UNIVERSIDADE CATÓLICA PORTUGUESA

Impacts of the implementation of Industry´s 4.0 technologies in the Portuguese Footwear Industry

Final Dissertation presented to
Católica Porto Business School to obtain the degree of
Master in Business management

by

Francisca Gomes Silva

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March 2019

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Once another stage of crucial importance in my academic career is over, it is time to give a word to those who have made it possible to close this chapter further, turning it into a personal milestone. To you I dedicate this final result and this achievement.

To my father who is my hero and my inspiration for pursuing my dreams and not giving up, even when the odds are not in my favor.

To my mother for being the most loving and caring person and giving me the motivation and faith needed to overcome all the obstacles in my life.

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Abstract

The first three industrial revolutions came about as a result of mechanization, electricity and IT. It is safe to state that a fourth revolution is currently taking place in manufacturing, with it being generally branded as Industry 4.0. These Cyber-Physical Systems comprise smart machines, storage systems and production facilities capable of autonomously exchanging information, triggering actions and controlling each other independently.

The present investigation takes this premise into account and focuses in pursuing what are the main implications of the implementation of Industry´s 4.0 technologies in the Portuguese Footwear Industry.

In order to lay the foundations for the study, an extensive literature review was executed. This was followed by a qualitative and exploratory investigation, based on twelve interviews with various relevant actors of the Portuguese footwear scene. The interviews resulted in insightful conclusions. Firstly, it is possible to notice that the Portuguese Footwear industry is generally well equipped and informed. Generally, the manufacturers are aware of the new technologies that are made available, being that there are already successful examples of companies using them. The study has highlighted the importance for companies to develop an extensive evaluation regarding their specific needs in order to better decide in which technologies to invest.

The path is being designed in order to continuously simplify technologies, so that they are easier to work with. The main constraint, to the present day, is linked with finding skilled workforce to perform tasks at the shop floor level and also with the generation of enough value that allows the manufacturers to invest in more advanced technology.

Keywords: Industry 4.0; Portuguese Footwear Industry; Portuguese footwear cluster; Industry´s 4.0 technologies; Smart production; Automation; Degree of digitization

Index

List of Acronyms

3D- Three-dimensional

AM- Addictive manufacturing

APICCAPS- Portuguese Footwear, Components, Leather Goods Manufacturers' Association

CPS-Cyber Physical Systems

CTCP- Portuguese Footwear Technological Center

DM-Distributive manufacturing

ERP- Enterprise Resource Planning

ICT- Information and Communication Technologies

IMS: Integrated management system

IoT- Internet of Things

MC- Mass customization

RFID-Radio-Frequency Identification

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1. Introduction

Industry 4.0 has its epicenter in Germany and comes to be affirmed as the 4th Industrial Revolution. This paradigm relates to the creation of "intelligent factories" through cyber-physical systems (CPS), that is, systems that create a replica of the physical world and facilitate decentralized decision-making based on the large volume of data that they can collect and treat in real time.

Since it was first mentioned in the Hannover fair event in 2011, the term of Industry 4.0 is one of the most popular manufacturing topics among industry and academia in the world and has also been considered as the fourth industrial revolution with extreme impact on manufacturing in the future.

1.1 Study motivation

As one of the main components of Industry 4.0, the future factory is going to involve a new integrative, where not only all manufacturing resources (sensors, actuators, machines, robots, conveyors, etc.) are connected and exchange information automatically, but also the factory will become conscious and intelligent enough to predict and maintain the machines; to control the production process, and to manage the factory system.

The topic of Industry 4.0 is a very complex and complete topic, being that it was necessary to restrict the scope of this study to some of the subjects that are under this thematic.

For this investigation, the motivation was to study the concept of industry 4.0 in the Portuguese footwear sector in order to have a better understanding of what is the current state of the industry in regard to this technologies, and also be able to make assumptions in regards to future actions of the Portuguese manufacturers.

1.2 Objectives of the Investigation

With the arise of the 4th industrial revolution, the paradigm of the companies has shifted and will continuously change throughout the upcoming years. This changes will affect companies and the way they produce, manage and process the different activities in the value chain.

Industry 4.0 is an extremely broad topic, that encompasses different departments and activities in a company. In this study, the focus is to analyze the effect that this revolution is having in the Portuguese footwear cluster and also at the level of the factory. The main goal is to understand what are the Impacts of the implementation of Industry´s 4.0 technologies in the Portuguese footwear industry.

After the research question, it was imperative to design the objectives that are going to be addressed in order to achieve valid results: The first objective is to evaluate the degree of knowledge that the Portuguese manufacturers have in regards to Industry 4.0, in order to have a more clearer notion of the dissemination of this topic among the Portuguese manufacturers.

The following objective is to analyze the degree of digitization of the Portuguese footwear industry according to the inputs given by the producers interviewed. After analyzing the previous topics, is important to evaluate the implementation Industry's 4.0 technologies in the Portuguese footwear industry. The fourth and fifth objectives focused on the benefits and challenges that come with this revolution in order to have a more accurate idea of the major pros and cons that the producers deal with in their day-to-day operations. The two final investigation objectives regard the main drivers for the implementation of these technologies in the footwear sector and finally evaluate the impacts that the implementation of Industry´s 4.0 technologies might bring to the company's workforce.

1.3 Investigation methodology and structure

The methodology adopted to answer to the proposed research question in the scope of this final master's work is qualitative and exploratory, in the form of a survey, composed by twelve interviews.

In the first place, a literature review is carried, , aiming to make a collection of the state of the art among different authors who have been addressing the theme and, therefore, to contextualize the study and support the methodology adopted. Then twelve interviews were carried in order to collect the information in the field. Two of the twelve interviews, were considered preliminary and were made in order to contextualize the sector. These interviews were performed with the director of CTCP (Centro Tecnológico do Calçado de Portugal) - Portuguese Footwear Center- and to two directors of APICCAPS (Associação Portuguesa Industrial de Calçado, Componentes, Artigos, Pele, Sucedaneos) - Portuguese Footwear, Components, Leather Goods Manufacturers' Association. Ten of the twelve interviews were held with footwear manufacturers, being that eight of the ten interviews were focused in the main footwear clusters - Felgueiras and São João da Madeira. In order to add value to this investigation, and portrait the realities of different Portuguese companies, two more interviews were added with companies located in other areas.

This decision was made due to the fact that these two companies were named by the APICCAPS director as being some of the most automatized and technologically advanced producers in Portugal. After the collection of all data, the investigation proceeded to analyze the compiled information.
The last topic focuses on the main conclusions of the investigation.

2. Industry 4.0

2.1 Introduction

The fourth industrial revolution – or Industry 4.0 – emerged from several developed countries and it was consolidated in a German public-private initiative to build smart factories by the integration of physical objects with digital technologies (Brettel et al., 2014; Hermann et al., 2016). The key element that characterizes this new industrial stage is the deep change in the manufacturing systems connectivity due to the integration of ICT, IoT and machines in cyber-physical systems (CPS) (Kagermann et al., 2013; Schwab, 2017). Industry 4.0 is considered a new industrial stage in which vertical and horizontal manufacturing processes integration and product connectivity can help companies to achieve higher industrial performance. In this sense, Industry 4.0 can be understood as a result of the growing digitization of companies, especially regarding to manufacturing processes

The following sector will focus on the concept of Industry 4.0 and in the main technologies associated with the term. The starting point is to explore the concept of Industry 4.0, followed by its main benefits and also challenges.

The next subject focuses on the understanding of the concept Smart Factory followed by the shift in the workforce capabilities. Also, concerning Industry´s 4.0 technologies, it is important to explain the concept of Industrial Internet of things and its main concerns regarding security, privacy and standardization.

The following topics deal with Industrial Big Data and Industrial Cloud Computing as well as Vertical and Horizontal Integration. Deriving from Industry 4.0 and the new manufacturing processes is the concept of Distributive manufacturing which is linked to the concepts of Additive manufacturing systems, Product mass customization and Customer Co-Design.

2.2 Conceptualization

The three industrial revolutions of the past were all triggered by technical innovations: the introduction of water and steam-powered mechanical manufacturing at the end of the 18th century, the division of labor at the beginning of the 20th century and introduction of programmable logic controllers (PLC) for automation purposes in manufacturing in the 1970s (Brettel et al., 2014).

Since the first Industrial Revolution, subsequent revolutions have resulted in radical changes in manufacturing. Manufacturing processes have become increasingly complicated, automatic and sustainable, which means people can operate machines simply, efficiently and persistently. Nowadays modern manufacturing plays an essential role in the world, especially in European countries (Qin et al., 2016).

With the technological development, a new concept, Industry 4.0, was introduced in German during the Hannover Fair event in 2011, which symbolizes the beginning of the 4th industrial revolution (Qin et al., 2016).

Industry 4.0 is a collective term for the technologies and concepts of value chain organization. This concept aims to introduce technical advances such as wireless network systems, cyber-physical systems, the Internet of Things, and cloud computing in industry **(**Satoglu et al., 2018). Lu (2017) claims, that "*Industry 4.0 can be summarized as an integrated, adapted, optimized, service-oriented, and interoperable manufacturing process which is correlate with algorithms, big data, and high technologies*" (Ślusarczyk,2017).

The fascination for Industry 4.0 is twofold. Firstly, for the first time an industrial revolution is predicted a- priori, not observed ex-post. This provides various opportunities for companies and research institutes to actively shape the future. Secondly, the economic impact of this industrial revolution is supposed to be huge, as Industry 4.0 promises substantially increased operational effectiveness as well as the development of entirely new business models,

services, and products (Hermann et al. 2016).

According to Baur & Wee (2015), in the article "Manufacturer´s next act", Industry 4.0 is defined by the next phase in the digitization of the manufacturing sector, driven by four disruptions:

- The increase in data volumes, computational power, and connectivity, especially new low-power wide-area networks;
- The emergence of analytics and business-intelligence capabilities;
- New forms of human-machine interaction such as touch interfaces and augmented-reality systems; and
- Improvements in transferring digital instructions to the physical world, such as advanced robotics and 3-D printing.

There are many drivers forcing this new upcoming revolution but according to the Global Industry 4.0 Survey (PwC, 2016) the main ones are:

1) **Digitization and integration of horizontal and vertical Value Chains:** all data about operations processes, process efficiency and quality management are available in real-time supported by augmented reality and optimized in an integrated network; Horizontal integration includes technologies from track and trace devices to real-time integrated planning with execution;
2) **Digitization of product and service offering:** includes expansion of existing products as well as the creation of new digital products which focus on completely integrated solutions. By doing so, companies are able to generate data on product use and refine products to meet increasing needs of end-customers;
3) **Digital business models and customer access:** Leading industrial companies also expand their offering by providing disruptive digital solutions such as complete, data-driven services and integrated platform solutions. Disruptive digital business models are often focused on generating additional digital revenues and optimizing customer

interaction and access.

In Industry 4.0, businesses will establish global networks that incorporate their machinery, warehousing systems and production facilities in the shape of Cyber-Physical Systems (CPS). In the manufacturing environment, these Cyber-Physical Systems comprise smart machines, storage systems and production facilities capable of autonomously ex- changing information, triggering actions and controlling each other independently. In order for Industry 4.0 be successfully implemented, research and development activities will need to be accompanied by the appropriate industrial machinery and industrial policy decisions (Kagermann et al., 2013).

According to Kagermann et al. (2013) there are seven key areas that should be considered in order for companies to be successful when implementing Industry's 4.0 technologies. The first one focuses on standardization and reference architecture, which stands for the necessity to develop common standards in the collaborative partnerships that are made between companies. A reference architecture will be needed to provide a technical description of these standards and facilitate their implementation. Since the value network in Industry 4.0 comprises several different companies with very different business models, the role of the reference architecture is to pull together these divergent approaches into one single, common approach. This will require the partners to agree on the basic structural principles, interfaces and data.

The second one is about managing the complex systems between products and manufacturing systems that are becoming more complex. The third one focus on the fact that is imperative to have a comprehensive broadband infrastructure for industry which means, that because of the premise that the core technology of industry 4.0 is the internet, it is jussive that there is a reliable, comprehensive and high-quality communication networks, therefore, a broadband infrastructure is needed to be expanded on a massive scale.

The fourth requirement is about safety and security. These topics are especially important in order to ensure that production facilities and even the

products themselves, do not pose a threat to people or the environment. These should be protected against misuse and unauthorized access.

Number five revolves around the transformation of the work content that the increase of real-time oriented control will bring. In order for companies to be able to implement a socio-technical approach to work organizations and offer workers a better work experience, it is necessary to deploy participative work design and lifelong learning measures.

The sixth measure links to the previous one, and focuses on training and continuing professional development. It will be necessary to implement appropriate training strategies and improve the learning processes in order to respond to the radical transformation that will happen in the requirements of competences for job profiles.

Whilst the new manufacturing processes and horizontal business networks found in Industry 4.0 will need to comply with the law, existing legislation will also need to be adapted to take account of new innovations. Number seven focuses on the regulatory framework that is required in order to better implement these changes and includes protection of corporate data, liability issues, handling of personal data and trade restrictions.

In order for a company to know whether they should implement these changes or not, it is important to calculate the trade-offs between the additional resources that will need to be invested in smart factories and the potential savings generated, which means, see if there are substantial gains in resource efficiency.

As with any new Industrial and technological revolution, there are benefits and challenges that should be addressed.

2.3 Benefits of Industry 4.0

There are important benefits that arose from this upcoming industrial movement and the potential for companies is huge.

Industry 4.0 allows individual, customer specific criteria to be included in all the phases of production which include design, configuration, ordering,

planning, manufacture and operation with the difference that, due to the end-to-end integration of all the stakeholders, it is now possible to make last-minute changes and incorporate them in the products without generating any extra costs. With these new technologies, it is also possible to meet individual customer requirements and to produce one-off items or have very low production volumes whilst still making a profit (Rüßmann et al., 2015). Flexibility is going to increase due to the fact that CPS-based ad *hoc* networking enables dynamic configuration of different aspects of business processes, such as quality, time, risk, robustness, price and eco-friendliness. This also means that that engineering processes can be made more agile and manufacturing processes can be changed in a short space of time (Kagermann et al., 2013).

One very important key factor of Industry 4.0 is the fact that it provides an end-to-end integration and transparency in real-time allowing to have an early verification of any design or process changes that may occur and also, be able to be more flexible in adopting the necessary alterations across of the company´s site. Another advantage focuses on the fact that CPS systems allow the optimization of manufacturing processes on a case-by-case basis across the entire value network. The Cyber-physical-systems also provide the opportunity to, instead of stopping production, optimize the systems during production in terms of their resource and energy consumption or reducing their emissions (Schuh et al., 2017).

Through the Industry 4.0 technologies, it is possible for companies to create new services and value opportunities through the creation of new forms of employment, for example. Industry 4.0 also creates new opportunities, especially for SME´s and Startups to develop new B2B technological services. Another benefit of this new technological wave, has to do with the fact that there has been a growing number of companies that use CPS and adopt models that have a more flexible organization so they are well placed to meet growing need of employees to strike a better balance between their work and their private lives and also between personal development and continuing professional development (Rüßmann et al., 2015)

2.4 Challenges of Industry 4.0

As promising as the idea of a self-prophesying "Fourth Industrial Revolution" may sound at first sight, it is essential to remark that there is a multitude of challenges, risks and barriers with regard to its implementation. Traditional industry boundaries will vanish due to the reorganization of value creation processes and cause severe changes within and across organizations. Defining appropriate infrastructures and standards, ensuring data security and educating employees are among the issues that need to be addressed on the road to Industry 4.0 (Hoffman, 2016). Also, due to Globalization and enhanced competition in the global market, more complex products with shorter lifecycle and fluctuating customer demands gave rise to new technologies, business processes and the application of global supply chains.

The tendencies of the 21stcentury such as cycles of products being shorter while consumers demand more complex, unique products in larger quantities, poses many challenges to the production. There are many sings that show that the current practices in the utilization of resources is not sustainable, which will limit the production (Bartodziej, 2017).

Short innovation cycles result in the need for constant updating of the regulatory framework and cause chronic failings in terms of enforcement (Kagermann et al., 2013).

The sector is going through a paradigm shift, which will change the production drastically. The traditional centrally controlled processes will be replaced by decentralized control, which is built on the self-regulating ability of products and workpieces that communicate with each other (Bartodzie, 2017).

Another constraint is the fact that companies might have a limited pool of skilled workers on the labor market that have the skills to respond to the new demands. Still in regards to new technologies, their disruptive nature and impact on legal issues (e.g. with regard to technology, sensitive corporate data, liability, data protection, trade restrictions, use of cryptography, etc) can pose a threat to

the enforceability of existing legislation. Issues such as safety and security, confidence, reliability, usage, operator model convergence, real-time analysis and forecasting will all need to be reviewed for the orchestration and subsequent efficient, reliable, safe and secure operation of collaborative manufacturing and service processes as well as for the execution of dynamic business processes on CPS platforms (Kagermann et al., 2013).

It is not an easy task to achieve Industry 4.0, and according to Zhou et al., (2015) it is likely to take several years until the full potential of this revolution is established. Currently, Industry 4.0 is a vision for the future, because it involves many aspects, and faces many types of difficulties and challenges, including scientific challenges, technological challenges, economic challenges, social problems and political issues.

2.5 Smart Factory

Industry 4.0 is to set up intelligent manufacturing and intelligent factory based on CPS. CPS or cyber-physical systems, are integrations of computation with physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa (Lee, 2008).

In the manufacturing context, this means that information related to the physical shop floor and the virtual computational space are highly synchronized. In the smart factory, products find their way independently through production processes and are easily identifiable and locatable at any time, pursuing the idea of a cost-efficient, yet highly flexible and individualized mass production (Kagermann et al., 2013).

Since the field of Smart Manufacturing is still in a rather immature phase, there are no fully established definitions. However, one example of definition of Smart Manufacturing could be: "*a (fully)-integrated and collaborative manufacturing system that responds in real-time to meet the changing demands and conditions in the factory, supply network, and customer needs*" (NIST, 2014) . It means that the active

manufacture-based technologies and systems can respond in real-time to internal and external changes, thus by getting more adaptive and diversified (Wiktorsson et al., 2018).

Industry 4.0 is focused on creating smart products, procedures and processes. Smart factories are capable of managing complexity, are less prone to disruption and are able to manufacture goods more efficiently. In the smart factory, human beings, machines and resources communicate with each other as naturally as in a social network. Smart factories will be embedded into intercompany value networks and will be characterized by end-to-end engineering that includes both the manufacturing process and the manufactured product, achieving seamless convergence of the digital and physical worlds (Kagermann et al., 2013).

It will be possible to create Smart products that know the details of how they were manufactured and how they are intended to be used and are linked to smart mobility, smart logistics and smart grids which will make the smart factory a key component of tomorrow's smart infrastructures. In a near future under Industry 4.0, it will be possible to incorporate individual customer- and product- specific features into the design, configuration, ordering, planning, production, operation and recycling phases (Wan et al 2015).

Jain et al. (2001) defined the Virtual Factory, which is another name for Smart Factory, as "*An integrated simulation model of major subsystems in a factory that considers the factory as a whole and provides an advanced decision support capability.*" In addition, Azevedo et al. (2010) proposed the Virtual Factory Framework as a virtual advanced software environment that aims assisting the design and management of all physical factory entities including all products, manufacturing resources, and even the network of companies during all phases of the factory life-cycle.

The development of intelligent factories is a new direction of industry 4.0 showing some manifest advantages such as the ability to collect and analyze inside and outside information to better program the factory's behavior. Another advantage relies on the fact that in Smart Factories it is possible to combine with signal processing, reasoning, estimating, simulation and multimedia technology

to show the design and manufacturing process truly (Wan et al., 2015).

Virtual Factories also have coordination, reorganization and expansion features: Any part of the system can make the best system structure according to their own tasks and it is possible, through its self-learning technology, to supplement, update and diagnose the system during production. Then it is possible to solve the problem or request the personnel to handle. It is also noticeable human-computer coexistence systems, where human and computer coordinate and cooperate with each other to play their respective advantages (Wan et al., 2015).

Hence, the potentials that might come along with smart factories are expected to be huge. It is important to understand that not only production processes but also the roles of employees are expected to change dramatically. Spath et al. (2013) expect employees to enjoy greater responsibility, to act as decision makers and to take on supervising tasks.

In the same context, some critics have recently pointed out that the automated and self- regulating nature of the smart factory might cause severe job destruction due to the fact that the most routine tasks will be done by machines, creating opportunity for humans to be in charge in more creative and intellectual activities, which might not please everyone (Hofmann, 2017).

2.6 Industry 4.0 : Shift in the workforce

In today's global environment, sustainability and competitive advantage of companies depend mostly on their capability of adaptation to changing business requirements. The Fourth Industrial Revolution, driving from the advancements in new digital technologies known collectively as Industry 4.0, has been profoundly changing dynamics of most industries. Automation of business processes together with emergence of novel business models impose new digital skill requirements for workforce. In order to meet these new requirements, companies will have to focus their strengths, not only in attracting and developing new talent, but also re-skilling current employees through training

programs as well as re-designing work processes for reducing the skill mismatch between jobs and employees (Karacay, 2017).

According to Frey and Osborne (2013), the impact of technological innovations and automation on labor markets mostly indicate decline of employment in routine intensive occupations— i.e. occupations consist of tasks which follow a detailed and specific course of actions so that they could be easily performed by complex algorithms. Likewise, Brynjolfsson et al. (2011) argue that, as a result of advanced pattern recognition of the workers abilities, using sophisticated algorithms on big data, non-routine cognitive tasks have also become feasible for automation.

The rapid and significant developments in computer skill and abilities not only make automation more feasible to substitute human workforce in a wider range of occupations, but also change the nature and scope of work across industries and occupations. As machine intelligence capacities develop further, applications of artificial intelligence like machine learning, 3D printers, driverless cars, and others, are likely to abolish more jobs currently done by humans, not just in manufacturing but also in service industries, ranging from low-skill tasks like home delivery to high-skill professional tasks (Karacay, 2017).

According to Autor et al. (2003) and Berger and Frey (2016), workers with occupations that previously involved routine tasks progressively performed more analytic and interactive work once their industries experienced fast digitalization. This idea is linked to the fact that extensive automation of routine activities will reduce the demand for lower-skill and routine-intensive occupations, while it will increase the need for high-skill workers with novel skills.

As automation and digitalization of work processes increase, workers will be required to take charge of less automatable and more complex tasks, whose completion necessitate solid literacy, numeracy, problem-solving, and ICT skills together with soft skills of autonomy, co-ordination and collaboration. Overall, there will be higher demand placed on all members of the workforce in terms of managing complexity, problem-solving and higher levels of abstraction for

obtaining simplified representation of the bigger wholes (Grundke et al. 2017).

Having this changes in consideration, producers must set priorities and upgrade the workforce, which means, analyze the long-term impact on the workforce and conduct strategic workforce planning. Adapt roles, recruiting, and vocational training to prepare the workforce with the additional IT skills that will be required (Rüßmann et al., 2015).

2.7 Industrial Internet of Things

Industry is a leading application domain for the Internet of Things (IoT). The promise of the technology is expected to revolutionize manufacturing as we know it and influence application domains like transport, health, and energy with the models that are emerging (Serpanos et al., 2017).

Internet of Things (IoT) refers to the connectivity between digital and physical world (Atzori et al., 2010). The term was initially proposed to refer to uniquely identifiable interoperable connected objects with Radio- Frequency IDentification (RFID) technology (Ashton, 2009). Later on, researchers did relate IoT with other technologies, such as: sensors, actuators, GPS devices, and mobile devices.

It is possible to find a various number of other descriptions from different authors:

–''*a dynamic global network infrastructure with self- configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'Things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network*" (Kranenburg, 2008).

-"*Things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts*" (Networked Enterprise & RFID & Micro & Nanosystems, 2008).

Nolin and Olson note that the IoT "*seems to envisage a society where all members have access to a full-fledged Internet environment populated by self-configuring, self-*

managing, smart technology anytime and anywhere" (Hofmann, 2017).

The next wave of innovation will be driven by the Internet of Things, Data and Services, an "Internet of everything" where subjects and objects alike can communicate in real time. Whilst this process began slowly, it is now gathering more and more momentum. Processing power, memory size and network capacity are all growing exponentially, while their cost is falling at a similar rate (Kagerman, 2015).

Thanks to the spread of RFID technology, embedded systems have now come to be regarded as a basic technology. At the same time, these embedded systems are now being equipped with sensors and actuators. The resulting systems are capable of recording, storing and processing a wide variety of data from their surroundings that can then be used to enable them to influence their environment. The result is an in- visible digital upgrading of traditional objects: the real and digital worlds converge and physical objects are enhanced with the flexible capabilities of digital functions, turning embedded systems into Cyber-Physical Systems that are capable of gathering a huge amount of data about their real environment and digital processes which is delivering higher and higher data resolution, enabling fine-grained monitoring of the environment. It will also be possible to connect manufacturing systems and business processes in factories and businesses in real time and across different companies—from ordering up to outbound logistics (Kagerman, 2015).

With the evolution of IoT technologies is also possible to interconnect all the stakeholders involved in the manufacturing industrial processes. Interconnection provides a link between partners, customers, employees, and systems to accelerate business performance and create new opportunities with collaborating on a shared platform. Interconnection is a requirement for instant access to interdependent and real-time data between industries or between different geographies. The industrial cloud provides a common platform to store data and to collaborate users from various geographies (Ervural et al., 2018).

According to Karacay et al.(2018), there are three major barriers in scaling IoTs adoptions in business are standards, privacy and security concerns:

Privacy

Privacy concerns is a huge barrier in adoptions of IoTs. Many IoTs or smart devices transmit information across networks without encryption, which creates huge risks of privacy;

Standardization

Standardization is another important barrier for IoTs adoption, and has been holding back the value generation potential of the market. As the adoption of IoTs based systems spread, companies will fundamentally need to rethink their accepted and traditional views about value creation strategies in markets. IoTs are not just about new smart devices, but more significantly they mean productivity improvements as well as uninterrupted connectivity of economies all over the world;

Security

The occurrence of the Internet of Things (IoT) has dramatically altered the appearance of cyber threat. The increasing data density with Industry 4.0 and the fusion of information technology and operational technology, brings newer challenges, particularly regarding cyber security.

2.8 Industrial Big Data and Industrial Cloud Computing

As the name implies, Big Data literally means large collections of data sets containing abundant information. A brief definition can therefore be that big data refers to data sets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyze. From an industry point of view, big data is going to play an important role in the fourth industrial revolution. The fuel of the fourth industrial revolution, will be big data to be made available through Cyber- Physical Systems (CPS). The goal is to realize smart factories, in which machines and resources communicate as in a social network (Yin et al.,

2015).

Smart factories will produce intelligent products (smart products) that know how they have been produced, and will collect and transmit data as they are being used. These huge amounts of data (big data) will be collected and analyzed in real time, generating new insights to be used in order to generate from smart factories to smart processes, and finally, to the level at which intelligent services can be provided to the customer through internet-based services. At a higher level, the data sent by the smart devices can help the manufacturer to pinpoint the preferences of the consumers and, thus, shape future products (Yin et al., 2015).

Big data and cloud computing are highly interdependent. Without cloud computing, big data is useless and vice versa.

Industrial sensors, radio frequency identification systems, bar codes, industrial automation control systems, enterprise resource planning, digital aided design and other technologies are increasingly rich in industrial data volume. These data are huge and unstructured, which is difficult to process, so it is imperative to use some professional tools to solve it. Cloud computing will change the traditional way of passive market research model and use the active perception, discovery to realize accurate insight into market information. In addition, cloud computing is to use public servers and network device. It will reduce most cost on equipment and allows companies to focus on increasing their core value services (Yue et al., 2015).

In the information age, the core competitiveness of a company is fast information and real-time responses, which require the cloud technologies to provide fast, accurate and uninterrupted computing from social resources and manufacturing resources. In another part, Industry 4.0 will generate countless data from various domains like sensors, machines and social networks. This means that the cloud computing must integrate these data and find the useful information (Yue et al., 2015).

2.9 Vertical and Horizontal Integration

Most of today's IT systems are not fully integrated. Companies, suppliers, and customers are rarely closely linked. Nor are departments such as engineering, production, and service. Functions from the enterprise to the shop floor level are not fully integrated, even engineering itself - from products to plants to automation- lacks complete integration. But with Industry 4.0, companies, departments, functions, and capabilities will become much more cohesive, as cross-company, universal data-integration networks evolve and enable truly automated value chains. This is made possible by having a full Vertical and horizontal integration (Rüßmann et al., 2015).

As stated by Kagerman et al. (2013), vertical integration refers to the integration of the various IT systems at the different hierarchical levels (e.g. the actuator and sensor, control, production management, manufacturing and execution and corporate planning levels) in order to deliver an end-to-end solution. The setting for vertical integration is the factory. In tomorrow's smart factories, manufacturing structures will not be fixed and predefined. Instead, a set of IT configuration rules will be defined that can be used on a case-by-case basis to automatically build a specific structure for every situation, including all the associated requirements in terms of models, data, communication and algorithms

On the other hand, the horizontal integration consists in the collaboration between enterprises, with re- source and real time information exchange (Brettel et al., 2014). This end- to-end engineering is the integration of engineering in the whole value chain of a product, from its development until after-sales. This implies that there is an integration of the various IT systems used in the different stages of the manufacturing and business planning processes that involve an exchange of materials, energy and information both within a company (e.g. inbound logistics, production, outbound logistics, marketing) and among several different companies (value networks). The goal of this integration is to deliver an end-to-end solution (Gilchrist, 2016; Kagerman et al, 2013).

2.10 Distributive Manufacturing

Distributed manufacturing involves disaggregating the value chain and dividing a product into its sub-parts, or related sub-processes, such that production occurs at separate locations. Distributive manufacturing is often linked to sustainability and the need to sustainability performance measurement in manufacturing and enterprise operations. This subject gained traction, largely motivated by the growing awareness of industries, consumers, and government agencies of responsibilities for the environment, economic development, and social welfare through standards, policies, and regulations (Nagarajan et al., 2018). Thus, a progression toward virtual cloud enterprises, including cloud manufacturing, through information technology advancements, has enabled a fluid transition from a centralized traditional manufacturing system to independent, autonomous, and decentralized production units (Nagarajan et al., 2018).

In distributed manufacturing (DM), the fabrication is decentralized, and the final product is manufactured very closely with the final customer. Cloud-based manufacturing combined with cyber-physical systems are enablers of manufacturing networks for geographically distributed production. According to Wu et al. (2013), Cloud Manufacturing is a customer- centric manufacturing model that exploits on-demand access to a shared collection of diversified and distributed manufacturing resources to form temporary and reconfigurable production lines that enhance efficiency, reduce product lifecycle costs, and allow for optimal resource loading in response to variable-demand customer generated tasking (Rauch et al., 2018).

There are several subjects that can be addressed under the distributive manufacture scope. For this research it is important to address the following:

Additive Manufacturing systems

A fundamental factor that permits individualization and customization of product is the flexibility of the fabrication technology in terms of product variety.

One of the emerging technologies that seems to ensure the fulfillment of these requirements is additive manufacturing (AM) (Rauch et al., 2018).

Up to now, prevalent method in manufacturing industry has been subtractive methods, which they generate a product with high precision by grinding a material or cutting it away from the block of solid material. It can be done by either manual or automatic processes. However, there is another manufacturing method that may challenge traditional subtractive methods: Additive manufacturing. Additive manufacturing technique builds a product by adding layers onto other layers using raw material **(**Beyca et al., 2018).

According to the authors Beyca et al. (2018), it is possible to identify some key advantages of this new manufacturing process such as:

- Decrease in waste: In traditional subtractive manufacturing techniques, large amount of raw material is cut and wasted in order to manufacture a part. On the other hand, AM only uses the raw material needed to manufacture the part and also leftover raw material can be reused;
- Increase in time: With conventional techniques, producing a prototype may take several days or even weeks while AM technologies can provide functional working prototype mostly within hours;
- Production flexibility: Most of the parts need several manufacturing steps and assembly workshops which affects the overall quality of the product. AM technique manufacture the part in one process and eliminates the effect of operator on product quality;
- Increase in variety: Since complex parts can be produced with little setup, custom designed products can easily be produced with little cost;
- Decrease in labor skill: Automated production requires little or no operator skill.

As reported by Tuck et al. (2006), AM technology is ideal for lean supply

chain and Just in Time (JIT) manufacturing. With the help of AM, set up and changeover time will be reduced, and the assembly process will also be shortened. This will eliminate most of the non-value added processes such as material handling and inventory management which will minimize the supply chain cost.

In addition, a responsive supply chain can be constructed using AM process. A made-to-order strategy can be applied to eliminate the stock out and inventory. Customization of the products will ensure that the made-to-order strategy will be implemented successfully and increase the responsiveness **(**Beyca et al., 2018).

Additive manufacturing and 3D printing are closely linked, and some authors consider that these are two different names for the same phenomena **(**Beyca et al., 2018).

3D printing employs an additive manufacturing process whereby products are built on a layer-by- layer basis, through a series of cross-sectional slices. While 3D printers work in a manner similar to traditional laser or inkjet printers, rather than using multi-colored inks, the 3D printer uses powder that is slowly built into an image on a layer-by-layer basis. All 3D printers also use 3D CAD software, that measures thousands of cross-sections of each product to determine exactly how each layer is to be constructed (Berman, 2011).

Current applications of 3D printing typically involve small production runs of small and complex items. These include mass-customized products, prototypes and mockups, replacement parts among others.

According to Berman (2011), 3D printing has undergone a three-phase evolution process. In phase one, architects, artists, and product designers used 3D printing technology to make prototypes or mockups of new designs. The second evolutionary phase of 3D printers involves their use in creating finished goods. A popular second phase application is larger production runs that encompass bridge manufacturing and the manufacturing of goods to be used in test marketing. In test marketing, multiple prototypes – different sizes, styles, and colors – can be more easily produced and market tested. In the third phase,

3D printers will be owned and used by final consumers, just like traditional desktop laser printers (Klaft, 2010).

Using social network and 3D printing technology, anyone can participate in the process of production chain and any computer may become a small factory. With the transformation of information and manufacturing, intelligent manufacturing has reached a new level of development (Wan et al.,2015).

3D printing has been both compared to and contrasted with mass customization. Advocates of 3D printing argue that this technology, like mass customization, enables firms to economically build custom products in small quantities. While both processes can profitably make limited-quantity lot sizes and share other benefits, they are very different in terms of their manufacturing technology and logistics requirements (Berman, 2011).

Product Mass Customization

In this 4th Industrial era, it is possible to notice that there is a preparation of a computerized, intelligent manufacturing environment, guaranteeing flexibility and high efficiency of production, integration of different activities and effective communication between a client and a producer, as well as between the producer and suppliers. Having this in consideration, it is safe to assume that the smart factories of the future will be autonomous units, able to plan, organize and even control the production themselves. This is why the idea of Industry 4.0 can be key in realizing assumptions of a strategy known as mass customization (MC), which is focused on fulfilling individual client requirements by production companies (Zawadzki et al., 2016).

There are many different authors that have different descriptions of the term Mass customization. Davis (1987), refers it when "*the same large number of customers can be reached as in mass markets of the industrial economy, and simultaneously treated individually as in the customized markets of pre-industrial economies*".

Other description is giving by Pine (1993), who made this term popular and described it has "*providing tremendous variety and individual customization, at prices comparable to standard goods and services*" to enable the production of products and service "*with enough variety and customization that nearly everyone finds exactly what they want*."

Tseng and Jiao (2001), introduced another more pragmatic definition which is "*the technologies and systems to deliver goods and services that meet individual customers' needs with near mass production efficiency*."

Piller (2005), defined that, Mass customization is a "*Customer co-design process of products and services, which meet the needs of each individual customer with regard to certain product features*." All operations are performed within a fixed solution space, characterized by stable but still flexible and responsive processes. As a result, the costs associated with customization allow for a price level that does not imply a switch in an upper market segment.

In order for companies to achieve this level of customization, it is necessary to take risks and make investments in new tools, virtual reality technologies or additive manufacturing processes, aiding both virtual and physical preparation of a new product design (Zawadzki et al., 2016).

Digital models of products and production processes, enriched with a properly prepared knowledge base, are essential elements of intelligent IT systems, integrating configuration of a product by a client on the one side, and automatic preparation of an appropriate product design and its manufacturing process in a company on the other side (Zawadzki et al., 2016).

According to the same authors, the highest degree of customization, known as the collaboration customization, is achieved when a recipient is assumed to be engaged during design and manufacturing of a product variant where is possible for clients to define their requirements themselves, through special product configurators.

Having this in consideration, it can be stated that the Mass customization strategy becomes a competitive strategy under the condition that the company is able to quickly respond to expectations and requirements of its customers. In

other words, it is able to join the MC strategy with another strategy known in literature as Quick Response. This connection is possible if a company has a flexible manufacturing system and a possibility of rapid design (in terms of duration), as well as implementation of new products and processes of their manufacturing (Zawadzki et al., 2016).

Customer Co-design

The core of mass customization is customer co-design. Customers are integrated into value creation by defining, configuring, matching, or modifying an individual solution. Customization demands that the recipients of the customized good transfer their needs and desires into a concrete product specification (Piller, 2005). According to Ramirez (1999), the activity of Co-Design is done in a mode of interaction with the manufacturer who is responsible for providing the custom solution to the specific needs of a client.

Customer co-design also establishes an individual contact between the manufacturer and customer, which offers possibilities for building up a lasting relationship. Once the customer has successfully purchased an individual item, the knowledge acquired by the manufacturer represents a considerable barrier against switching suppliers (Piller, 2005).

From a managerial point of view, customization can be carried out with regard to fit, style, and functionality. Take the example of a shoe. Here, fit is mostly defined by its last, but also by the design of the upper, insole, and outsole etc. Style is the option to influence the aesthetic design of the product, i.e., colors of the leather or patterns. The functionality of a shoe can be defined by its cushioning, form of heels, or the structure of cleats. From a client point of view, and referring Chamberlin´s theory of monopolistic competition (1962), customers gain from customization and from the increment of utility of a product that fits their needs better than the best standard product attainable.

In order for companies to be successful in implementing Mass customization strategies, it is imperative to define the solution space (Piller,

2005). The solution space represents the pre-existing capability and degrees of freedom built into a given manufacturer's production system" (Von Hippel, 2001). Having the solution space well defined, customers can perform co-design activities within a list of options and pre-defined components. This space determines the universe of benefits that an offer intends to provide to customers, and then within that universe, the specific permutations of functionality that can be provided (Pine, 1995).

Mass customization does not mean to offer limitless choice, but choice that is restricted to options which are already represented in the fulfillment system (Piller, 2005).

Having all of these factors in consideration, it is possible to conclude that the fourth industrial revolution will have impact in all spheres of society's life— especially, in economy. According to Popkova et al.(2018) the main directions of change are:

1. Self-optimization and self-adaptation of cyber-physical systems" the means of self-optimization and self-adaptation, endogenous adaptation of the system's goals to changing external influences, which conforms to the tasks of activities and ensures effective correction of the system's behavior. Reliability of such cyber-physical systems will grow substantially, as they will be more reliable against temporary errors.
2. Man-machine symbiosis: growing complexity of intellectual systems set high requirements to natural and intuitively understandable man-machine interfaces. Flexible setting for developer ensures consecutive and well-structured interaction, which supports convenience of usage of technical systems.
3. Intellectual networks (artificial intelligence): intellectual technical networks consist of a lot of closely connected and complex systems which connection leads to global changes in production.
4. Energy efficiency: cyber-physical systems allow determining and using

reserves of economy of electric, heat, and other energy from the stage of design to exploitation,

Changing the structure of costs along the whole chain of formation of product's cost.

Industry 4.0 is considered a new industrial stage in which vertical and horizontal manufacturing processes integration and product connectivity can help companies to achieve higher industrial performance. This new industrial stage is affecting competition rules, the structure of industry and customers' demands (Gilchrist, 2016). It is changing competition rules because company's business models are being re-framed by the adoption of IoT concepts and digitization of factories (Dregger et al., 2016).

Innovation is especially critical as a driver of productivity growth and value creation in the 4th Industrial revolution. It is already at the core of the growth agenda of most advanced economies and a growing number of emerging economies. In order for companies to be competitive in this new era, it is imperative that they adapt to these changes and innovate not only their production sites, as well as their knowledge and processes.

According to APPICAPS (2018), by 2020, the Portuguese footwear industry aims to be a key point of reference for the industry worldwide. In order to achieve this position companies are currently and consistently, implementing a set of strategic initiatives that cover qualification, innovation and internationalization. In this sense, and with the emergence of the new concepts of Industry 4.0, the Portuguese Footwear Cluster has created a roadmap to address the digital economy - FOOTure 2020. With a planned investment of 49 million euros, the Portuguese Footwear Cluster intends to significantly improve the flexibility, while working towards greater customer engagement, higher levels of product customization and the development of tailored services.

3. The Footwear Industry

In the present section, some relevant data regarding the Portuguese footwear sector is highlighted. Based on the data collected, is possible to realize that the current situation in Europe is not favorable and that the market demands are more difficult to deal with and also more heterogeneous, which puts the Portuguese manufacturers in an unfavorable position.

In order to respond to the new demands of the clients and also, be able to compete with emerging producers based in Asia and Africa, Portuguese manufacturers will have to invest in new technologies and innovation in order to become more flexible, more efficient and have a quicker response capacity.

Innovation will be key to achieve success, and there are already good examples of Portuguese companies that are following this route in order to highlight their capacities. Some examples, such as Undandy Shoes, allow for a 100% customizable shoe that can be ordered online. This company is applying the 4.0 technologies not only in their production, but also in their services and marketing AMF Safety shoes is another example of a company that is using new production technologies in order to be more competitive in the market, and be able to have a better response to the client´s increasingly changing demands.

3.1 The Footwear Industry

One of the most profitable markets in the world is the fashion and lifestyle industry and it is defined to be a billion-dollar industry employing millions of professionals all around the word. Fashion industry is one of the most dynamic supply chains in the world and due to this nature, there are new challenges and many opportunities presented. The footwear industry is part of the fashion industry and will be the focus of this study.

This sector is characterized by a season-driven product lifecycle. Marketing campaigns are linked to exhibitions and fairs tied to two typical season collections, for summer and winter. Its main product life- cycle activities

refer to collection creation, sample production, sale campaign, production, finished product stock, shop sales monitoring, and re-orders. It is also characterized by a centralized procurement: shoe producers often contract different companies for labor-intensive production phases (Chituc et al., 2008).

A trend commonly identified is the increase of the number of models offered, with very low volumes. In this way, traditional shoe producers are forced to focus on high-quality, and high- fashion shoes, which are available in very small quantities, in a make-to-order approach (Chituc et al., 2008).

3.2 The Portuguese Footwear Industry

Evolution

The Portuguese footwear industry has displayed, throughout the last six years, a remarkable performance in several economic and competitive indicators. Leather shoes are the main category of footwear products manufactured in Portugal, being that the country is the 10th World Exporter of Leather Shoes. It represents around 75% of all products done in this industrial sector (Marques et al., 2017).

In fact, if in the 1970s and 1980s, the industry grew based on the low labor costs and on scale-economies based on large volumes, in the 1990s this was not possible anymore. Throughout the 1990s, many global buyers of footwear moved their operations and orders from Portugal to Asia and Eastern Europe. While not discarding, by any means, the importance of cost, it is fairly obvious that Portuguese companies can only remain in the market and prosper by pursuing a differentiation strategy, supported by innovation (Abrunhosa & Moura E Sá, 2008).

Exports: benefits, challenges and threats

In 2017, Portugal consolidated its position in most of the countries of the European Union, where its traditional business partners are mainly located,

being the destination for 86% of its footwear exports. While continuing to consolidate its position in its most important markets, the Portuguese footwear industry also ventured into new ones, overcoming the constraints of the international markets and the uncertainty that has dominated the world economy (APPICAPS, 2018).

Despite facing challenges within national and international macroeconomic frameworks, the Portuguese footwear industry is expanding, which suggests that it is implementing appropriate strategies (BP, 2012).

In the last 3 years, there has been a global slowdown in economic growth and a deep recession in the eurozone, with gross domestic products contracting in 2012 and 2013. For a highly export-oriented industry such as footwear, with exports mostly directed towards Europe, the crisis imposed an extremely unfavorable environment for further external expansion (APICCAPS 2014).

In these unpromising circumstances, the industry asserted itself, yet again, as a mainstay of the Portuguese economy (APICCAPS 2013; BP 2012). Between 2010 and 2012, contrary to the national recession, the sector managed to increase both its employment and output significantly: 10 and 20 %, respectively, according to its employers' association, APICCAPS (2013). According to the same source, there are 1354 footwear firms with a total of 35,355 employees, suggesting that, on average, the bulk of these firms are small rather than medium-sized (Marques et al., 2016).

In 2016, the footwear cluster carried on in a moderately favorable economic climate, not differing greatly from the previous year. The political events of the year, however, particularly the United Kingdom's "Brexit" and the results of the United States elections, had their effect on economic agents and were reflected in a downturn, although slight, in the growth rate of GDP, both world-wide and in the Euro Zone (APICCAPS, 2017)

In the same year, Portugal has exported more than 81.6 million pairs of shoes with a total value of more than 1.9 billion euros. This performance represents a growth rate of 3.2% over 2015, and also the seventh consecutive year of growth in sales to the foreign markets. In this short period, the Portuguese

footwear industry has presented an outstanding growth dynamic, increasing its exports revenue in roughly 50%. A particularly positive performance considering the instability felt in foreign markets and the uncertainty impacting important footwear consumer markets (worldfootwear.com).

The industry's exports are growing over 7 % annually, and they account for 96 % of total production. Portugal is second only to Italy in the international ranking of average footwear export prices, with prices rising 25 % between 2006 and 2012, placing the former country in seventh position in terms of worldwide export values, although it is ranked twenty-first in terms of volume. In achieving this position, an enhanced focus on innovation and design has greatly contributed to gaining a larger market share and consolidating the positive image of Portuguese footwear worldwide (Marques et al., 2016).

Taken together, these changes forced Portuguese companies to adopt technological innovations at the shop floor level in order to shift from the production of large to small batches, and to constantly develop and produce fashionable shoes (Abrunhosa et al., 2008).

Technological Enhancement: a new era of modernization

In the last few decades, the Portuguese footwear industry has undergone rapid and intensive transformation. Footwear companies braced the challenge to modernize their facilities and production methods, also investing in the less tangible aspects that gave them a competitive edge. Nowadays, Portuguese companies are known worldwide not only for the quality of their footwear but also for the excellence of their service, the ability to deliver small series, always based on a quick response to the market needs and requirements (worldfootwear.com).

Having this in mind, the Portuguese shoe industry is already taking the steps in order to become more competitive in this new technological era. Some examples of this new wave of startup companies, that are taking advantage of the new technologies that are embedded in the Industry 4.0, are the ones that use the App and photos in order to build a 3D model of the person´s feet in order to

better advice the customer in which shoe fits better; other example is a Portuguese company that is making custom shoes for brides; It is possible to find companies that use the online store to sell totally customized shoes, where the client is able to choose every aspect of the shoe, from the material, color and shape (Dinheirovivo.com, 2017).

According to a study from a 2013 study by APPICAPS - Footure 2020 - in order for the Portuguese shoe industry to be capable of competing with emerging markets such as Asia and Africa, it is crucial to innovate the technologies used in production of leather products, nanotechnologies, robotization, biotechnology, processes and solutions that reinforce the flexibility of production. It is also imperative that the companies focus in new manufacturing and processing technologies, information and communication, and new solutions for e-commerce.

Innovation is key. Innovation in terms of products, materials, equipments, processes and business models. Only through innovation and through differentiation factors, will the Portuguese companies be able to compete with other companies outside of Europe, that compete with lower prices (APPICAPS, 2013).

In order to be more competitive, Portuguese manufacturers have to invest in the digitalization and sophistication of both producing and selling methods. Having this in mind, the CTCP (is continuously investing in the application and sharing of know-how amongst specialized workers, through different projects such as Step2Footure. This project promotes innovations that are based in the application of advanced producing systems based on plasma and laser technologies, in new ways of using materials and shoe products, as well as 3D printing. Another priority is also the flexible manufacturing that envisages the production of customized products, made possible by intelligent robots and Cyber physical systems. This also entails the digital integration of consumers, retailers and producers (CTCP.pt, 2018).

Implementation of Industry 4.0 Technologies

These technologies are based in advanced balancing and sequencing production algorithms. It also incorporates a web and mobile interface that promotes an efficient management of the production, pre-sewing and sewing lines. In terms of production, the new technologies based on the IoT and Cyber Physical systems, allow the production of an unlimited number of models at the same time, which allows the manufacturer to produce different categories of products, with smaller volumes simultaneously. This has an huge impact on the times and flexibility of production (CTCP.pt, 2018).

In order for companies to be more competitive is imperative that they invest in new technologies and innovations in order to have a faster response to the on-going demands of customers. The companies that do improve their production and technologies will be able to be more flexible in the market. A good example is Timberland.

Due to the increasing pressure to quickly and affordably turn the marketer's vision and the consumer's taste into reality that performs well, feels good and looks great, the company adopted a 3D printing system to produce their prototypes. According to Toby Ringdahl, Computer Aided Design Manager of The Timberland Company, the Color Jet printers have allowed compressing the design cycles, lowering the costs and helping produce better products for the customers. The full color printers accept CAD files from Timberland's 3D mechanical design software and produces physical models affordably and quickly. For example, a prototype that used to cost Timberland $1,200, now costs $35. A prototype that used to take a week to make now takes 90 minutes, enabling engineering and marketing employees to collaborate more often and more closely. And printing out rapid color prototypes onsite has enabled Timberland to compress its typical design cycle from three weeks to two (3dsystems.com, 2018).

The adoption of this technology is also making an impact on sales due to close collaboration among designers, engineers and marketers. This brings to the market a product that is exactly what the customers demand and, because sales

people occasionally bring prototypes to sales calls with major retail chains, this give them a bigger advantage over competitors who come with only sketches. In these instances, sales people can land large sales earlier. According to the manager, "*CJP printers have allowed compressing our design cycles, lowering our costs and helping us produce better products for our customer*" (3dsystems.com, 2018).

Another example of success in implementing the 3D technology is the Portuguese company AMF Safety Shoes, that uses this technology to print soles for samples and mockups.

3.3 Interoperability

(One) of the key factors of industry 4.0 is Interoperability. According to Chen et al. (2008) , interoperability is "*the ability of two systems to understand each other and to use functionality of one another*." It represents the capability of two systems exchanging data and sharing information and knowledge. The interoperability of Industry 4.0 will synthesize software components, application solutions, business processes, and the business context throughout the diversified, heterogeneous, and autonomous procedure (Lu, 2017).

This interoperability is possible by using RFID tags in order to facilitate the communication between the products, machines and people. RFID or radio frequency identification is a wireless tracking technology that allows a reader to activate a transponder on a radio frequency tag attached to, or embedded in, an item, allowing the reader to remotely read and/or write data to the RFID tag (Curtin et al., 2007).

This technology increases the ability of the organization to acquire a vast array of data about the location and properties of any entity that can be physically tagged and wirelessly scanned within certain technical limitations. RFID can be applied to a variety of tasks, structures, work systems and contexts along the value chain, including business-to-business logistics, internal operations, business-to-consumer marketing, and after-sales service applications (Curtin et

al., 2007).

An example of use of the use of this technology is given by the authors Schroder et al. (2015). They present a case study about a shoe manufacturer that uses an automated shoe assembly line using RFID tags.

In this case study, the authors analyze the differences in production and defects per day in using traditional methods and using RFID systems in order to improve productivity. The results were an increase in productivity, a decrease in defects per day and a more flexible producing system without compromising the job positions of workers. This is made possible by installing RFID tags in all the parts of the shoe that go into production. These tags are read by the sensors, which are installed in all the machines in the production line. This process is completely automatized and do not require any human interaction. With this type of identification, it is possible to control the velocity of the line and the potential issues that may occur during production. Due to the fact that these processes are automatized, there are more workers available to resolve the problems or defects that may occur during production (Schroder et al., 2015).

4. Methodology

In this section, different investigation strategies that were used are presented in order to develop the study. Explanations on the reasons that were behind the choice of the type of methodology used to answer to the research question "Implications of the implementation of Industry 4.0 technologies in the Portuguese footwear industry", are presented. Next on, it is explained how the study tools, that were used to collect the data, were designed and also how the sample was chosen. Once the choice of methodology, data collection process and sampling is done, it is important to analyze the information using different study tools.

4.1 Investigation Strategy

According to Robson (2002), the distinction between the quantitative and qualitative methods is the best way to classify an investigation strategy. Sale et al (2002) argued that the quantitative paradigm is based on positivism. Science is characterized by empirical research and all phenomena can be reduced to empirical indicators which represent the truth. Having this in mind, it is possible to assume that the ontological position of the quantitative paradigm is that there is only one truth, an objective reality that exists independently of human perception. Some techniques used in this type of research include randomization, blinding, highly structured protocols, and written or orally administered questionnaires with a limited range of predetermined responses. Sample sizes are much larger than those used in qualitative research so that statistical methods to ensure that samples are representative can be used (Carey, 1993).

In contrast, the qualitative paradigm is based on interpretivism (Altheide & Johnson, 1994) and constructivism (Guba & Lincoln, 1994). Ontologically speaking, there are multiple realities or multiple truths based on one's construction of reality. Reality is socially constructed and so is constantly

changing (Berger & Luckmann, 1966). The investigator and the object of study are interactively linked so that findings are mutually created within the context of the situation which shapes the inquiry (Denzin & Lincoln, 1994).

The emphasis of qualitative research is on process and meanings. Techniques used in qualitative studies include in-depth and focus group interviews and participant observation. Samples are not meant to represent large populations. Rather, small, purposeful samples of articulate respondents are used because they can provide important information, not because they are representative of a larger group (Reid, 1996).

Having this in mind, the qualitative approach is better suited to real-life problems where is possible to find some confusion derived from the different meanings given to the same reality (Checkland, 1988). In the table below are represented the main differences between the quantitative and qualitative methods.

	Quantitative research	Qualitative research
Purpose	Test hypothesis	Develop hypothesis
	Prevision	Interpretation
	Explanatory: what is the relation between the hypothesis	Exploratory: which are the variables involved
Approach	Starts with theories and hypothesis	Starts with the research question
	Formal instruments	The investigator is the main instrument
	Aims for consensus	Aims for pluralism
	Analyses the different components	Looks for patterns
Responses	Predetermined, unbiased and objective	Undetermined and biased
Measurement tools	Objective	Interviews, focus groups

Role of the investigator	No involvement, objective and impartial	Involvement and partiality
Methods	Reliable and valid measurement tools	Interviews, focus groups
Outcomes	Statistical analysis	Rich narratives
Context	Context free	Context dependent

Table 1 : Differences between Quantitative and Qualitative research methods
Source: Salkind, 2018, Glesne & Peshkin, 1992; Healy & Perry, 2000; Hancock *et al.,* 1998

Having all this information in consideration it is considered that, in order to answer to the research question "Implications of the implementation of Industry 4.0 technologies in the Portuguese footwear industry?" the investigation should follow a qualitative analysis with an exploratory nature. This is due to the fact that the research question is about a subjective reality that is open to different interpretation and beliefs and will vary according to the point of view of different individuals which leads to a multitude of interpretations.

The aim is to contextualize the topic of Industry 4.0 and the implications of the adoption of its technologies in the footwear industry. The conclusions derived from the interviews are very different and dependent of the opinions, perspectives, experiences and believes of each person interviewed.
In terms of approach, the investigation starts with the development of the research question cited above. The main goal of the study is to find an answer to this research question that is constructed with different patterns within the pluralism of hypotheses raised by the different points of view and their interpretations, instead of basing it in numeric data, which is linked with the quantitative methodology. In this type of study, the role of the researcher is to get involved in the investigation in an empathic and partial way. The fundamental basis of this study is based on personal opinions which are constructed having in consideration the academic and scientific state of the art and the application of the different study tools.

4.2 Qualitative research

Qualitative research, in the simplest terms, is social or behavioral science research that explores the processes that underlie human behavior using exploratory techniques such as interviews, surveys, case studies, and other relatively personal techniques (Salkind, 2018).

According to Rosenthal (2016), qualitative research methods are used in two circumstances. Firstly, qualitative research methods are employed when the researcher is interested in understanding the "why" behind people's behaviors or actions. From this perspective qualitative research provides a way to get an in-depth understanding of the underlying reasons, attitudes, and motivations behind various human behaviors. Secondly, qualitative research methods are also used when the researcher is interested in better understanding a particular topic from the perspective of participants in order to develop a survey to draw upon a larger, generalizable sample.

There is a number of methodologies in qualitative research including observations, in-depth interviews, and focus groups that may be used to collect data. In this study the methodology used is the interview.

Before conducting an interview, it is important for the researcher to have carefully considered which data collection approach will provide the best information to answer the research question under investigation. Next researchers must carefully construct their interview guide, and collect their sample of participants. Finally, all interviews or transcripts must be completely transcribed and analyzed to identify important themes (Rosenthal, 2016).

According to Patton (2002), in-depth interviews involve the posing of open-ended questions and follow-up probes designed to obtain an in-depth understanding of participants' experiences, perceptions, opinions, feelings, and knowledge.

However, the quality of the data received from an in-depth interview or focus group is dependent upon the level of thought put into the development of the questions posed to interviewees. According to the same author, there are six primary kinds of open-ended in-depth interview questions:

1) Experience or behavior questions: these questions are designed to get at an interviewee's actions, either past or present. In particular, a participant's responses should reflect a direct observation that could have been made by watching the participant;
2) Sensory questions: the focus is on things that the interviewee physically experienced, and can help them to better remember other experiences or behaviors;
3) Opinion or value questions: are designed to elicit interviewees' understanding of a particular phenomenon or experience, and provide specific insight into their goals and intentions;
4) Knowledge questions: questions seek factual information from interviewees;
5) Feeling questions are slightly different than opinion or value questions as they are intended to elicit a description of an emotion from the participant. As such, it is particularly important to develop the wording of these questions carefully
6) Background or demographic questions allow for the characterization of the people participating in the in-depth interview or focus group. However, if a careful and thoughtful sampling strategy has been utilized much of this information should already been known by the researcher

4.3 Interview

There are a number of different types of interviews that can be implemented in social research. Each type has its own objective and focus. Research questions and the information needed to provide holistic answers to these questions will determine the most convenient type to be employed. Structured interviews are a

type of interview that implies the control of the way to obtain information from interviewees. In other words, it is a pre-planned interview where the researcher writes down the interview questions before conducting it. Such a format is an effective way to keep the interview tightly focused on the target topic (Bryman, 2008). It also makes the interview comparable among interviewees. However, this type of interview lacks richness and limits the availability of in-depth data. Therefore, the flexibility of the interviewer in terms of being able to interrupt, and the interviewee to elaborate, is restricted (Dörnyei, 2007).

Unstructured interviews are the opposite of the above, in that the flexibility of this type is wide open. Interviewees can elaborate, leading into unpredictable directions. This type is similar to a conversation in which the interviewer might ask a single question and then the interviewee has the choice with regard to the extent to which s/he responds (Bryman, 2008).

Semi-structured interviews are a mix of the two types mentioned above, where the questions are pre-planned prior to the interview but the interviewer gives the interviewee the chance to elaborate and explain particular issues through the use of open-ended questions. This type is appropriate to researchers who have an overview of their topic so that they can ask questions. However, they do not prefer to use a structured format which may hinder the depth and richness of the responses (Bryman, 2008).

In this study the investigation tool that better suits the research question was the semi-structured interviews in order to better capture the richness of the respondents and also to ask questions and make the conversation as smooth as possible.

These interviews were conducted with internal and external informants. Internal informants included top and middle managers that were listened to with the aim of getting acquainted with the firms' history, culture, strategy and the way they perceive and react to environmental changes.

These interviews were complemented with extensive talks with external informants such as industry experts. The role of these experts was critical in two

key stages of the research: the design of the questionnaire and the interpretation of some results. Interviews administered to the top managers of the firms, together with the ones that were conducted in the Footwear Technological Center (CTCP) and to two directors of APPICAPS, allowed the understanding of the circumstances under which innovations are being adopted and the main types of innovations introduced over the period of analysis. Additionally, the interaction with the experts facilitated the contact with the firms.

Direct observation took place throughout the visits to a sample of firms. These visits, which had an average duration of 1 hour, allowed the observation of behaviors displayed by managers, designers and production workers in the shop floor. In some cases, some participant observation was conducted while working alongside the production workers and gaining in-depth understanding of the activities involved in the production process.

Due to the fact that some of the companies chosen for the study are located in peripheral places and also, due to the difficulties in managing the schedule of the managers, one of the interviews were conducted over the phone. This modality is particularly enticing because it is cost-effective and allows the researcher to obtain results from a geographically disparate sample (Rosenthal, 2016).

In the past telephone in-depth interviews have been disparaged because of concerns such as the interviewer not being able to pick up non-verbal cues from interviewees. However, there is currently little evidence that demonstrates that the data collected over the phone is different than that collected in in-person (Novick, 2008). Moreover, with the proliferation of free video-chat apps, like Skype, these concerns are further mitigated.

Once the sample has been identified it is time to consider the approach to the in-depth interview. While the in-depth interview should feel like a casual conversation to the interviewee, the interviewer must be aware of the interview's flow and how the interviewee is reacting to the questions and let the interviewee know what kinds of responses are helpful. Note-taking during in-depth

interviews should be kept to a minimum, as it is often distracting to the interviewee (Patton, 2002).

From a technical perspective it is also important to consider how to capture the data collected during the in-depth interview. Typically in-depth interviews are audio recorded for the purpose of later transcription.

Once the in-depth interviews have been conducted the next step is transcription of the audio files to written text for further analysis. This can be a very lengthy process depending on the quality of the recording and the experience of the transcriber, but is necessary for the analytic process and to maintain the confidentiality of participants.

With the transcriptions complete, analysis of the in-depth interviews can take place. At its most basic level qualitative analysis involves "thick description" that is the process of taking the reader into the setting, context, and content of the in-depth interviews (Rosenthal, 2016).

To start the thick description the researcher independently reads, and re-reads each of the transcripts to identify recurring ideas, as well as omissions by interviewees. This process is called coding, and often involves highlighting interviewee comments and writing notes in the margins of transcripts. In general, this process identifies a large number of codes, many of which will overlap in meaning and intent. Thinking about words or phrases that are synonyms can identify these overlapping codes. As such, the next step in the analytic process is to abstract those related codes into themes (Austin & Sutton, 2014).

Question design

Once the in-depth interview questions have been drafted it is important to make sure that they conform to a few additional guidelines. Firstly, the questions should be truly open-ended and neutral. In practice this means that the questions should neither make assumptions about what the interviewee thinks about the topic, nor should they offer any clues as to what the interviewer hopes the interviewee will say. Secondly, the questions should be singular, asking about

only one topic at a time. Thirdly, the question must be clear (Patton, 2002).

Sampling

Determining the appropriate sample size for in-depth interviews is an important step in the research process. In quantitative studies researchers are particularly concerned with obtaining a generalizable sample (Singleton & Straits, 2010). However, generalizability is not the primary objective for in-depth interviews, but the objective is rather to develop an understanding of the meaning behind the behaviors (Kaae &Traulsen, 2015).

4.4 Description of the participants

The sample used in this investigation can be separated in two main cluster groups, with one being focused in factories in São João da Madeira and the second group in Felgueiras. Two extra interviews were added in order to have a more complete sample for the investigation. These two companies, are not located in Felgueiras nor São João da Madeira, but were specifically chosen due to their high degree of automation and for being technologically more advanced than the remain factories used in this investigation.

The two main groups (Felgueiras and São João da Madeira) are formed by 4 companies that operate in the shoe manufacturing sector. In order to better contextualize the information derived from the interviews, it is important to understand the different realities of these two different locations in regards to manufacturing conditions.

S. João da Madeira is known as the Portuguese "shoe capital" due to the fact that this was the place where, in 1483 was registered the first shoe factory in Portugal. Today, this industry is known for being less technologically advanced, when compared with other places like Felgueiras, but the type of product is also different. The production in São João da madeira is typically focused in better quality shoes and in a complex type of production that requires more labor intensive activities. Felgueiras, on the other hand is known for having a larger

production capacity and producing higher volumes of the same design, which in the early years, was linked to less quality products, but nowadays, due to the technological advances of the machinery and processes, these factories are more able to produce large quantities while maintaining high quality standards.

In order to have a better understanding of the Portuguese footwear sector, an interview to the manager of the CTCP was conducted and also to two different managers of APICCAPS. The following interviews were conducted to ten different companies, four located in Felgueiras , four located in São João da Madeira, one in Guimarães and the last one in Pedroso, Vila Nova de Gaia . Eleven of the interviews were conducted *in loco* and had the average duration one hour each. Due to difficulties in scheduling, one of the interviews was conducted over the phone. All the interviews were conducted with factory´s managers.

4.5 Data collection methods

The interviews were set according to the availability of the participants. Eleven of the interviews were face-to-face, while only one of the interviews was done over the phone due to incompatibility of schedules. All the interviews were recorded in order to elaborate the transcription afterwards. At the beginning of the interviews, a brief explanation was given about the Industry 4.0 concept, as some examples of the implications of the technologies in the footwear industry in order to guarantee that all the interviewed managers had some knowledge about the topic. It was also given an explanation about the scope of this study.

5. Results and Data analysis

After presenting the research method, it is time to analyse the results that were obtained through the study tools that were utilized, constructed and applied. Having this in consideration, in this part of the study, the results are going to be presented and the data collected will be analysed in an objective and pragmatic way.

5.1 Introduction

Methodology of data collection

As it was previously mentioned, the collection of data was performed in order to answer to the research question that is guiding the study. It started with an extensive revision of literature, followed by the interviews that were performed to the managers of ten different Portuguese shoe factories. Preliminary interviews were also made, in order to have a better understanding and overview of the Portuguese footwear cluster. These interviews were conducted with two Directors of the Portuguese Footwear, Components, Leather Goods Manufacturers' Association (APICCAPS) - Dr. João Maia and Dr. Alfredo Jorge and to the Director of the Portuguese footwear Technological Center (CTCP) – Eng. Leandro de Melo.

APICCAPS is a nation-wide association based in Porto, founded in 1975 and representing the following business sectors: Footwear industry ; Footwear components industry ; Leather goods industry and Equipment for the mentioned sectors. The association started as a support for the employment relationship and union management, but quickly became much more. On top of this service, activities were created to support the competitiveness of companies, which means that the focus is no longer only in the area of problem solving but in a proactive position to create conditions for Portuguese companies to have better capacities to compete in the markets. The Footwear Technological Center, on the other hand, was created as a

department of APICCAPS in 1982, and then formally became an autonomous entity in 87/88.

There has been a growing number of activities supporting the industry, being the center of support for everything that is industry activities and seeking to support the competitiveness of the sector that today functions as a cluster. In this work, the association divided their attention into 3 organizations: the association itself, the Technological Center, which encompasses all that are technical support activities, and the Center of professional training for all that are training actions.

Both the Technological Center and the Training Center are based in São João da Madeira and have branches in Felgueiras.

Since the beginning of the 1980s, APICCAPS has tried to have regular strategic plans, that is, all activities are framed in a strategic way of thinking for the sector.

In 2013, APICCAPS launched a new strategic plan for the footwear industry named FOOTure2020. This plan was developed in two different phases: the first one, started in 2014 and focused in applying the global strategic plan within the Community framework. That gathered global sector information such as strategy, markets, areas of innovation and areas of training. In a second phase, a strategic plan for the digital sector was developed as well. The goal was to create a specific plan on which is the sector's digital strategy and set out guidelines, i.e., what the sector should do to get a stronger digital footprint and how to take more advantage of the technologies that are available in the market. The aim of this strategic plan was to reflect on what are the technologies; to understand how they will impact the industry from a theoretical point of view, and try to select which are the ones that would have the greatest impact on the footwear sector. It was also important to seek and establish guidelines to introduce these technologies in the companies and realize how they will be implemented in different types of companies.

The previous sections were dedicated to the literature review, followed by the work methodology – qualitative and exploratory research- that justifies the tools used in this study - Interviews. It is now the moment to present the data that was collected during the interviews and that consubstantiate the results that were obtained.

The footwear cluster

The industries represented by APICCAPS are highly concentrated geographically, which justifies the correct assumption that the areas of Felgueiras / Guimarães and Santa Maria da Feira / São João da Madeira / Oliveira de Azeméis, in the North of Portugal, constitute their two main centers, with a third center of some significance in the Alcobaça / Alcanena region. Companies in the cluster are mainly small sized: 88% employ less than 50 people. A strong geographical concentration is one of the most noticeable characteristics of the Portuguese footwear industry, which is usually considered one of its strengths as it favours the diffusion of knowledge and the development of strong and resilient formal and informal business networks (Marques et al., 2016).

This can be perceived as the basis for the creation of a cluster, which according to Porter (1998) is a "a geographical concentration of firms and other interrelated institutions together in a particular field that compete but also cooperate".

The footwear industry follows a cluster organization firstly, because it follows the geographical concentration that is required in order to be denominated as a cluster. Even though, there are some other areas in which it is possible to find some very influential companies, the two main concentrations of shoe factories in Portugal are both in the north of the country and are located in Felgueiras and in São João da Madeira, being that these two locations have a very significant expression in the regional economic activity. Secondly, because it is possible to find that, in these regions were formed very complex formal and informal commercial networks among the companies, namely sub-contracting relations and sharing of information and knowledge (APICCAPS, 2013).

The Portuguese footwear cluster also has an institutional support network composed by the technological centre, the formation centre and the footwear association with actions that are recognized both nationally and internationally.

The cluster development in the last decades, was due to the fact that there is a narrowing of the relationships established between all the players that are part of the

footwear value chain. It is also possible to notice that the relations between the equipment industry, the fashion accessories industry, other suppliers of various kinds, the shoe distribution companies and institutions linked to the universe of design and fashion were intensified.

After conducting the CTCP interview, it is possible to notice that, in terms of size of the companies, production capacity and type of product, there are major differences between the Felgueiras and São João da Madeira region. According to Eng. Melo, the São João da Madeira region is characterized for having smaller companies that focus on producing smaller volumes of a higher quality products. This product is often more expensive and is more labour intensive which can justify the fact that, in these companies, it is not as usual to incorporate Industry's 4.0 technologies.

Felgueiras, on the other hand, is known for having factories of greater dimensions, with more employees and larger production volumes which is often linked to a type of production that is more machine dependent with more modern equipment.

The footwear cluster is strongly dependent on machinery suppliers, local software developers and on another identified cluster: the leather cluster, located in the center of the country. As this is a fashion-driven industry, it has to rely in different functional and aesthetic aspects as well, such as product design, branding strategies, marketing and distribution features.

Industry 4.0 in the Footwear sector

According to APICCAP´s strategic plan, FOOTure2020, there are 4 main axis that are important to incorporate in order to become the world leader in customer relationships through product sophistication, rapid response and better level of service:

1st Customer experience innovation, which is focused in creating new forms of customer interaction in a digital and network context;

2nd Smart Manufacturing with the aim of improving productive flexibility, response time, business intelligence and sustainability;

3rd Qualification, in order to qualify the footwear sector for industry 4.0 making it more dynamic, innovative and capable of creating new business;

4thSectoral leadership and plan coordination by promoting the knowledge of the markets and the image of the sector.

For this specific study, the analysis will only focus in the axis of Smart manufacturing, more specifically in the quick and flexible production which encompasses the advanced planning of footwear production for fashion and also automatic machines that allow a more efficient and faster production.

Another important aspect is the product development and efficient prototyping which include the development of new flexible production equipments with customization capacity and 3D additive manufacturing in sample production**.** Lastly, it is important to analyze the business intelligence and digitization caused by the increasing automation of the factory using the internet of things, production monitoring for virtual monitoring in real time and the increased business intelligence of footwear companies.

Main technologies

- **Production automation**

Automatic Cutting machine

Nowadays, there is a clear difference in cutting technologies applied to leather. Industrial leather processing serves the purpose of mass production of leather items in order to satisfy the demand of essential products like clothes, shoes, bags, etc. these demands for the technology to be economically efficient, fast, adaptive and to provide maximum possible results with minimum possible cost. Manual cutting with use of scissors and special knives is used in leather crafting. This enables the production of individual unique items whose value is not determined by functionality but based more on visual effects and design features. Currently technologies which are applied

to the leather cutting process include slitting knifes, manual cutting, die press techniques and Laser Cutting.

Laser cutting technology is revolutionary insofar as it comes to "alleviate" many of the costs associated with traditional cutting processes which were very high due to the waste of raw material created.

In the past, cutting was done manually or through a type of equipment commonly known as a *balancé (* hydraulic cutting machine *)*. While the use of a *balancé* is a faster process, compared to manual cutting, it has the drawback of inevitably creating waste, not being capable of utilizing the complete piece of raw material into production. The automatic cutting machine is much faster than manual operations and does not require sharpening. A very positive aspect is that it is very easy to operate and does not require highly skilled labor either in order to perform day-to-day operations. The negative aspect is its initial investment costs, that are still too high for most factories (Eng. Melo, CTCP).

Automatic Sewing machines

Computerized sewing machines contain digital microprocessors that control different programs. The computer receives the user's settings for simple setup and operations. The processes are automatically controlled by the machine after the user inputs the desired instructions. There are many automatic features as well such as automatic needle threader, automatic needle up and down, automatic thread cutter and auto tension. These features are convenient and time-saving, also allowing the worker to have a better speed control**.** (textilemates.com)

Automatic Assembling machines

Shoe lasting machine automation: One of the most critical aspects in shoe production automation is the machine automation. For the shoe lasting process, the manual operation required is to correctly position both sole and upper coat on the last and feeding the lasting machine. The shoe lasting machine then glues shoe upper and shoe last. Fully automated shoe lasting work-station setup consists of the lasting

machine, 6 DOF industrial robot equipped with special gripper and upper and sole positioning device (Nemec & Žlajpah, 2015).

Automated cell for finishing operations: Finishing operations in shoe manufacturing process comprises operations such as application of polishing wax, polishing cream, spray solvents and brushing in order to achieve high gloss. These operations require skilled workers and are generally difficult to automate due to the complex motion trajectories (Nemec & Žlajpah, 2015).

3D Bonding: This technology was developed in the University of Alicante (Spain), for three processes (cutting, injection and finishing). The common production process encompasses 5 stages: cutting, sewing, assembly, gluing or injection and, in the end, finishing. With this new technology it is now possible to shorten the process to only three steps: cutting, injection and finishing.

Automatic Storage:

The automatic storage in addition to saving space, allows greater efficiency and the correct handling of the cutters. This high-tech system for storage organization and materials handling saves time, storage space and costs, and enables a much more efficient workflow.

- **Product development and efficient prototyping**

Digital platforms, simulation and sensing - development of tools for collaborative platforms and simulation tools;

3D additive manufacturing in sample production.

- **Control, monitoring and business intelligence**

Production monitoring for virtual monitoring in real time: advanced solutions for digital footwear monitoring in real time integration of RFID or QR codes across the shoe value chain and/or through the different production stages for product and components tracking.

Integrated management system**:** an Integrated Management System (IMS) integrates all of an organization's systems and processes into one complete framework, enabling an organization to work as a single unit with unified objectives. There are many different programs that can be used in order to manage the different units of a company. Some programs are more complex and evolved than others, but the key is to have a system in which all the company's information is gathered in the same place so that it can be consulted by any employee at any given time. This will aid the control and monitorization of the different processes in the company and shall produce improvements in terms of efficiency throughout the workflow.

General Description of the Interviewed Companies

In this study, ten footwear producers were selected to be interviewed. One of the objectives behind this selection was to be able to get a real feeling of the reality and perceptions of industry players regarding Industry 4.0, thus, with the expectation of meeting managers that would display different notions and approaches about it, with various degrees of implementation noted in their production facilities as well. The producers were chosen based on preliminary interviews with institutions in the footwear sector, such as the technological footwear centre (CTCP) and the entrepreneurial footwear association (APICCAPS). The companies were selected against criteria of placement, operating in the B2B segment, being a manufacturer and having different market strategies. Data gathering methods consisted in intensive face-to-face interviews with business representatives (owner, director or manager).

Table 1 lists the general characteristics of the companies observed. Two different types of companies can be identified concerning their location: 4 companies are located in the Felgueiras area and other 4 are located in São João da Madeira . It is important to note that the companies with more than 50 employees, are generally located in Felgueiras, and the smaller ones are in the São João Madeira area.

Two other interviews were conducted in Procalçado and AMF Safety shoes.

Procalçado S.A.is one of the leading European companies in the footwear industry. The project began with FOR EVER ®, 40 years ago, producing soles for the largest

European footwear brands. Over the last few years it has grown towards the creation of brands of injected footwear: WOCK ® for the professional market and LEMON JELLY ® for the Fashion segment. It is also gaining a lot of attention due to their sustainability project that in recent years has been developing and that allows this northern company to reach 2019 with a production 100% powered by energy from renewable sources and also, according to Dr. José Silva (COO), "*Our brand follows a vegan line where we want to make ourselves known for sustainability, environmental concern and the possibility of recycling. A different and distinct concept*".

AMF Safety Shoes developed a distinctive approach in the area of protection footwear, by allying the expertise and experience gathered throughout the years with a strong dynamism at the level of innovation, design and product development. The AMF Safety Shoes safety concept includes a full solution for foot protection, always in the forefront of the safety sector.

This company has a product development department that is comprised by a multidisciplinary team of experts in the areas of design, ergonomics, podiatry, engineering and marketing. This department is completely dedicated to the development of new ideas and the creation of models for safety footwear, with the aim of satisfying the expectations of their clients. This company is also one of the most technologically innovative companies in the world due to a new technology incorporated - 3D Bonding. With this new technology, the company will be able to produce internally all the components needed and compete with the Asian markets. In conclusion, AMF Shoes is on the way to discover a way to make a shoe "with a very technological base", employing a method that guarantees much larger margins, since the production is less costly in resources and the final product continues to be of top quality (publico.pt, 2019).

These interviews were conducted in order to have a better and more informative notion of what is being made in the most technologically advanced Portuguese companies. In this case, the most important variable and criteria was the high degree of automation and digitization of the companies. Another important aspect is that only these two manufacturers have their own brands which are

marketed in accordance with their marketing rules and policies. These two companies, unlike the other 8 companies interviewed, work in the B2B segment which means that they do have efforts regarding marketing and brand positioning.

In table 2 are presented the names of the companies and the names of the interviewees. It is also discriminated the location, nº of employees of each company, daily production and main export markets.

Company	Interviewed	Location	Nº of employees	Daily production	Main Export markets
Samba S.A.	Dr. Rui Oliveira (Manager)	Felgueiras	100	800 pairs	Spain, Netherlands, Sweden, Germany
Cunha e Freitas	Dr.Vítor Freitas (COO)	Felgueiras	86	600 pairs	Germany, Russia, Canada, UK
Caminhar	Dr. Paulo Sousa (Owner)	Felgueiras	44	300 pairs	Germany, Netherlands, USA, Chile
Mazoni Indústria de calçado S.A.	Dr. Pedro Sampaio (Commercialdirector)	Felgueiras	92	750 pairs	France, Netherlands, UK
Newaim	Dr. Artur Silva (Manager)	S.João da Madeira	38	200 pairs	France, Switzerland, , Belgium, Germany
UedamaLda	Dr. Mauricio Guimarães (Owner)	S.João da Madeira	15	100 pairs	France Scandinavia, USA
Calçado Hércules	Dra. Maria da Luz (Financial Manager)	S.João da Madeira	58	200 pairs	France, Netherlands, Denmark

Company	Interviewed	Location	Nº of employees	Daily production	Main Export markets
LFC Industria do calçado Unipessoal LDA	Dr. Filipe Costa (Owner)	S.João da Madeira	16	130 pairs	France, Belgium, Denmark
Procalçado S.A.	Dr. José António Silva (Production Manager)	Pedroso, Vila Nova de Gaia	400	1000 pairs	France, Germany , Netherlands, USA, Canada , Turkey
AMF SafetyShoes	Dr. Rui Moreira (Plant manager)	Guimarães	140	-	Portugal, Spain, France, Netherlands, UK, Switzerland, Sweden, Germany, Austria, USA, Canada, Chile, Uruguai, Australia.

Table 2 Interviewed companies info

Eight of the companies analyzed operate in the production of leather shoes. Notwithstanding the industry's drive towards innovation, whether through the use of new forms of technology or of new materials, leather continues to be the first choice so far as footwear manufacturing materials in Portugal are concerned. This material

was used in almost 80% of the pairs produced in this country in 2016, corresponding to 90% of the value of Portuguese production (Statistical Report, APICCAPS, 2017).

Procalçado operates in a different segment being that their production is focused on plastic, rubber and synthetic materials.

AMF Safety shoes' production is focused in Shoes, Sandals, Boot, High boot, sportive shoes, and executive shoes. Different protection levels: S1, S2, S3, 02, 03, S1P. Different materials: leather, nubuck, microfiber, suede. Different toe caps and insoles: steel, kevlar, aluminium.

Main Export markets

	2011	%	2015	%	2016	%	Δ 16/15	Δ 16/11
Quantity: Thousand Pairs / Quantidade: Milhares Pares								
France / França	16 729	21,39%	15 984	20,13%	16 708	20,48%	4,53%	-0,13%
Germany / Alemanha	11 433	14,61%	13 408	16,89%	13 487	16,53%	0,59%	17,97%
Netherlands / Holanda	8 762	11,20%	10 417	13,12%	10 489	12,85%	0,69%	19,72%
Spain / Espanha	19 784	25,29%	13 700	17,26%	12 921	15,84%	-5,68%	-34,69%
UK / Reino Unido	5 711	7,30%	5 790	7,29%	5 819	7,13%	0,51%	1,91%
Denmark / Dinamarca	2 105	2,69%	3 017	3,80%	3 446	4,22%	14,23%	63,74%
Italy / Itália	3 554	4,54%	1 966	2,48%	2 527	3,10%	28,56%	-28,90%
Belgium / Bélgica	1 426	1,82%	1 713	2,16%	1 999	2,45%	16,67%	40,20%
Sweden / Suécia	813	1,04%	876	1,10%	1 245	1,53%	42,16%	53,17%
Switzerland / Suíça	845	1,08%	803	1,01%	662	0,81%	-17,53%	-21,60%
Russia / Rússia	714	0,91%	783	0,99%	741	0,91%	-5,42%	3,69%
Ireland / Ireland	490	0,63%	628	0,79%	603	0,74%	-3,89%	23,15%
USA / EUA	457	0,58%	1 909	2,40%	2 239	2,74%	17,27%	390,19%
Norway / Noruega	478	0,61%	431	0,54%	469	0,57%	8,85%	-1,91%
Angola / Angola	919	1,17%	1 402	1,77%	1 100	1,35%	-21,56%	19,70%
Canada / Canadá	434	0,56%	820	1,03%	774	0,95%	-5,61%	78,28%
Japan / Japão	369	0,47%	479	0,60%	353	0,43%	-26,37%	-4,49%
Greece / Grécia	359	0,46%	308	0,39%	374	0,46%	21,47%	4,41%
Finland / Finlândia	205	0,26%	181	0,23%	195	0,24%	7,95%	-4,91%
Australia / Austrália	133	0,17%	495	0,62%	620	0,76%	25,48%	365,96%
Austria / Áustria	177	0,23%	322	0,41%	403	0,49%	24,97%	127,09%
Others / Outros	2 328	2,98%	3 962	4,99%	4 422	5,42%	11,59%	89,90%
Total / Total	78 226	100%	79 395	100%	81 599	100%	2,78%	4,31%

Figure 1: Main export markets for Portuguese footwear producers

Source: Statistical Report, APICCAPS, 2017

In 2016, there were no changes of significant relevance in the main destinations for Portuguese footwear. The five main markets were, as usual, France, Germany, Spain, The Netherlands and the United Kingdom, in that order, which together received 73% of the footwear exported by Portugal, in quantity, and 70% in value (APICCAPS, 2017).

According to the data collected in the interviews, it is possible to verify that the main export markets are still in Europe, but, due to the difficulties in the European business environment, some manufacturers are now being forced to try to penetrate other markets such as USA, Canada and Chile.

Portuguese footwear has been endeavoring to diversify its exports geographically. Although this is a slow process, the results are already visible in the statistics: whereas in 2006 the European continent absorbed over 95% of Portuguese footwear exports, in 2016 that share fell to below 90%. Outside Europe, the presence of Portuguese footwear is most significant in America.

The type of footwear produced in Portugal, predominantly middle and top-of-the-range leather footwear, and Portuguese companies' business model, based on flexibility and quick response, contribute considerably to this pattern of spatial distribution of exports. It is in Europe, thanks to its geographical proximity that Portuguese companies are able to make the most of the competitive advantages conferred on them by their business model; in more distant markets, the gains achieved by flexibility of production tend to be counterbalanced by logistical and transportation costs.

Finally, it is in Europe and America that the largest core groups of consumers with a preference for the type of product in which Portuguese manufacturers have come to specialize are found. It is to be expected that geographical diversification of exports will be a slow and difficult process (Statistical Report, APICCAPS, 2017).

5.2 Results and Data analysis

Evaluation of the degree of knowledge that the Portuguese manufacturers have in regards to Industry 4.0

In this regard, it was possible to notice that all the manufacturers that were a part of this study are well aware of all the technologies that are released in the market, even though some of the interviewees are not aware of the term "Industry 4.0".

APICCAPS and the Technological center do an extensive work in order to keep the manufacturers informed of all the technologies that are released. These information are shared via email, website and via specialized newspapers. CTCP also has a service that provides diagnosis and consultancy to all companies that wish to better their performance. All this is complemented by training and requalification actions, if applicable, of the employees who are also, to a large extent, assured by the Technological Center. Besides making a diagnosis, proposing solutions and monitoring, it also evaluates the qualifications of the human resources that are necessary.

One other very relevant way to share information and the technological novelties in the market, are the international tradeshows like Lieneapelle (International Leather fair) and SIMAC Tanning Tech, both happening in Italy.

According to Dr. Alfredo Jorge (APICCAPS Director), the high degree of knowledge of Industry's 4.0 technologies of the Portuguese footwear manufacturers has to do with the fact that the 4th industrial revolution is a revolution different from all others in the sense that it is being announced, prepared, programmed, spoken about and encompasses several areas. In the footwear sector, it is possible to see that this type of thinking has already existed for a long time, focusing on making equipment more intelligent, working on different operating ranges, production flexibility model and different business models. All of these changes are very important aspects especially for sectors that depend on fashion and that have great seasonality. The focus now, is

to deepen and intensify the speed of implementation, so the technologies of the 4.0 revolution are nothing new and disruptive.

When it comes to the technologies known by the manufacturers, it is possible to verify that all the interviewees are well aware of the most important novelties launched in the market. Some of these technologies, such as the automatic cutting machine, have been in the market for at least 20 years. These machines and technologies have been evolving and improving their efficiency over the years and, naturally, the companies that use them keep up with all their technological advancements.

Referring to Eng. Melo from CTCP, "*a shoe manufacturer in order to make shoes does not need to know in detail all of these technologies. What they need to know is how to make shoes. Most of them, when faced with the theme of industry 4.0 will ask what it's all about. But if we ask if he (manufacturer) has a machine with microprocessors or if he has an automatic sewing machine, he can already know how to respond. It is important to see in which sector we are operating in. In the automotive sector, for example, it is possible to have a fully automated production line where the robots do all the operations, but in the footwear sector this is not possible, it takes human labor.*"

Another relevant way to be aware of these new technologies are the partnerships with institutes such as Inesctec and with faculties such as FEUP. The Companies and these entities work together in order to evaluate the shop floor and see which improvements are possible to implement.

The main technologies that were mentioned by the interviewees when inquired about which technologies that they know are applicable to the footwear sector are: Automatic Cutting machine, Automatic Sewing machines, Automatic Assembling machines, Automatic Storage, Additive manufacturing and 3D Printing and Integrated management system.

Degree of digitization of the Footwear Industry

When analyzing the degree of digitization, 5 degrees of digitization were given to the interviewees in order for them to provide their opinion, being that 1 is very low, and 5 is very high. In the table below (Table 3) is possible to see the different degrees and opinions from the different manufacturers.

Company	Degree of digitization	Citation
Samba S.A.	3	*"It is an industry that requires a lot of manual labor. It still depends on the different models, because there are models easily elaborated by machines while others, being more detailed or being more difficult to produce, require more manual labor".*
Cunha e Freitas	3	*"This number comes from the analysis, not only of large industries, but also of the smaller ones that are in larger numbers in Portugal. The companies we subcontract are small companies that work very archaically"*
Caminhar Comfort Shoes Unip. Lda	4	*"Having in consideration the information I have obtained from colleagues in the footwear industry, the processes and the industry are increasingly more and more digitalized"*
Mazoni	3	*"This is an industry where there has been an increase in the automation of processes but still depends heavily on human labor"*

Company	Degree of digitization	Citation
Newaim	3	*"In production there is already introduction of many automated and more independent machines. Digitization and automation is increasingly present in industrial processes but there are still many processes that are manual"*
UedamaLda	4	*"In the last few years I have been stunned by the technologies that have emerged. The value of 3D, forms digitization. .. directly, I do not use these technologies, but my business partners already benefit from them which ends up benefiting me as well and makes my job easier"*
CalçadoHércules	3	*"There have been many technological advances in the footwear sector which allows for higher quality as the products come out more perfect and more fluidly. Companies produce more and in less time."*
LFC Industria do calçado Unipessoal LDA	3	*"According to what is said in the news, this number would be higher, but the truth is that the industry is not yet so automated. I think it is in the middle."*

Company	Degree of digitization	Citation
Procalçado	2	*"We begin to realize that it is in a 2, but that comes from a very recent 1. In the last two years there has been a great evolution. In my opinion, I think this degree will move to 3 or d 4 in the next 2/3 years. The tools already exist, and more and more manufacturers have this awareness and the market itself will impose demands that will lead companies to follow this path. The traditional way of working no longer results in many cases. Industries that do not follow this path may have some difficulty evolving. There are some companies that disappear, however new companies arise that already follow the 4.0 logic"*
AMF SafetyShoes	2	*"Despite not having contact with many companies of reference, I think we are already beginning to see steps in this direction, but I think everything is still very much in the beginning stage"*

Table 3: Degree of digitization of Portuguese footwear industry

According to Eng. Melo from the CTCP " *in general, the Portuguese industry is well equipped. Our companies are typically well-equipped, modernized and with an adequate manufacturing capacity. Being it a more manual manufacture as it is typical here in the São João of Madeira area, or a manufacture more dependent of machines that is more typical of the Felgueiras area*."

It is also important, when analyzing the degree of digitization of Portuguese companies, to compare them to other players in the world being that the Spanish and Italian markets, are the two most direct competitors of the Portuguese footwear industry. It is possible to verify that Portuguese manufacturers are among the most

advanced in the world, because, when analyzing the investment made in the factories, the Italians and the Spanish have made virtually no investment over the years and continue to produce shoes as it was twenty years ago. The Chinese are now beginning to invest in factories because until now, as they had very cheap labor, they did not need machines at all (João Maia, APICCAPS).

Regarding the opinions collected, the majority of the manufacturers say that there are significant advances regarding the technologies available for the sector, but that this industry is still very dependent on human labour. Even the more technologically advanced factories, such as Mazoni, Procalçado and AMF, report that, in their opinions, the digitization and automation process of the industry is still in its early stage.

Evaluation of the implementation Industry's 4.0 technologies in the Portuguese footwear industry

From the ten interviews held with the manufacturers, only two of the interviewees claimed that they don´t have any of the studied technologies implemented in their factories. Only one of the interviewees foresaw that there is not going to be any invest in technology in the future stating that "*We have a management system but we do not even use it because, for the volume of orders we have, it is not worthy for us to invest in training for using the system because, in our case, it is faster to introduce everything manually and to manage the orders and materials this way. These technologies work well in large companies. Here, in my company, I treat all the information necessary for all suppliers. The people I work with do not even have the training to use these systems so I prefer to keep everything manual. I do not want to implement anything else because this factory works like a big fashion atelier: small production of very different designs.*"(Dr. Mauricio Guimarães – Uedama Lda).

The nine remaining manufacturers all said that they have some technologies implemented in their factories.

In the table below (Table 4) are discriminated the technologies that are at the moment, implemented in the Portuguese factories that were part of this study.

Company	Automatic Cutting machine	Automatic Sewing machines	Automatic Assembling machines	Automatic Storage	Additive manufacturing and 3D Printing for sampling	Integrated management system (IMS)	Digital footwear monitoring in real time (QR codes; RFID tags)
Samba S.A.	X			X		X	x
Cunha e Freitas	X	X				X	
Caminhar Comfort Shoes Unip. Lda		X					
Mazoni	X		X			X	X
Newaim	X					X	X
UedamaLda							
CalçadoHércules	X						

Company	Automatic Cutting machine	Automatic Sewing machines	Automatic Assembling machines	Automatic Storage	Additive manufacturing and 3D Printing for sampling	Integrated management system (IMS)	Digital footwear monitoring in real time (QR codes; RFID tags)
LFC Industria do calçado Unipessoal LDA							
Procalçado	X	X	X			X	X
AMF SafetyShoes	X	X	X		X	X	X

Table 4: Main Technologies used in the factories interviewed

According with the information collected, it is possible to notice that the majority of companies interviewed have already implemented the automatic cutting machine. According to João Maia- APICCAPS Director - the automatic cutting machine is probably the most important technology and example of what is Industry 4.0 in the Portuguese footwear sector. This technology has been implemented for over 20 years now, but keeps being improved in order to better assist the players in the industry.

Four companies claim that they already use the automatic sewing machine, in order to achieve more efficiency and have quicker processes. Regarding this technology, and according to Dr. Paulo Sousa, owner of Caminhar- "*Automatic sewing machines allow for greater speed and efficiency compared to a seamstress…The machines do the same job as an experienced seamstress. The use of the automatic sewing machine can be done by anyone, does not even need to have sewing training or be an apprentice. As long as the person knows how to deal with the computer system, the rest of the work is done automatically.*" This can be of great value especially due to the fact that is getting progressively harder to find qualified workforce.

The downside of this technology is that it still requires high investment regarding the specific materials for each new model. In a time in which it is more common to have orders of smaller series, to deploy a considerable investment in technology such as this, has to be a very carefully thought decision for any industry player.

Regarding the automatic assembling machines, usually the processes are more labor intensive and the common rate of automation is low. From the data collected, it is possible to see that only three of the manufacturers have automatic assembly machines- Mazoni, Procalçado and AMF Safety Shoes. These are the most technologically advanced companies, and are also the ones with a higher degree of automation. Two of the manufacturers produce plastic and rubber shoes, which are materials more prone to automatic processes because they are

not as sensitive and uneven as the leather. Leather production is often more difficult and requires more labor intensive activities due to the characteristics of the material. Mazoni is the only 100% leather manufacturer that has implemented an automatic carding machine. According to Dr. Pedro Sampaio, "*In the assembly, we have an automatic carding machine where the shoe is placed and the machine card automatically through the previous programming of the machine. This process is accompanied by a technician in charge of programming the machine and ensuring there are no failures, but the worker is no longer in charge of the process of carding itself because it is now automated.*"

The Production Manager of Procalçado refers: "We *have E.V.A machines and thermoplastic rubber injection machines. We also have rubber injection machines in addition to the compression machines which is the more traditional method*".

As for AMF, they are the first company in the world to invest in the 3D Bonding technology. This technology enables the simultaneous action in which one injection bonds all the pieces of the product in a few seconds. One easily places the materials in a finished 3Dimensional mold. Then with a polymer injection - the pieces bond together creating the finished product. With this technology, the company was able to shorten the production cycle, instead of going through the five steps that are usually required for producing a shoe (cutting, sewing, assembling, bonding or injection and finishing), now it is possible to produce with only three phases, cutting, injection and finishing.
3D Bonding eliminates most of the manual work required for the construction of the shoe because all the pieces of footwear are put together simultaneously instead of being done one by one as the traditional sewing (sequential) process requires. It is a simultaneous action in which one injection bonds all the pieces of the product in a few seconds.

Only one of the companies- Samba S.A.- uses the automatic storage. This is due the fact that they needed to prevent costs that come along with damaged cuts. In this factory, both cutting techniques are used- Automatic cutting, which do not generate the leather cuts, and *Balancé* , which wastes some of the material from the cuts.

The majority of the companies (six) also have an integrated management system. This means that they already work with programs that allow for all the company information to be stored in one common place. All the different departments have access to this information, and it is possible to share and work in line. There are more complex and complete systems than others. The majority of the systems used in this study sample are a more simple system that allows all departments to be connected and have access to each other's information. One of the main advantages of this system is the fact that it is possible to always have easy access to the inventory, preventing the purchase department to acquire items that are already in doors.

Procalçado has an ERP system that is more complex, called SAP. This system provides end to end solutions for financial, logistics, distribution and inventories. Referring to Dr. José António- Production manager at Procalçado- "*This system is already connected to the machines, with a specific development algorithm that also helps us to respond to the small series. We have an IT department with 4 people, and we still have external partnerships, to continue to develop this tool. It still has a huge growth potential of what is its use in shop floor*". By working with these programs, it allows to the workers to always have access to the information in real time through an internet connection. The majority of the systems are also customizable, which means that the manufacturers can adjust some of the functionalities of the program, according to their needs in their operational tasks. This work is often done in partnership with IT companies and universities.

AMF safety shoes uses a program called SOFTGI, that has several interactions in the process/production steps that allows tracking each production state from material separation, assembly, finishing, quality control, packaging and shipping.

AMF Safety Shoes is the only company that is already using the 3D printing technology for their sampling production. This technology is used mainly for printing soles for mock-ups and samples. This process allows a clear improvement in efficiency as well as a shorter product development cycle and time to market. The development and approval of prototypes / samples

following the traditional production of shapes and their constants adjustments is an extremely time consuming process, with 3D printing it is possible to reduce the time from days to hours (Dr. Rui Moreira, AMF Plant manager).

As for the advanced solutions for digital footwear monitoring in real time (QR codes; RFID tags), five of the interviewed manufacturers claim to have implemented this technologies in order to have a more accurate control of, not only the raw materials that arrive to the factory, but also of the materials in the WIP stage. This is a very important feature of these new technologies and has to be done in line with the adopted management system.

It is possible to notice that different companies have different ways of implementation of technologies, which can affect the entire company, or just some of the departments.

Mazoni is a prime example of a company that uses QR tags in line with their management system in order to have total control and monitoring of processes.According to Dr. Pedro Sampaio - Commercial director at Mazoni " I*n 2014 we have upgraded our management system to a more modern and complete one that affects and integrates all of the company's activities from employee-oriented monitorization; financial software in charge of making part of current account and financial activities; order processing and samples. The receipt of the item indoors, is registered through QR tags that tells us the type of item, the quantity in stock and which customer is concerned. These QR tags are read with a tablet that every employee has and that allows for quick reading and integration of the data into the company's internal management system. We can have total control as long as the product enters the warehouse until it leaves for the production line. In the production line, production records are also labeled with a QR code in which everything that is being produced and everything that is a finished product is indicated. In this way, at the end of the day we get access to everything that was produced that day, and everything that is in production and in which phase of production. We have this fully integrated production component and I have access to everything that goes on in the different sectors of the company at any time".*

Procalçado, has a similar technology. In this case, the technology at the level of production control, ERP, is named SAP, which is a difficult program to deal due to its complexity. The company already implemented QR codes, registration of operations in shop floor, in order to work in a paper free way, that is, to have the LCD and touch screens, where the orders fall directly with resources to the algorithms that discriminate the sequence of production. Everything is already integrated, and the order appears on the monitor with the quantities and product details.

Newaim and Samba S.A. on the other hand, use the QR tags to have a better horizontal integration with their suppliers and aid the share of information.

According to Dr. Rui Oliveira from Samba S.A., " *At this time, we are in a phase where our supplier will have to have a QR code and a printing machine in order to print the requisitions that are sent by our purchasing department. This request generates a QR code, which is then printed by the vendor where all order details are printed. A label is further generated which is then glued to the ordered products. When the products are sent to the factory, we have a scanner that reads the QR codes in order to automatically enter our warehouse and the data is updated in our internal management program. This way I can control everything that goes into and out of the company online and in real time. This program also allows sending daily alerts to our suppliers of our order. Another positive point is that the supplier does not have to work with Soft G, you just have to download the document sent by us and print out the QR Code. In this label, generated automatically, it is possible to find all the information from the number of production, customer, quantity of pairs to produce, price that will be billed among others*"

Benefits of the implementation of Industry's 4.0 technologies in the footwear industry

Some of the major benefits of this fourth industrial revolution can be linked to the fact that Industry 4.0 will make it possible to gather and analyze data across machines, enabling faster, more flexible, and more efficient processes to produce higher-quality goods at reduced costs. This will increase

manufacturing productivity, shift economics, foster industrial growth, and modify the profile of the workforce—ultimately changing the competitiveness of companies and regions.

For the present study were gathered the opinions and thoughts of the directors of CTCP and APICCAPS in the preliminary interviews, and later on, information regarding the opinions of the manufacturers were also collected in order to understand what are the major benefits that, according to them, arouse from Industry´s 4.0 technologies.

Interviewee	Citation
Eng. Melo- CTCP	*"There can be both advantages and disadvantages. When the technology is available for the function I need, what is it that it brings me back? If I have to hire people I do not have, then I have to understand very well why I'm going to invest. Perhaps the best decision, the most rational one is not to invest. The technology is available, and those who have gains with it must invest, those who have no earnings should not invest".*

Interviewee	Citation
Dr. João Maia- Apiccaps	*"Those advantages that are named in the FOOTure 4.0 document, such as flexibility, rapid response, product customization and large-scale customization, better customer relationship"*
Dr. Rui Oliveira- Samba S.A.	*"Better communication and relationship with suppliers and customers. Faster and more flexible production."*
Dr. Vitor Freitas- Cunha e Freitas	*"Less dependence on the workforce that is increasingly scarce."*
Dr. Paulo Sousa- Caminhar ComfortShoesUnip. Lda	*"First, there is greater productivity and quality in the products manufactured. Automated sewing machines allow me to produce more efficiently and with less margin of error. Human labor already encompasses many more mistakes. There is also a greater associated speed and the fact that it is not so dependent on the workers. In the case of automatic sewing machines, they allow me not to be so dependent on experienced seamstresses."*

Interviewee	Citation
Dr. Artur Silva- Newaim	*"Enables more effective management; allows for more optimized production, faster and more flexible and with less costs. In addition, it allows us to handle more efficiently with potential errors"*
Dr. Maurício Guimarães- UedamaLda	*"In recent years I have been amazed at the technologies that have emerged. The value of 3D and forms digitization. Our stakeholders already use very advanced systems. For example, our lasts supplier already works with technologies that allow the digitization of lasts and already send me the work done in a very automatic way which ends up benefiting my business because it makes everything much faster and more perfect. Directly I do not use these technologies, but my business partners already benefit from these technologies which ends up benefiting me as well and makes it easier for me to work. It makes everything faster, with more quality and more efficient. In order for me to build a shoe it is required a large list of suppliers, who already work with more advanced technologies that end up benefitting me."*
Dra. Maria da Luz- Calçado Hércules	*"There have been many technological advances in the footwear sector which allows for higher quality as the products come out more perfect and more fluidly. It is produced more and in less time. Machines, in spite of the initial cost, are cheaper than human labor, and with the advantage that they always work in the same way and pace"*

Interviewee	Citation
Dr. Filipe Costa-LFC Industria do calçado Unipessoal LDA	*"Improvements in efficiency. These technologies came to increase efficiency that translates into better communication and faster response to customers and also, in improvements in the production itself. Communication and information is more fluid and more "on time". The machines allow automation to the maximum production, although in the footwear sector there is still much work that is manual. These technologies make it possible to make better management and improve the relationship with the customer."*
Dr. José António Silva - ProcalçadoS.A.	*"The main benefits being the increase of the speed of production (high speed factory), rapid development of new samples and small orders. As the footwear goes on the online and in the online sales, it is requiring to have smaller productions and therefore, the benefits go a long way. The streamlining of shop floor processes, ie, wip (work in process) reduction and a substantial increase in the ability to respond in short lines; work cells. Automation helps in responding to shorter series production lines as employees have to be more flexible, have to perform more than one operation, and learn to be experts in more than one activity,. Reducing manufacturing cycles to shorter cycles and with less capital investment in order to be able to respond in other areas of the business."*

Interviewee	Citation
AMF SafetyShoes	*Automation Information in real time;* *Less productive cycle time;* *Minor dependency in specialized human resource*

Table 5: Benefits of the implementation of Industry's 4.0 technologies in the footwear industry

After analyzing the information collected, it is possible to notice that there were recurrent themes in the responses. Benefits such as improvements in efficiency, production flexibility, increased product quality and improvements in the times of production are the main points identified as being beneficial and that are a result of the implementation of Industry's 4.0 technologies.

Another important aspect is in the fact that, by having a production that is more dependent in automatic machinery and processes, the dependency in specialized human labor is less predominant which can be very helpful especially in a time where there is a lack of qualified workers.

All the twelve interviewees pointed out how scarce the human labor is and how difficult it is to find workers that have the motivation to perform this kind of tasks in a factory.

Identification of the challenges of the implementation of Industry's 4.0 technologies in the footwear industry

The degree to which Industry 4.0 applications are disseminated depends on size of enterprise. Large companies produce high volumes, being relatively capital intensively. Constant optimization of highly automated production is a permanent element of process management. In SMEs the proportion of manual and hybrid activities is much higher. These companies produce rather for niche markets and often have a high degree of specialization.

As the range of technological options increases, small and medium-sized industrial enterprises will have to take advantage of developments towards

networked production, otherwise their international competitiveness could be threatened (Schröder, 2017).

In the following table, the opinions of the interviewees regarding the main challenges/obstacles of implementation of industry's 4.0 technologies in their footwear factories are presented:

Interviewee	Citation
Eng. Melo- CTCP	*"I think is not possible to generalize. Moreover, the issue of changing human resources is also a matter of concern. I get worried when I hear licensees talking about their qualifications and lack of employment. Qualifications always depend on what companies need."*
Dr. João Maia- APICCAPS	*"The main difficulty is finding people and then implementing them in companies. Usually the technologies that are available are known, are on the market, there are already successful examples of companies that use them both in the footwear sector and sometimes in other sectors. The hard part is finding people both inside and outside organizations, so you can implement them both within the factory and within the industry. The most difficult is to find people with the necessary skills and the attitude needed to learn."*

Interviewee	Citation
Dr. Rui Oliveira- Samba S.A.	*"A very large gap that I want to mention is the fact that there is a shortage of competent personnel in the corporate management of the companies, that is, the positions are occupied by people who have been working on the footwear industry for many years but do not have the competencies for the position in question. In many companies in Felgueiras and even in São João da Madeira there is not even a production director, there is no planning.* *Another obstacle is the lack of internal communication within companies. Lack of technical skills. In production, we will soon be lacking people because there are fewer and fewer people wanting to work in the factory. In this context it makes sense to replace people with machines, but today there are still no machines to replace people."*
Dr. Vitor Freitas- Cunha e Freitas	*"Lack of training for people on how to work on machines so that they know how to work with these programs. It is increasingly difficult to find people who want to work in factories, and what is happening is that workers are asking for more and more money, and the manufacturers themselves almost "fight" to get the good workers and steal from each other's.* *More customers are asking for smaller quantities and different designs. "*

Interviewee	Citation
Dr. Paulo Sousa- Caminhar Comfort Shoes Unip. Lda	*"I think the first obstacle is that machine prices are very high and require a lot of investment from manufacturers, mainly for the typical Portuguese producer, who is small in size and produces a very diversified type of product.* *Another factor to take into account is the current state of the footwear industry in Portugal which is not at all favorable since the footwear sector, such as the textile sector, depends very much on the different seasons and economy of the different countries to whom we export."*
Dr. Pedro Sampaio- Mazoni	*"The main challenges are focused on continuing to make small series. I know brands such as Undandy Shoes, which manufactures on a par, and proposes to deliver the shoe in 48 hours. This is a major challenge for today's business…here is the main challenge, eventually reduce daily production because we have fewer and fewer series"*
Dr. Artur Silva- Newaim	*"Lack of skilled labor and who can deal with the digital programs and use it unequivocally; A major obstacle is the costs of machines and technologies that are currently impossible to support for the typical Portuguese manufacturer"*

Interviewee	Citation
Dr. Maurício Guimarães- UedamaLda	*"There is a lot of reluctance in the acceptance of the new technologies by the workers. Mos t of my workers are in their 40s and 60s, they already have many years of experience but are unable to learn how to work with these new technologies. There is no training available. The footwear training center has already been a great institution but nowadays the training they give is neither advantageous nor adds value."*
Dra. Maria da Luz- Calçado Hércules	*"Our production focuses on small lots of different models. These technologies are more profitable for large and repetitive series and for factories that work with large volumes. We work with customers who order us few quantities of many different designs which makes it not so profitable to use the machines because we do not produce in large series."*
Dr. Filipe Costa- LFC Industria do calçado Unipessoal LDA	*"One of the main obstacles could be the lack of information, which is my case.* *Another challenge is the cost of the machines and implementation on the factory floor. We may also have problems to the extent that in order to know how to operate these machines is required a more advanced computer knowledge, something our current employees do not have."*

Interviewee	Citation
Dr. José António Silva - Procalçado S.A.	*"There is always some resistance to the implementation of new technologies, but if the processes are first developed in a closed area and, after being tested and well founded, are transported to the factory, the degree of success is much higher. I think there is not so much risk of going wrong if things are done this way. There must be a process survey, training of people, within a closed environment first and then transportedit to the factory."*
Dr. Rui Moreira- AMF Safety Shoes	*"Costs of access to necessary technologies, difficulty of interconnection with existing systems, lack of knowledge to manage implementation, lack of standards in industry"*

Table 6: Challenges of the implementation of Industry's 4.0 technologies in the footwear industry.

Regarding the obstacles mentioned by the interviewees, it is possible to notice that there are some topics that are recurrent in their answers. The one obstacle that was mentioned the most was the difficulty in finding skilled work force. This is a recurrent topic that was brought up many times during the interviews and that is linked to the fact that, nowadays, the human labor is very scarce and the people´s willing to work in factories is also very low.

Another point that was often mentioned has to do with the fact that manufacturers are now facing a shift in the orders' specificities that they receive from their clients. If in the past, the clients' requirements were more homogeneous, today that reality is not as much observed. Clients' requirements are more heterogeneous, which means that the orders are of smaller series of different products and designs. This requires bigger production flexibility from

the manufacturers, which can be a major step back when implementing these technologies. This also has to do with the different nature of the analyzed technologies. There are some technologies that increase the time of production and allow for the automatization of processes, but they do not help in terms of flexibility due to the associated costs and set up times.

When asked in this regard, Dr. João Maia from APICCAPS mentioned that "*automatic sewing or assembly, as opposed to automatic cutting, usually means less flexibility. In the automatic cutting machine, it is possible to cut one pair at a time while the automatic sewing machine and assembly have to be programmed to produce a certain pair, ie, it has a fixed cost. In these cases, the automatic has opposite meanings. That is, an automatic sewing machine is a machine that has to be programmed to sew a certain part which means that I have a setup cost sand to support that setup cost, I have to have long series.*"

It is possible to conclude that not all the technologies aid in terms of production flexibility, even though they are extremely important in terms of automation and production time improvement.

The goal for the future is to tackle the sewing and assembly processes and try to find ways to reduce the set up costs in order to have, as in the cutting process, a slightly higher average cost but eliminate the fixed costs. It is expected that this change will still take some time to reach this level.

Lastly, it is imperative to mention that the sizeable initial investment costs of the machinery and technologies still present a major obstacle for implementation of Industry's 4.0 technologies.

Drivers for the implementation of I4.0 in the Portuguese Footwear industry

Regarding the drivers for the implementation of Industry´s 4.0 technologies, it is important to analyze the opinions of the interviewed manufacturers that have an experienced overview regarding this matter.

In the table below (Table 7) is displayed the information collected during the interviews.

Interviewee	Citation
Dr. Rui Oliveira- Samba S.A.	*"What drives the adoption of these new technologies is the need for more automatic processes, at the production level, since there are fewer and fewer competent people to work in the factories. It is still required for workers to be multi-task. It is necessary to train the employees in order for them to learn how to operate these new technologies "*
Dr. Vitor Freitas- Cunha e Freitas	*"There are advances in machinery and systems, but the training of the employees does not follow these changes. It is necessary to have more and better training"*
Dr. Paulo Sousa- Caminhar Comfort Shoes Unip. Lda	*"At this stage the government should help companies more, as it should create credit lines and other actions that should help companies. If there were more incentives, if the tax burden was relieved then companies could have the space and funds to invest more in these technologies and consequently increase exports"*
Dr. Pedro Sampaio- Mazoni	*"Work in partnership with our clients, develop collections in partnership with them is definitely a great way to create value. The corporate tax burden also prevents an increase in workers' compensation which is one of the major factors for attracting new workers to the industry. I believe that theneed will drive the implementation of these new technologies"*
Dr. Artur Silva- Newaim	*"Access to cheaper credit, government support for companies so that we can invest in new technologies; training of skilled labor."*
Dr. Maurício Guimarães- UedamaLda	*"Training programs"*

Interviewee	Citation
Dra. Maria da Luz- Calçado Hércules	*"More training programs for workers in order for them to be able to follow the evolution of technologies"*
Dr. Filipe Costa- LFC Industria do calçado Unipessoal LDA	*"There must be renewal of the workers as these technologies require a more technical type of knowledge. There needs to be more training."*
Dr. José António Silva - Procalçado S.A.	*"Partnerships with universities play a very important role because of the technical capacity they have within universities. Bringing the talent and know-how of young people inside companies is very important.* *The support that comes from the government is also very important in order to boost the entry of these people into the labor market"*
AMF SafetyShoes	*"Definitions of standards among the various players, training in the necessary areas and a financial help / support in order to boost the whole process."*

Table 7: Drivers for the implementation of Industry´s 4.0 technologies

All the interviewees have similar opinions regarding this matter. The main drivers for the implementation of industry´s 4.0 technologies are the training programs for the workers. It is stated that the technologies are available and improving each year. Now, with the right investment, the technology allows for a much more autonomous production and processes, but the main issue is in the workers and their ability to operate these technologies. Having this in mind, it is imperative that both the managers of the companies and the formation entities such as CTCP as well as formation centers, become capable on delivering

the specific technical courses in order to qualify new workers and requalify the ones that already work in the industry.

The role played by the government can constitute a barrier or a driver for the industry, depending on the policies and fiscal plans applied to it. A clear barrier that entrepreneurs face in this industry are the financial constraints related with investment, operations and R&D. The interviewees stated that, if the financial tax load wasn't as heavy, companies would have more financial leverage to increase the worker´s salary and become more attractive for jobseekers.

Evaluate the impacts that the implementation of Industry´s 4.0 technologies might bring to the company's workforce

In the process of trying to integrate IT through the use of Industry 4.0 practices at the organization level, companies often face a shortage of talent to plan, execute, and maintain new systems. The number of engineers trained in handling unstructured data and big data tools—crucial for the type and scale of data generated by connected systems—is gradually increasing, but still falls far short of anticipated demand (Woo, 2013).

The challenge extends to the shop floor as well. With vast experience in conventional manufacturing, many leaders feel uncomfortable with advanced manufacturing: They simply have less experience with the properties and behavior of materials, as well as the technologies and methodologies that use them. This can result in a tentativeness or unwillingness to adopt new approaches (Sniderman et al., 2016).

This information must be taken into consideration when analyzing the impacts of the implementation of Industry's 4.0 technologies the companies' workforce. More information regarding this matter was collected with the interviews conducted in this study. The data collected is presented in the table below (Table 8):

Interviewee	Citation
Eng. Melo- CTCP	*"…the people who are in front of an automatic cutting machine are the same cutters from 20 years ago. The seamstresses who operate the most modern machines are the same ones who worked on manual sewing in the past. The natural tendency of technologies is that they must be brought down to the level of workers' knowledge. Good management systems should be developed for being used by ordinary people. Thinking about whether I'm going to introduce new people to work with the new technologies and dismiss the people you already have is not a good strategy."*
Dr. João Maia- APICCAPS	*"Our view on 4.0 is that it can bring new services to companies so they can provide new services to their customers. In some cases, they may need fewer workers to do so, while in other cases they will need more workers. There is always an adaptation process, of course there may be people who do not adapt and who will be qualified for other tasks. This happened in all technological revolutions. If you can generate more value, the final customer may be willing to pay more, which will generate more money to be distributed by the same people. From my point of view it is a fallacy to say that the 4.0 technologies will end with the employment of many people."*
Dr. Rui Oliveira- Samba S.A.	*"There are fewer and fewer people qualified to do this type of work. One of the great challenges is finding people who want to work in the factories and who are open enough to learn how to use these new tools and technologies that are emerging. The average age of factory workers is high and they often are not willing to learn because they have been working for the same way for too many years. In my opinion, the workers do not have the right skills to operate the technologies."*

Interviewee	Citation
Dr. Vítor Freitas- Cunha e Freitas	*"There are advances in machinery and systems, but employee training does not follow these changes. Apart from that, there is a high resistance from the workers in learning new things after having 20 years of experience in making shoes."*
Dr. Paulo Sousa- Caminhar Comfort Shoes Unip. Lda	*"In my view, the new technologies and the fact that you are using newer machines and more informative processes, can attract younger people who want to work in the factory.* *Younger people are the future as older people are not so receptive to dealing and working with these new technologies, which creates the need for younger people to work with us.* *"Another factor that I think will be important is that there will be fewer jobs available in the future due to the replacement of people with machines, which will make people more "subject" to the jobs that exist."*
Dr. Pedro Sampaio- Mazoni	*"In my view, in the footwear sector it will always be necessary to look for specific skills necessary for the production of shoes. Remuneration is the key factor that attracts workers to the sector. I do not know if the fact that the industry is becoming more automated may bring more young labor to the sector."*
Dr. Artur Silva- Newaim	*"Technologies are increasingly advanced and available to entrepreneurs, but there is a lack of skilled manpower and training. The training of workers does not follow the technological evolution, which means that there is a gap between new technologies and the workforce to operate them. The training centers do not have quality and do not support the entrepreneur."*

Interviewee	Citation
Dr. Maurício Guimarães- Uedama Lda	*"There is a shortage of trained people. The training center is not competent.* *There is progress of the technologies andmachines but it doesn´t match with the evolution of training for the employees. The courses are not good enough."*
Dra. Maria da Luz- Calçado Hércules	*"In the footwear sector, a substantial percentage is composed by people of a considerable advanced age. This population is not so apt to capture these evolution.* *The training is crucial, and is done both by the suppliers of the machines themselves and by the Footwear Training Center. They even provide us with support and interns."*
Dr. Filipe Costa- LFC Industria do calçado Unipessoal LDA	*"It is necessary to train the workers so that they can deal and work with these new technologies and I do not know if the Training Center is training workers for this purpose. I do not think it is. You will find it hard to find qualified people . Also, the people who have been working for many years on the footwear industry, may be reluctant to learn new things. What happens in my factory and even in other factories around here is that there is a great difficulty in finding people to work there, and our workers are already in a higher age range which can be problematic for us as manufacturers."*

Interviewee	Citation
Dr. José António Silva - Procalçado S.A.	*"Personally, I do not think there will be job losses, I think there will be requalification of people to work in another way and, who knows, in other tasks. One area that could be further worked on is the commercial part of the company, and many of those workers on the shop floor could be allocated to more commercial tasks.* *Everything has to do with the involvement, training and perception on the part of the workers, of what is happening in the company. It is normal to have resistance when there is something unknown ahead and this is transversal to all employees.* *It is necessary to have good communication, to explain the objectives and to involve the employees in the changes to be made."*
AMF SafetyShoes	*"Clear transformation of the necessary skills and reconversion of existing employees to incorporate new methods and processes.* *Hiring of employees with technological development capacity"*

Table 8: Impacts that the implementation of Industry´s 4.0 technologies might bring to the company's workforce

Regarding the data collected it is possible to notice that, according to Dr. João Maia from APICCAPS, the implementation of Industry´s 4.0 technologies will not cause significant job losses. Companies are making their way to automatization of processes in order to be quicker, more flexible and more competitive in the markets. This can be translated in the automatization of some more routine tasks. By improving their processes and production, it is expected that this is followed by an increase in sales which will be beneficial for the entire company workforce. Also, by improving the performance and sales, the probabilities of expansion are bigger which means that, new work stations may

arise. In this scenario, there won´t be a dismissal of employees, but a relocation and requalification of the work force.

This scenario is not coherent with the testimonials collected by the manufacturers. The footwear sector, especially the leather production, is still very labor dependent which means that, in a near future, this industry will still depend heavily in human skills. According to the opinions of the leather manufacturers, it is possible to notice that the majority of them indicated, as being very problematic, the lack of skilled human labor available. Another factor that was recurrently mentioned as a struggle is the fact that the majority of employees are older and might show some resistance in learning new techniques and how to handle new technologies. It is also difficult to attract young people to this industry that are willing to work in the shop floor.

There is not a consensual opinion regarding whether the implementation of new technologies in the factory will attract younger people, but some of the manufacturers argued that that might be a possibility being that these younger workers are more willing and motivated to learn and work with new technologies and automatic processes.

Another recurrent aspect is the lack of training of the employees and the opinions regarding the Footwear Training Center are not consensual. Some manufacturers said that this institution hasn´t been successful in qualifying its trainees and that this is a major setback when it comes to adapting the skills of the new and older workers to the new upcoming technologies. But according to Dra. Maria da Luz- Calçado Hércules- the training center has been developing a good job in training younger workers and to provide interns.

With the implementation of new technologies in the factories, it will also be necessary to invest in qualified workers such as engineers and managers that are able to perform back office tasks such as programing of the machines and control and monitorization of the output generated by these new technologies.

5.3 Summary

Generally speaking, it is possible to notice that there is a coherent train of thought and opinions from the manufacturers, regarding the implications that the implementation of Industry´s 4.0 already brings, and also might bring in a near future, in different aspects of production.

Regarding the first parameter - Evaluate the degree of knowledge that the Portuguese manufacturers have in regards to Industry 4.0 - it is possible to notice that this is a very well informed industry and that all the manufacturers interviewed are well aware of the new technologies that exist and that are being released, even though four of the interviewees are not familiar with the term "Industry 4.0". The main sources of information are the news and constant updates from the CTCP and also from APICCAPS. Tradeshows and partnerships with different institutions such as universities were also revealed as being important tools for information gathering and knowledge expansion within the industry.

For the second point of analysis - Evaluate the degree of digitization of the Footwear Industry - there is also a consensual opinion among manufacturers. Applying a scale from 1 (lowest degree of digitization) to 5 (highest degree of digitization), the average score is 3. This value is in line with the opinions given by the manufacturers that say that there are some technological advances in the industry and that the technologies are of great value in order to better their production. This value also encompasses the reality that, even though the technologies are more advanced, the footwear industry is still very much dependent on human labor and skills.

Concerning the third topic of analysis regarding the implementation of Industry's 4.0 technologies in the Portuguese footwear industry, it is possible to notice that the technology with the highest degree of implementation is the automatic cutting machines. This is due to the fact that this machine allows for a more efficient, flexible and automatic production and 7 out of the 10

manufacturers that were part of this study have this technology already implemented. Two of the three that don´t have it implemented yet, are planning to do so in a near future. The technologies with the lowest degree of implementation are the automatic assembling machines and automatics storage machines. This is due to the fact that automatic assembly machines are still very new in the leather footwear industry, thus, the new technologies in the market are still extremely expensive. The automatic storage machine is more useful in bigger factories that also use manual cutting techniques in their production. The majority of the companies interviewed in this study are small companies that don´t have the need to invest in this technology.

The fourth topic is focused on the benefits of the implementation of Industry's 4.0 technologies in the footwear industry and in this topic some of the advantages that stood out were increasing flexibility, quicker production, better efficiency, better client interaction and also, the fact that, by automating the processes, the manufacturers are less dependent on human labour which is increasingly scarce.

The fifth point of analysis approaches the challenges of the implementation of Industry's 4.0 technologies in the footwear industry. In this topic the most recurrent issue was finding skilled professionals that are willing to learn and work in a shoe factory. Another constraint to the implementation was the high costs of machinery and the demand for smaller and more diversified series from de clients. This type of demand makes it difficult to compete with foreign prices, like in Asian countries, that produce in large scale and high volumes.

As for the main drivers for the implementation of industry´s 4.0 technologies, it is important to conclude that the main ones are the training of the employees in order for them to keep up with the technological advances and also government support through the applied fiscal policy, enabling a lighter tax burden.

Finally, when asked to evaluate the impacts that the implementation of Industry´s 4.0 technologies might bring to the company's workforce, some of the interviewees argued that this fourth industrial revolution will not be the cause of

job losses, due to the fact that, even though some of the more routine tasks can be done by machines, new job opportunities will arise due to new services that can be created within the companies. The formation of new jobs has to do with the expansion that is hoped to happen in the factories, by using industry´s 4.0 technologies in order to improve their overall performance. While some of the interviewees believe that this is the future scenario, others say that, in their opinions, with the mass adaption of machinery and automation, there are going to be jobs that will be inevitably lost. One other important conclusion is that, according to the manufacturers, the training and education of the employees is not following the evolution of the machines, which means that there are new technologies and machinery available, but it is extremely difficult do find qualified people to perform these tasks.

6. Conclusion

The present section comprises the conclusion of the main topics that were approached throughout this investigation, as well as the main findings in order to answer to the research question: "Impacts of the implementation of Industry´s 4.0 technologies in the Portuguese footwear industry". Furthermore, it includes the main limitations of this investigation as well as recommendations for future studies.

6.1 Conclusions

When analyzing the degree of knowledge that Portuguese manufacturers have in regards to Industry 4.0 it is possible to conclude that the producers are well informed regarding new technologies that are already being used in the industry and also new technologies that are being released. It was possible to

notice that the manufacturers have a proactive attitude when it comes to researching ways of improving their businesses and keeping in touch with the latest innovations. CTCP and APICCAPS play an huge role in the dissemination of this type of information and novelties that come up in the market.

Different types of information channels are used such as email, news on their websites, events and presentations related with new technologies. Also, it is very common for manufacturers to attend various tradeshows, not just for footwear but also for technologies and materials. These gathering of knowledge and up-to-date information might impact the decisions made regarding the different partnerships established with the stakeholders. While some of the interviewees were not aware of the term "Industry 4.0" nor the implications behind it, they are well aware of the technologies that could be useful for their specific production sites.

"Most producers are not sensitive to the term "Industry 4.0" because this is a very technical word that is very linked to the academic world. A shoemaker,, in order to make shoes, does not need to know any of this. What they need to know is how to make shoes. Most of them, when faced with the theme of industry 4.0 will ask you what it's all about. But if we ask them if they have a machine with microprocessors or an automatic sewing machine, they will be able to respond immediately " (Eng. Melo, CTCP).

Concerning the degree of digitization of the footwear industry, it is possible to notice that Portugal is receiving a lot of attention due to its new positioning and marketing campaigns that claim that the Portuguese footwear industry is "the sexiest industry in Europe". This campaign has a big focus on the marketing aspects of the industry which is not the main concern of the manufacturers in this investigation, especially due to the fact that eight out of ten manufacturers, don´t have their own brands and develop their business activities within the B2B segment. The manufacturers believe that the industry has already some tools that allow for the automation of some processes but all of them also say that this is a sector that is still very dependent on human labor and that the technologies have not evolved enough in order to allow full process automation.

In conclusion, the industry is evolving and improving but it still has a long way to go in terms of automation and establishment of processes.

"*At this point companies must make the diagnosis to realize what is useful to them or not, because many of these technologies may be useful for some but not useful for others. It is important to do this initial diagnosis before investing in anything. Here we enter in a field of opinion, where businessmen must realize what is useful or not"(* Dr. João Maia, APICCAPS).

There are many technologies available in the market, and it is not objective to assume that one is better than other. It all depends on the type of product, client, and which are the goals of a specific company. Having these aspects under consideration, each company decides which technologies are the best fit in order to produce an answer to their needs. In this investigation, it was very common to hear the manufacturers say that they would like to produce in a more automatic way, without having to rely so much on human labor but, at the same time, they also need to be flexible in order to respond to clients' demands. Bearing this in mind it is important to refer that not all the technologies provide the much needed flexibility that manufacturers require. Technologies, such as automatic sewing machines and automatic assembling machines, require set up processes that aren't very cost/time efficient yet. The automatic lines are profitable when the production is focused in large volumes of the same design. Each time that is required to make changes, the set up times and re-programming of production lines end up being highly time consuming and costly adjustments.

Other technologies, such as automatic cutting machines, have been used for decades and are constantly improving. This is the type of technology that presents the highest degree of implementation in the companies that were part of this study. This is due to the fact that, because this technology has evolved over the years, it allows for a more automatic, quick and flexible production, with the manufacturers being more familiar with the overall functionality and requirements of the equipment.

Another important aspect that must be highlighted is that, especially in the leather production, due to the fact that this is a very specific and particular raw material, there are still many operations that are not automated, as it requires the application of highly technical procedures by a professional employee.

"*The operators are more sensitive and aware of how to handle the treatment of leather and to know how to deal with the specificities of each type of leather product. The more you advance in automation, the more you advance to synthetic products. For example, Adidas has released some news about a state-of-the-art factory in Germany with extremely automatized processes, but that only works with synthetic materials."(*Eng. Melo, CTCP)

According to Dr. João Maia, "…*one of the objectives that is foreseen in our strategic plan (Footure 2020) is to look for ways to shorten set up times. There are already automatic machines, but the learning mechanisms are still very complex. The same can be observed In the assembly machines."*

Having this in consideration it is possible to assume that in the future, it will be expected that these technologies will allow for a more flexible production which will increase the degree of interest of Portuguese manufacturers.

As far as the 3D printing technology, and according to Berman (2011), current applications of 3D printing typically involve small quantity production runs of small, complex items. These include mass-customized products, prototypes, mockups, replacement parts among others. This is exactly the application that AMF Safety Shoes is giving to this technology, by using it mainly for printing soles for mock-ups and samples. This process allows a clear improvement in efficiency as well as a shorter product development cycle and time to market.

Regarding the benefits that arise from the implementation of Industry´s 4.0 technologies, it is important to conclude that the most recurrently mentioned was the fact that the automatization of processes allows a lower degree of dependency on human labor. Also, improvements regarding flexibility of processes, especially due to the automatic cutting machines, faster production and more efficiency were also very common topics in the answers of the interviewees. Some of the advantages named by the interviewees are in line with the authors

Rüßmann et al. (2015), that state that through the Industry 4.0 technologies it is possible for companies to create new services and value opportunities, for example, through the creation of new forms of employment. Industry 4.0 also creates new opportunities, especially for SME´s and Startups to develop new B2B technological services. This is already being implemented in companies such as Samba S.A. and AMF Safety shoes, that are developing digital platforms that allow them to have a better relation with their stakeholders which creates the need for new job positions. These new services also provide an end-to-end integration and transparency in real-time allowing an early verification of any design or process changes that may occur and also, be able to be more flexible in adopting the necessary alterations across of the company´s site, which are some of the main advantages named by Schuh et al., 2017.

On the other hand, observing the present overall setting, the main challenges identified were the lack of skilled human labor to work with these new technologies and machines. This problematic was identified both from the preliminary interviews and from the opinions collected from manufacturers. There is a common consensus regarding the difficulty in finding people that are willing to work at the shop floor in the factories and that have the proper training to perform more technical activities. These problems were already identified in literature by Hoffman, 2016, that argued that defining appropriate infrastructures and standards, ensuring data security and educating employees are among the issues that need to be addressed on the road to Industry 4.0. There is also a general discontent regarding the courses given by the Formation center and the CTCP.

Some other important constraints are the high cost of the machinery and the fact that orders from clients are not as homogeneous. According to Bartodzie (2017), the tendencies of the 21st century such as cycles of products being shorter while consumers demand more complex, unique products in larger quantities – poses many challenges to the production and it was definitely one of the main constrains identified by the manufacturers. In today´s market, the orders are

increasingly more diversified, which means that clients need less quantities of a higher number of designs. In order to be able to respond to this demand, the manufacturers have to find ways to increase their production flexibility but also have a better communicational flow with their clients in order to understand their needs.

One other challenge identified by the company AMF safety shoes, has to do with the standardization of processes which is in line with the authors Karacay et al., (2018), that argue that there are three major barriers in scaling IoTs adoptions in business: standards, privacy and security concerns.

This company is developing a program with their suppliers in order to develop the QR tags to improve the reception of the components in the warehouse. The biggest limitation is the difficulty that the different suppliers have to adjust to new ERP programs and also the lack of a standard protocol of information communications, something that is already a standard practice in the automotive industry, for example.

It is not an easy thing to achieve Industry 4.0, and according to Zhou et al., (2015), it is likely to take ten or more years to realize it. Currently, Industry 4.0 is a vision for the future, because it involves many aspects, and faces many types of difficulties and challenges, including scientific challenges, technological challenges, economic challenges, social problems and political issues, many of those identified by the interviewees in this study.

The Fourth Industrial Revolution, driving from the advancements in new digital technologies known collectively as Industry 4.0, has been profoundly changing dynamics of most industries. According to Karacay (2017), automation of business processes together with emergence of novel business models impose new digital skill requirements for the workforce. In order to meet these new requirements, companies will have to focus their strengths, not only in attracting and developing new talent, but also re-skilling current employees through training programs as well as re-designing work processes for reducing the skill mismatch between jobs and employees. Having this in mind, it is important to refer to Rüßmann et al. (2015), that states that producers must set priorities and

upgrade the workforce, which means, analyzing the long-term impact on the workforce and conduct strategic workforce planning. Adapt roles, recruiting, and vocational training to prepare the workforce with the additional IT skills that will be required. This is very much in line with the findings that were retrieved from the interviews with the manufacturers, that say the major drivers would be more training programs for the workers and also government support and less tax burden in order for the producers to be able to improve the salaries and make the job positions more attractive in terms of payment.

Concerning the implications in the work force, it is possible to conclude that most of the interviewees do not believe that the implementation of these technologies will cause drastic job losses.

The common belief is that, there are some more routine tasks that are already automatized, with the tendency of more tasks to following this route. The same workers that performed manual procedures are being trained and requalified in order to learn how to cope with the new technologies.

*"It is important to mention that, even with the arrival of the automatic cutting machines, those responsible for these operations are the same ones who did the cuts manually, that is, these workers were converted and requalified to work with these new technologies."(*Dr. Alfredo Jorge, APICCAPS).

According to Hoffmann (2017), the automated and self-regulatory nature of the smart factory might cause severe job destruction due to the fact that the most routine tasks will be done by machines, creating opportunities for humans to be in charge in more creative and intellectual activities, which might not please everyone. Having this in mind, it is imperative that the competent entities such as the Formation Center and CTCP, invest in training and developing courses that are able to slowly but surely integrate the former and new workers in this new mindset, also giving them the specific tools in order to be able to work with the new equipment and resources that are available. It is also the responsibility of factories' managers to be aware of the importance that these formation programs represent in, not only to requalifying the employees, but also in giving them motivation and incentives to learn new processes and techniques.

"*The technologies are no longer very complex nor require an engineer to know how to deal with them. The advancement of technologies has followed a logic of simplifying the systems so that dealing with them is as intuitive as possible, i.e., the problem in finding skilled workers is not so only at the level of the shop floor. Usually the problem is finding the right people that are able to support these technologies, like the engineers who will manage the process. Also, in digital marketing there is an huge difficulty in finding people who dedicate themselves to these functions and help companies that want to develop their own brand."(Dr. João Maia, APICCAPS).*

Finally, when asked about the intention of investing in new technologies in the future, seven out of ten manufacturers say that are going to invest in more technology in the future. The three that said that are not going to invest, justify this decision in the high costs that come along with these investments and the fact that some of the automatic equipment is not in line with the production flexibility that is demanded from the clients.

All the other manufacturers claim that they have the intention to invest either in machinery, bettering their management system or improving the technologies to have a better relationship with their clients.

One very important aspect is the horizontal integration that, according to Brettel et al (2014), consists in the collaboration between enterprises, with resource and real time information exchange. Regarding this matter, companies are already developing technologies that allow them to be more competitive. Samba S.A. is partnering with other technological companies, in order to create a platform that incorporates several stakeholders of the value chain. This project aims to develop a mobile APP through which it is possible to build and deconstruct a shoe quickly and simply, with access to a database previously fed with textures, colors and real prices of suppliers, all through the application on the mobile phone. The main target of this new platform will be the sellers, that is, the commercial department but will end up affecting the entire company. With this application, the seller can show the physical sample with the standard colors and materials and then make the changes that the customer wants, in real time.

This allows the creation of a digital sample and generation of the new price automatically.

After the digital sample is created, it can be printed both in 2D and 3D. The benefits of this project, focuses on the integration of multiple agents of the value chain such as clients and suppliers. The creation of an APP with these features focuses on the benefits of customer co-design which is highly linked to mass customization. According to Piller (2005), with customer co-design, customers are integrated into value creation by defining, configuring, matching, or modifying an individual solution. Customization demands that the recipients of the customized good transfer their needs and desires into a concrete product specification. This is a very important step in the realization that Portuguese companies do need to improve their services and also, their relationship with the clients in order to be competitive in the market.

According to Chen et al. (2008), interoperability is "*the ability of two systems to understand each other and to use functionality of one another*." This interoperability is possible by using RFID tags in order to facilitate the communication between the products, machines and people. RFID or radio frequency identification is a wireless tracking technology that allows a reader to activate a transponder on a radio frequency tag attached to, or embedded in, an item, allowing the reader to remotely read and/or write data to the RFID tag. RFID tags are an information-feeding process. But the difference between an RFID tag and a QR Code is mainly in the contact field, i.e., with an RFID tag is possible to read the information at a greater distance and with the QR Code it is necessary to have a pointer to read that reduced area where the tag is. In terms of information provided by both, there is no difference. The main difference resides in the ease-of-use. The possibility to manage processes such as warehouse products coming in the factory, products that go from one workstation to another, finished product ready to be shipped, among others, is possible with both the RFID tags and QR Codes.

Companies are already taking advantage of these technologies in order to improve the flow of information and their relation with the stakeholders. With

this technology, manufacturers can have a better control of everything that enters in the factory; of all the products in WIP and everything that is already finished and ready to leave the factory.

"The goal of industry 4.0 focuses heavily on this flexibility of processes. Then, it is necessary to apply this flexibility to other areas of the company and, on top of that, add a layer that we call customer experience which is how to relate business with the customer. This vision is recent and focuses on harnessing the technologies we have today to see if it is possible for companies to take the leap and create their own brands. About 20 years ago, our Spanish colleagues followed a path more focused towards brand creation, while in Portugal we followed a path more focused on investment in factories and productive competence. The point is not that either one is wrong, but it's important to see if we can now leverage these new technologies like social networking and online sales, to create a stronger end-customer connection" (Dr. João Maia, APICCAPS)

6.2 Investigation Limitations

As of any study of this character - Exploratory and qualitative - the present investigation presents some limitations that deserve to be referred.

Firstly, it is important to refer that Industry 4.0 is a broad subject that encompasses many different technologies and affects several departments in a company. In this study, specially due time constrains, the focus was only directed to some of the technologies used mostly at the shop floor level, with the intent of portraying the most realistic scenario possible regarding the companies present in the observed Portuguese footwear production clusters, while maintaining the goals of this research.

Secondly, the sample used in this study was also limited and the investigation could be more complete if there were more companies involved. This limitation had to do with the time constraint for the development of the study and also due to scheduling incompatibilities with the interviewees.

Concerning the interviews, some difficulties were experienced due to the fact that some companies were not willing to participate in the present investigation.

One example was the company Kyaia, which was referred many times by other interviewees, namely Dr. João Maia from APICCAPS and Eng. Melo from CTCP, as being the most technologically developed company in Portugal. There were made many attempts to schedule an interview but there was no positive answer.

It is important to refer that some of the potential interviewees were not willing to reveal any information regarding their factories and business, which was a major setback in terms of data collection and ended up imposing the exclusion of some interviews and the necessity to find other companies to proceed with the investigation.

Finally, the qualitative nature of the study also encompasses some limitations such as:

- Although the researcher seeks to be impartial, the analysis of information collected through this type of instrument is always subject to the researcher's interpretation of the answers;
- Even though the point of view provided by the interviewee is explored, there is no certainty that this is indeed his personal point of view;
- The answers given to the questions are always influenced by the background of the interviewee.

6.3 Recommendations for future studies

As it was mentioned previously , according to the strategic plan, FOOTure 2020, there are 4 main axis that are important to incorporate in order to be the world leader in customer relationships through product sophistication, rapid response and better level of service. In this study, the focus was only in some subtopics of the main topic regarding Smart Manufacturing. Subtopics such as the quick and flexible production which encompasses the advanced planning of footwear production for fashion, and also automatic machines that allow a more efficient and faster production.

Another important aspect that was mentioned is the product development and efficient prototyping which includes development of new flexible production equipments with customization capacity, and 3D additive manufacturing in sample production. Lastly, it was briefly analyzed the business intelligence and digitization caused by the increasing automation of the factory using the internet of things, production monitoring for virtual monitoring in real time and the increased business intelligence of footwear companies.

This strategic plan is extremely well developed and has a complete overview regarding which are the implications of the implementation of Industry´s 4.0 technologies in the different departments of a footwear factory. In the axis of Smart Manufacturing there are still many topics that can be addressed in order to have a full understanding of how these technologies are impacting the Portuguese footwear sector. One of the suggestions lies in the development of a study based on the Footwear value chain and sustainability.

Industry´s 4.0 technologies could be beneficial in several aspects of the manufacturing, and one of the major implementations is the 3D Printing which, at the moment, is more used in the printing of components such as soles. This technology allows for a quicker and better time of response from the soles manufacturers to the shoe manufacturer, which ends up benefiting the entire shoe value chain.

This is just an example of how the technologies can have a positive impact in all the different stakeholders and that could be studied more profoundly.

Another very important aspect, that could be developed , is the digital marketing actions that are being more and more developed in the Portuguese manufacturers, with special focus on the ones that do have their own brand and that would benefit in large scale of well-designed digital marketing campaigns which is a another important strand of what is Industry 4.0.

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