advanced analytics.
- **Cloud**
  The implementation of cloud services is increasingly essential to all types and sizes of companies. This allows the companies to have different services as information storage, deploying applications, create data pipelines, security services… everything in same place with the advantage of choosing what the client need now without a previous investment. The company pay for what they use this can decrease the significantly investments costs.
  Cloud Services low-cost solution suggestions:
  - Google Cloud Platform
  - Azure
  - Amazon Web Services
- **Data Analytics**
  The possibility of creating value from the company data it is something more common every day, from simple analysis to advanced analytics. There are many opportunities to improve the way of work of a company when they start to use data analytics.
  There are a lot of different software to work with data analytics. However, usually, these software are associated with the Cloud service that the company chooses. Despite that, the suggestion is to use open-source software and programming languages such as Python or R to enable the data analysts to extract insights from the data.
  It is possible to use data analytics for a lot of different purposes. The following paragraphs will present a set of different uses of data analytics in different types of SMEs.

- **Predictive Algorithms:** The use of predictive algorithms, commonly known as ML and AI algorithms, will help to predict events in the company. These algorithms could solve the different needs of a company. The best route for a vehicle for a delivery vehicle, the "ideal" number of products that should be produced due to the customer needs, anomalies predictions, creation of chatbots that will enable 24/7 online customer support, prediction booking cancelations… The capability of this kind of prediction will help the companies to be more efficient and profitable and to deliver a better service to their customers.
- **Anomalies detection Algorithms**: Anomaly detection is increasingly important to enhance reliability and resiliency in the Industry 4.0 framework. Automatic systems for anomaly detection can give relevant advantages to manufacturing companies by reducing their downtime due to machine breakdowns and by detecting a failure before this results in a catastrophic event, and this is enabled without the need for resorting to the work of expensive human experts in the field, usually these algorithms. Popular methods for anomaly detection could include charts or machine learning algorithms like deep learning methods autoencoders, support vector machines, and convolutional and recurrent neural networks.
- **Set KPI's:** The use of data analytics will able the setting of KPIs, these KPIs will help to measure progress over time and whether they are on track to reach their goals, they will provide information about performance levels about meeting strategic targets. Nowadays, almost every data analytics has the function of setting and tracking the KPIs in all company.

The application of data analytics in the different departments will be a cycle because the insights extracted from each department will affect the other departments' decisions.

- **Digital twin**

  Digital twins enable companies to represent, control, predict, and optimize the behavior of Cyber-Physical Production Systems.

  Connected with IoT and data analytics systems has a great potential to create a new paradigm in the manufacturing industry by decreasing the time to solve problems in production. There are a lot of different companies that sell Digital Twin solutions. Following (Gartner Peer Insights, 2022b) that are top 3 solutions for SMEs:
  - IBM Process Mining
  - General Electric Company
  - Celonis Execution Management System
- **Internet of things (IOT)**

  Iot enables companies to manage processes through connectivity, mobility, and data analysis generated by sensors. Like the other technologies, they are stronger together.

  Every business and process has different needs; for that reason, the model will not suggest any specific sensor or software because they can vary depending on the business area.
- **Robot Process Automation**

  RPA will allow the companies, using specific software, to create "bots" to perform repetitive tasks efficiently, that previous were performed by people, this will lead to the reduction of the quantity of errors, a more efficient task performance, and work 24 hours a day.

  Like the other Industry 4.0 technologies can reduces costs, saves resources and improve efficiency.

  There are a lot of different companies that sell RPA solutions. Following (Gartner Peer Insights, 2022a) that are best three solutions for SMEs:

— UiPath Platform
— Automation 360
— Blue Prism Intelligent Automation Platform…

It is vital that the choice of software and hardware providers is made thoughtfully and considers the various technologies used and the connection between them.

The tool presented below will facilitate the responsible for the project to choose the company's area and understand the technologies more valuable to that kind of business. This means that it can be used in different technologies associated with other business areas.

5.1.4. Stage 4: Implementation plan

The final step of the model is the starting point of the development of the digital revolution of the company. It will be at this stage that will define how to apply the chosen technologies (Step 3) to the identified weaknesses (step 2), considering the specifics of the company (Step 1).

To facilitate this step, a To-do list was created to guide in the implementation phase.

This will consist of steps to follow and apply in their own company. It is optional to strictly follow the order of the list, in the same occasions, it will be essential to throw back to a step to change the exact details related to another step.

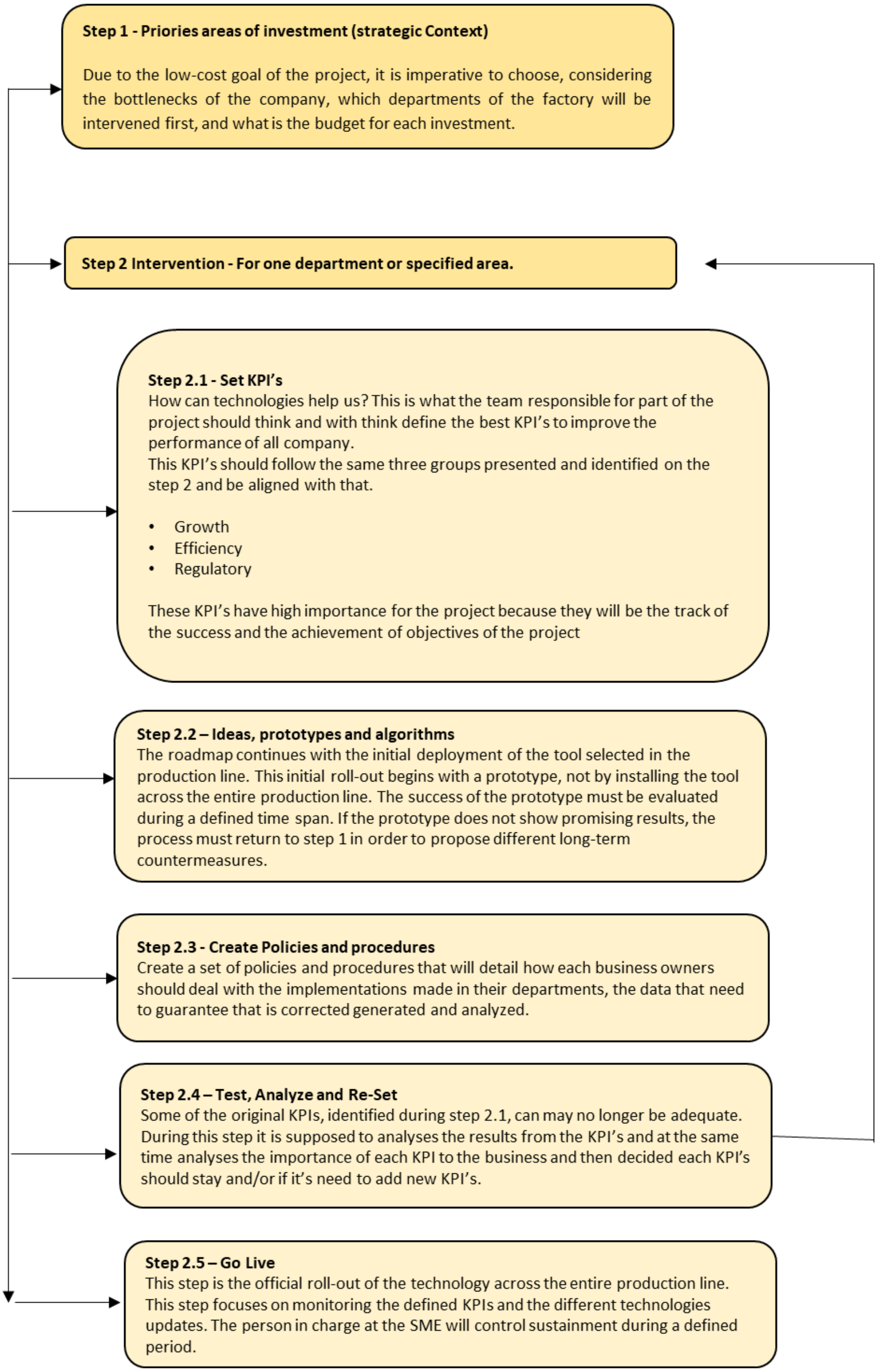

Figure 12- Stage 4: Implementation plan overview

In short, access to Industry 4.0 technologies must be simplified for SMEs. Therefore, the proposed roadmap shown in Figure 12 aims to facilitate decision-making and access to Industry 4.0 technologies in SMEs.

5.2. USE CASE

An essential step in the DSR methodology is a demonstration of the proposed artifacts, in this case, this thesis and in, specifically the, Chapter 4.6 of the same.

The demonstration is carried out through the model's fictional example (instantiation). Each step is documented, and the results are explained to understand the model's applicability. This exemplary use case shows how the model should be applied and how it works.

5.2.1. Company Context

Company: ViniVini Cooperativa vitivinícola.

Business: Wine Producer

ViniVini is a medium enterprise that focus focuses on the production and sale of wine. They have their vineyards, a small factory producing and bottling wine, a warehouse, and a small store.

After a good sales year, the CEO and owner of ViniVini Cooperativa vitivinícola want to improve the profits and technological level of the company. To implement that mission, the CEO chose a responsible from the company's IT department to develop and implement a plan. That will implement Industry 4.0 technologies and concepts in the company. It was defined as a yearly budget to create a team to help develop and maintain the project. To develop this plan, the project owner used the model presented before.

The following chapter will show all decisions and findings from the company needed for the implementation.

5.2.2. Model Implementation

5.2.2.1. Stage 1: Identification of the type and characteristics of the company

Step 1.1 – It is an SME?

The ViniVini Cooperativa vitivinícola it is a company with 25 permanent workers an annual turnover of €7M this means that the company it is considered and Small enterprise.

Step 1.2 – Identification of the area of the company.

The company have different activities but considering that the main business it is the production of the wine, will be consider that the company is present in the group of Manufacturing industries.

Step 1.3 - Have a Technological Maturity Level?

Table 12- Evaluation of the maturity level in the use case context

	Group	Options	Answer (Yes/No)
1	Security investments	The company ensures Internet of Things security	No
		The company uses solutions application security	No
		The company ensures network security	Yes
		The company uses solutions cloud security	No
2	Cloud migration	The company uses software as a service (SaaS)	No
		The company uses platform as a service (PaaS)	No
		The company uses infrastructure as a service (IaaS)	No
		The company uses a hybrid model	No
3	Digital transformation investments	The company uses tools for interaction through the website, e-commerce, and m-commerce	Yes
		The company uses mobile applications in business processes—Apps	No
		The company uses social networks in the digital transformation of business—Social media	Yes
		The company uses conversational interfaces—Chatbots	No
4	Digital adaptation	The company implements IT projects to support vulnerable processes discovered in times of crisis	No
		The company develops IT projects in support of the new operational requirements generated by the implementation of technology 4.0/pandemic crisis	No
5	Digital acceleration	The company develops IT projects that model business innovation	Yes
		The company develops IT projects to increase market share	Yes
6	Digital core	The company adopts industry 4.0 technologies in the automation process	No
		Has the company achieved digitizing the business	No
		The digitalization of business has led to its globalization	------
7	Digital innovation	The company introduces digital products	No
		The company uses customer touch points and gives enhanced sales pitches	No
8	Digital resilience	The company has established a strategy for developing the digital business model	No
		The company has improved customer experience: customer journeys, channels, and touchpoints	Yes
		The company uses platforms and infrastructure for digital processing of the data and information	Yes

After the analyses of the results of table 12 it was clear that the company needs to enable their IT service with resources (Human and technological) to start working with data and implementing IO 4.0. This elevates the company's maturity level and improves its way of working.

5.2.2.2. Stage 2: Identification of problems and bottlenecks of the company

Following the model, the project owner identified the bottlenecks in the from the three perspectives presented in the model. This process was made with collaboration of people from the different company departments because they have a clearer view of day by day of the company.

- **Growth:**
  - Only have physical on-store sales
  - To much time-consuming update production lines necessities
- **Efficiency:**
  - Differences in production times of different machines, forced to have wasted resources.
  - Impossibility to predict when a defect may arise and can affect all production.
  - Impossibility to see the whole factory and understand what a change in a point affect another different point
- **Regulatory:**
  - Reports for competent authorities are time-consuming to do
  - Data in reports are not reliable

5.2.2.3. Stage 3: Selection of IO4 technologies

In this stage, the goal is to choose the best technologies that can be applied based on the area of work and the bottlenecks of the ViniVini Cooperativa vitivinícola.

The model identified some technologies/concepts that should be applied in an SME independently of their area. The first step in this stage is to use the tool and make the first choice of technologies that historically made sense in the manufacturing industry.

The consulting of the tool revealed that the technologies most associated with Manufacturing industries are:

- Data Analytics
- Digital twins
- Cloud
- Big Data
- Internet of things (IOT)
- RPA

After understanding which technologies were more used. It time to decided were and how apply each one.

Cloud, Big data, and Data Analytics

First, it was essential to choose the data/cloud structures that should be implemented, which will be the foundations where the other technologies will be settled and that will be fundamental to implementing IO 4.0 and will serve the company.

Due to the low-cost objective of the project owner decided to implement an Iaas (Infrastructure as a Service) provided by Microsoft-Azure. This solution will enable the company to collect, store and analyze large amounts of data.

The first advantage of using an Iaas product is that implementation costs will be significantly reduced. All infrastructures will be contracted to the data service provider with the advantage of not being. The second one is the on-demand scalability that allows the company to pay for what they need without oversizing the systems. To guarantee a correct implementation of different IO 4.0 technologies, it is mandatory for the previous implementation of Cloud capability to store and process the data that will be generated and guarantee that all the systems and resources are compatible with Azure services.

Internet of things (IOT)

To have a real-time overview of all processes in each machine, it was decided to acquire " Azure IoT Hub" a solution that will be a perfect fit with all Microsoft Cloud services e that will host all the information that coming from machines' sensors and that will able the company to extract data that will be used to perform advanced analytics, Business process management and to create a digital twin model. The use of IoT will be the front door to all the information that will be used to improve the profits and quality of service that the factory will perform.

Digital twins

To have a real-time overview of all processes in each machine, it was decided to acquire " Azure IoT Hub". The solution will be a perfect fit with all Microsoft Cloud services. That will host all the information from machines' sensors and enable the company to extract data that will be used to perform advanced analytics, Business process management, and create a digital twin model. IoT will be the front door to all the information used to improve the profits and quality of service that the factory will perform.

RPA

To improve back-office processes by automatizing them and automatizing the communication between that processes and the processes in the factory and warehouse. To do that, it will be necessary to subscribe to an RPA software that will be able to make a connection between all systems and software.

5.2.2.4. Stage 4: Implementation plan

Step 1- Priories areas of investment (strategic Context) – IT evaluated the working sectors in ViniVini Cooperativa vitivinícola company. It was decided to prioritize the investment where the results will come faster and will be of a grander scale. Due to this selection technique, it as created the following priority investment list:

1 Factory
2 Warehouse
3 Vineyards

Step 2 – 2 Intervention – Factory

Step 2.1 – Set KPI's

Based on the bottlenecks previously identified, in this step, one more time with the collaboration of people from the different company departments, a set of KPIs was defined to measure the improvements that want to be obtained with the Industry 4.0 upgrades.

- **Growth:**
  - Total money saved in reparations
  - Annual costs in reparations
  - Number of salles
  - Number of anomalies prevented in each machine
- **Efficiency:**
  - Number of bottles bottled per month
  - Number of bottles labeled per month
  - Number of anomalies in each machine per month
  - Percentage of on-time deliveries delivered
  - Times that label machine was stopped because the bottling machine don't feed the label machine
  - Number of Scraped units
- **Regulatory:**
  - CO^2 Emictions
  - Electricity consumption
  - Liters of water consumed
  - Wasted creation
  - Energy produced

Step 2.2 - Ideas and prototypes and algorithms

In this step, the actual implementations will be made in the factory to achieve the different goals for the KPIs above.

- Acquisition and installation, in all factory systems, of an Iaas cloud service (Azure Services). This includes:
  - Cloud space.
  - Applications to control security and access of databases and services installed in the Applications needed for data analysis and IOT control.
- Acquisition and installation of IoT sensors to upgrade the existing ones in the actual machinery will allow a real-time understanding of what is happening in each machine, communicate between sensors, and save data cloud for later analysis.
- Acquisition and installation of Azure Digital Twins software to start modeling and testing the improvements in the factory.
- Acquisition of an RPA software that can map the back office processes such as sales, purchase of raw materials, and stocks… with the factory machines.
- Implementing a Multilayer Perceptron's algorithm to guarantee, based on sensors information, that all bottles are correctly bottled and labeled and the ones that are not packed. This algorithm

is used because it allows one to choose the number of inputs, and their weight can be configured and adjusted based on the number and quality of the sensors presented in the different machines.

- Implementing a hybrid system of deep machine learning architecture to predict anomalies in the operation of industrial equipment. The Bayesian online changepoint detection algorithm will be used to detect anomalies, the time-domain features extraction process for feature extraction, and the long-short term memory neural network to predict the values of the magnitudes that reflect the correct or not the operation of the equipment.

Step 2.3 - Create Policies and procedures

Due to all new equipment and technologies inside and outside the factory and in a way to guarantee its correct use it is important to create a set of policies and procedures that guarantee:

- A roadmap for day-to-day operations;
- Uniformity to operations;
- The reduction of the risk of an unwanted event;
- Business achieves its objectives more efficiently;
- Guarantee the legal compliance obligations of all processes.

Due to the points referred before it was defined to create the following new policies and procedures that will be used together with the already existing policies and procedures.

- **Machinery Procedures and Policies-** Explain the use of each machine to guarantee that the users know the correct steps to use the machine, the safety measures, how to evaluate the data presented by the machine, and how to guarantee the correct data caption;
- **Data Security Classification Policy -** Classify data elements according to its sensitivity in order to manage and control accessibility and availability to data consumers.
- **Data Quality Policy -** Ensure data quality management supported by data quality controls to control and monitor data flow consistency and business rules.
- **Data Processes Policy-** Manage data concepts within a central repository with "data about data" (data dictionary), regulating any change in data concepts under governance and Regulate the governance of data events, which can be triggered by data dictionary changes, data quality issues, new data demand and changes in operational systems.

All this policies and procedures should be used together with the already existent policies and procedures in the factory and company.

Step 2.4 – Test, Analyze and Re-Set

This step should be performed individually, and a general test of the "modules" presented in step 2.2 of the Implementation Plan, these tests will be performed in the digital twins' software environment. After the test implementation, their results will be analyzed to understand the effects of the different technologies through the KPIs values.

After this analysis, the KPIs and technologies should be updated based on the previous results.

Step 2.5 - Go live

5.3. EVALUATION, RESULTS AND DISCUSSION

To evaluate the proposed model, the artefact of this master thesis, an expert analysis was conducted, following Peffers et al. (2007) DSR Process. Considering the sixth (Hevner et al 2004) guideline, those artifacts were presented to three different experts, who answered four quality evaluation questions. The methodology applied to these evaluation sessions was individual interviews. Each expert was interviewed individually and asked to accept the recording of the session to enable its transcription.

5.3.1. Interviews planning

The interviews were accomplished between 25th October and 5th November of 2022

All the experts explicitly accepted not to be anonymized. The experts interviewed were:

- **Professor Rui Gonçalves (RG):** Head of Global KPMG Low Code and Automation capability Network, IT Advisor and Digital Transformation Partner at KPMG Portugal and ISEG Professor.
- **Professor Henrique São Mamede (HSM):** Professor on Universidade Aberta, and Nova-IMS, responsible of the Master in Business Information and Systems in Universidade Aberta.
- **Eng.Tiago Correia (CV):** Winemaker and responsible for the production area of "Casa Cadaval". "Casa do Cadaval" it is a farm in Santarem Region that is dedicated to the production of wine.

Each interview was followed by the artifacts' presentation Annex 1 and included three questions:

- **Question 1**: Do you consider the proposed framework as useful and why? If not, why do you believe it is not?
- **Question 2:** Do you have any criticism towards the proposed framework? Please explain.
- **Question 3:** Do you have any recommendation or suggestions for further improvements of the proposed framework?

All interviewees agreed to being recorded to enable the interview transcription. The three individual interviews were therefore transcribed for further discussion and artifacts improvement.

5.3.2. Interviews description

This chapter pretends to synthesize the answers to model validation. The interview records were analyzed to produce this description and compilated from different points of the different opinions of the different experts.

Question 1: Do you consider the proposed framework as useful and why? If not, why do you believe it is not?

All interviewees agreed that the proposed Model are useful and applicable to the market considering some modifications.

RG consider that nowadays the organizations/companies are very confused about the topic of digital adoption/transformation and need to structure their thought about this process, for that reason there is an important place to models like the one developed.

Due to the number of Industrial SMEs in Portugal, and to the lack of studies regarding Industry 4.0 for SMEs, HSM consider that this study could have an important impact. He re-enforced that there are a lot of studies about Industry 4.0 but these studies are mostly related with higher dimension companies because these organization don't represent the same barriers as an SMEs due to the limitations that they present, namely in terms of investment capacity. The expert considers too that there is a lot of confusion regarding Industry 4.0 and for that reason there is import the existent of models that guide not only on the implementation but in the understanding of the technologies.

TC considers the existence of this type of model has a great interest, especially when talking about SMEs. It is mentioned that many times in specific industries where production is considered ancient, there is a perspective that there is no need to develop the use of these new technologies. Through simplified methodologies, there is a need to demonstrate the advantages associated with their use.

TC also highlighted the importance of the model being something simple and with clear indications of the way to go because, in SME, there is no capacity to have teams dedicated to digital transformation that have extensive knowledge of the area and how to apply it.

Question 2: Do you have any criticism towards the proposed framework? Please explain

Regarding the model HSM presented two criticism points to the model.

The first one presented was the existence of a survey (Stage 1.3) to evaluate the Maturity level of the company that there isn´t validate by the academia, in his opinion the questionnaire should be validated our should be used one framework from another author that had been previous validated.

The second point presented by HSM was about the companies that are presented in the model as possible users of the model, the expert considers that Industry 4.0 it is focused only on industrial companies and that the approach taken by including various types was very broad and that was incorrect to the Industry 4.0 scope.

Both HSM and RG consider that the utilization of BPM in SMEs represent mistake. The utilization BPM technology represent a complex approach, with high license costs that SME can't afford specially in "low-cost" projects.

RG has an additional criticism due to the detail presented in the model, in his opinion the model should have more detail in the mapping and use of the different technologies.

Despite understanding the scope of the model, TC such as RG, considers that this type of methodologies should go to the heart of the matter by presenting detailed solutions for the improvements to be made for each kind of company, which allows them to do the same as larger companies but with limited resources.

Question 3: Do you have any recommendation or suggestions for further improvements of the proposed framework?

HSM consider that "Processing Discover" should not be included in the model, because process discover it is granted in Industrial environment and in an Industry 4.0 implementation this isn't a step that it is before the Industry 4.0 application.

For HSM the model should focus on back-office processes and in the automation of them. He suggested the inclusion RPA to automate these processes and their connection to the machines in the industrial space. The utilization of that technology could replace simple data analyses previous made by workers.

RG made 3 suggestions for the improvement of the model. The first one was regarding the identification of bottlenecks of the companies, he considers that should be a separation of different bottlenecks in Growth, Efficiency and Regulation, that separation will made the model more detailed, and will made a clearer guide to the companies what about the Business transformations that they want to implement. The second point was a suggestion to focus not only on the way to do the transformation but in a way to accelerate it. The last recommendation was to invest in solutions low code due to the simple adaptation that they represent and to the low license costs.

To improve the model TC suggested the creation of specific use cases that could be applied, not only by specific companies, but to specific areas of company. The utilization of how to apply an anomaly detection algorithm in a machine, the utilization of IOT in an agriculture production are examples that after presented to an administrative bord or to a business owner can make them aware of the advantages of implementing these technologies as well as ways to apply them to their business.

5.4. Discussion

Within this section, one will perform an analysis where the inputs and feedback obtained during the previous stages will be incorporated to reach a conclusive discussion. This discussion focuses on the artifacts' utility, possible improvements, and general observations of the participants during the interviews.

Regarding the relevance and utility of this work, all three participants agree that the model could be advantageous and relevant to some SMEs, especially in Portugal, where 95% of the manufacturing companies are SMEs. Many studies exist regarding Industry 4.0, but a significant number of these studies are only applicable to big ma manufacturers with much more resources than SMEs. This creates an essential space for studies like the one did.

Regarding improvements and recommendations, some points were suggested, and some of these points resulted in alterations to the model. The first example of these improvements was on the questionnaire used in stage 1.3. The questionnaire was constructed based on the performed literature review but was not scientifically validated, representing an issue in the model. To solve that problem, it was another questionnaire that has been scientifically validated to guarantee their quality and usability.

It referred the importance of the inclusion of the automation of back-office processes in the model. to do this kind of automation. It was suggested the use of RPA and low-code solutions due to their low-cost and more straightforward implementation compared to other technologies.

One of the experts referred that a kind of bottleneck that nowadays companies are looking to help deal with it is the regulation and report. More and more, companies need to follow many regulations, and smaller companies need to gain the expertise to implement systems that help them to comply with these regulations and reports so that so be one of the bottlenecks to include in the model.

Business Process Management technologies were considered out of the scope of this project by two of the experts that, based on their experience, consider a technology that is not low-cost or nether simple to implement.

Another point that was highlighted was the fact that the model contains just one use case. It could improve their utility if the model provides more specific use cases. Nowadays, in a world of constant change, it is crucial not only to implement improvements, but the time needed to do it. Different experts highlight the importance of including more use cases in the model because that will make the model easier to understand and apply, and that will help the companies accelerate their business transformation. Besides these considerations, the experts expressed that this could be out of the project's scope.

In the final of the different interviews, some interviewees showed availability to meet again to re-evaluate the model and give new suggestions to upgrade them.

6. Conclusion

The aim of the final chapter of this work is to conclude the developed work by reflecting on the most important conclusions, limitations, and future work. This chapter will allow a global overview and understanding of which objectives were or were not achieved.

After the analyses of feedback from the experts can be concluded that the achievement of the initial objectives was unanimous. It validated that the proposed model can help and guide SME with a low budget in the implementation of Industry 4.0 technologies to improve their growth and efficiency, as well as help in the report of regulatory obligations.

6.1. Synthesis of the developed work

The development of the " Low-Cost Industry 4.0 for SMEs" theme emerged from the identification of the difficulties that SME had to use and adapt their systems to the 4.0 industry, largely due to its costs and complexity.

The research begun with a literature review over the different fields that were considered relevant for this thesis. It started with the characterization, distribution, threats, challenges, and opportunities of SMEs and then the history, characterization, and different areas and related technologies of Industry 4.0.

After the first literature review, a Systematic Literature Review was performed to have a more restricted perspective about have been done and published about industry 4.0 and SMEs. The SLR differs from the first LR because it only retrieved articles that included both themes in their work.

Based on the previous research, a model was designed to answer the SMEs difficulties. The model is composed of four stages. Each stage will provide steps and guidance to help the company implement Industry 4.0 from the planning until the execution.

After the design, a use case was developed to test and exemplify the model's applicability. For the use case it was created a fictitious company to make an example of the applicability of the model.

To evaluate the model, three experts interviews were performed. The interviews showed different perspectives about the model, highlighting the importance that this model could bring to company that implements it. Based on their feedback the model has been tweaked, improved, and validated.

Based on all the work done and presented in this thesis, it can be affirmed that the objectives defined in chapter 1 were clearly achieved.

6.2. Limitations

The limitations of the proposed solution are mainly due to time and scope, since this research was conducted to complete a master thesis and was driven by its deadline.

The high cost of implementation of Industry 4.0 and the difficulty of implementation of these technologies by smaller companies lead to a lack of investigation resources to sustain and allow for a more detailed study of the topic.

Another investigation limitation was regarding the validation of the framework. Even though it was approved by a technical and non-technical audience, the number of participants could have been higher and, consequently, provide a more credible, and universal, validation. The theorical use case don't provide the most accurate feedback about the real application of the model.

In addition, given the high cost and complexity of intelligent systems connecting with existing systems in factories, the implementation of Industry 4.0 technologies is not always a simple task and is often loaded with aversions to changes by the very employees who would use the technology and the limitations of the company's existing infrastructure (Cachada et al., 2018).

6.3. RECOMMENDATIONS FOR FUTURE WORK

Reflecting on what are the next steps and future work, the validation process could be improved by applying the model to a real company and after that perform a more significant analysis of the results. Besides that, gathering more insights from a larger number of experts, will lead to a bigger improve of the model quality and applicability thus turning the model as much universal and accessible as possible. Different users from different areas of expertise should be interviewed to collect information from as many scenarios as possible.

Considering the diversity of technologies and their rapid growth and update in the market, a good improvement would be the continuous update of new technologies and software's that are launched in the market. Industry 4.0 is an area in constant innovating, new products and technologies will be inevitably launched, thus a follow-up of them would be recommended to future work.

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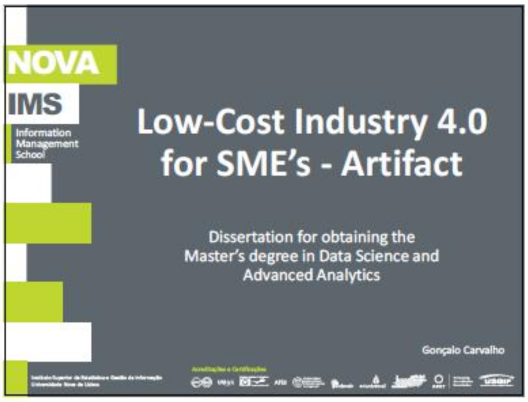
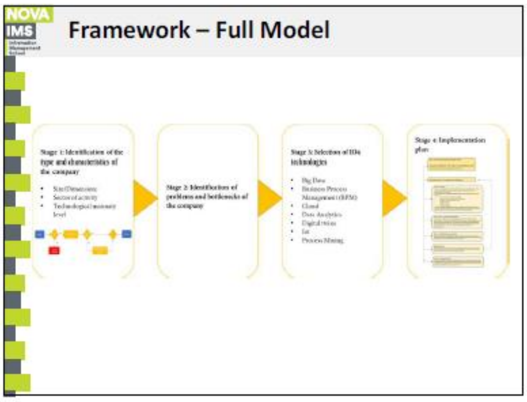
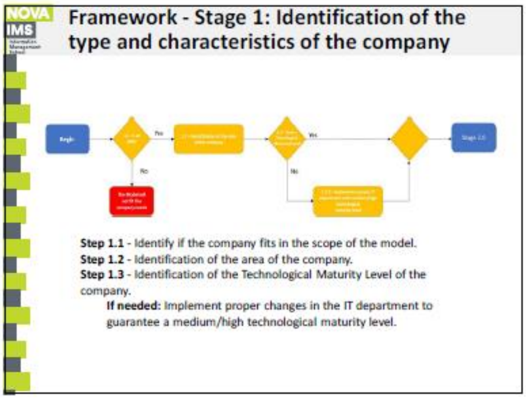
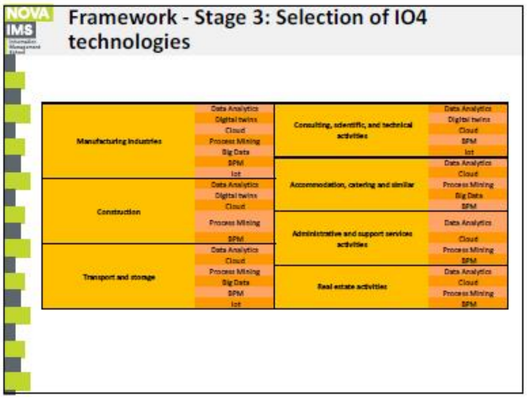
ANNEX

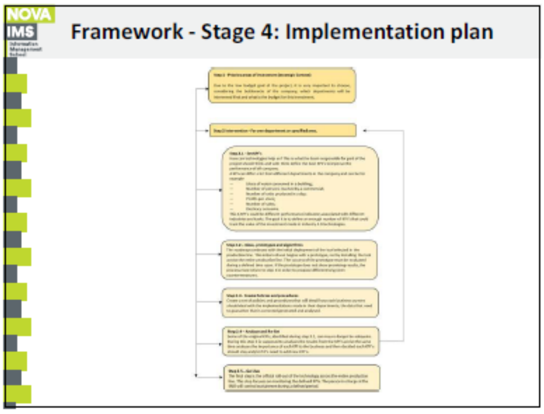
ANNEX 1- INTERVIEWS PRESENTATION







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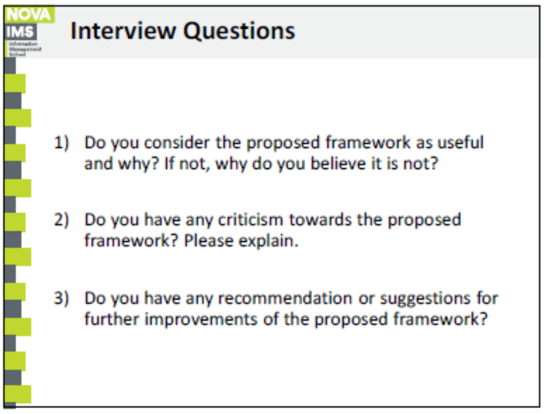
Framework - Stage 4: Implementation plan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Interview Questions
1) Do you consider the proposed framework as useful and why? If not, why do you believe it is not?
2) Do you have any criticism towards the proposed framework? Please explain.
3) Do you have any recommendation or suggestions for further improvements of the proposed framework?


Thank you for your time and expertise!
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