Digital Transformation in the Footwear Industry: Assessing the potential of IoT on Portuguese SMEs in the Footwear Industry

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Abstract

Title: Digital transformation in the Footwear Industry: Assessing the potential of IoT on Portuguese SMEs in the Footwear Industry

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In the last few years, manufacturing companies, from the most diverse industries and sectors, have been investing in industry 4.0 technologies. One of these technologies is the Internet of Things (IoT), which has been revolutionising industries, namely manufacturing, healthcare, energy, retail, and agriculture. Manufacturing firms are adopting IoT not only to improve quality, production and reduce costs but also to enhance the logistic chain and improve customer experience. However, very little progress has been made in the Portuguese footwear industry towards the implementation of the Internet of Things, particularly in the SME segment.

This dissertation has analysed the potential operational and production advantages of IoT, the associated economic impact, as well as the limitations of this technology and the challenges for its implementation in Portuguese footwear SMEs. Finally, this dissertation aims to present an adoption roadmap.

The results provided positive indicators of operational and productivity gains translated into cost reduction in work insurance, energy, travelling, acquisition of raw materials and decrease of inventory units, and production waste. Nevertheless, the associated potential of each IoT use case is dependent on the capacity of Portuguese footwear SMEs to invest and acquire the necessary technical resources.

The main barriers to the adoption of IoT derive from the limitations of the technology and the specific challenges associated to the Portuguese footwear SMEs economic and technical framework. Nonetheless, the technological advances, the cross collaboration among the different footwear stakeholders, and a well-defined implementation strategy can overcome these barriers and bring operational and economic benefits.

Keywords: digital transformation, Internet of Things (IoT), Portuguese footwear industry, SMEs, use cases, benefits, challenges, limitations, implementation.

Resumo

Título: Transformação da indústria do calçado: Avaliação do potencial da IoT nas PMEs portuguesas na indústria do calçado.

Autor: Diogo Vaz

A Internet of Things (IoT), uma tecnologia da indústria 4.0, tem revolucionado indústrias como a da manufactura, saúde, energia, retalho e agricultura. As empresas de manufactura estão a adoptar a IoT não apenas para melhorar a qualidade dos productos, eficiência produtiva, e reduzir custos, mas também para aprimorar a cadeia logística e melhorar a experiência do cliente. Contudo, poucos foram os progressos feitos referentes à IoT na indústria do calçado Português, principalmente no segmento das PMEs.

A seguinte dissertação analisou as potenciais vantagens operacionais e productivas da IoT e os seus impactos económicos, bem como as limitações da tecnologia e os desafios de implementação para as PME do calçado Português. Por último, é apresentado um plano de implementação da tecnologia.

Subsequentemente os resultados mostraram indicadores favoráveis de ganhos operacionais e produtivos, que se traduzem na redução de custos com seguros de trabalho, inventário, desperdícios de produção, custos de manutenção, encargos com deslocações, custos de energia e custos de aquisição de matérias-primas. Contudo, o potencial de cada caso de uso de IoT depende da capacidade das PMEs do calçado Português para fazer o investimento financeiro e adquirir os recursos técnicos necessários.

As principais barreiras à adopção da IoT derivam das limitações da própria tecnologia e dos desafios relativos ao quadro económico e técnico das PMEs Portuguesas do calçado. Não obstante, os avanços tecnológicos, a colaboração entre os diferentes intervenientes e uma estratégia de implementação bem definida podem superar estas barreiras e garantir a adopção e trazer ganhos operacionais e económicos.

Palavras chave: transformação digital, Internet of Things (IoT), indústria do calçado Português, PME, casos de uso, benefícios, desafios, limitações, implementação.

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Glossary

IoT – Internet of Things

IT – Information Technology

RFID – Radio Frequency Identification

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

CTCP – Footwear Technology Center of Portugal

WSN – Wireless Sensor Network

MIoT – Internet of Things in manufacturing

1. Introduction

In recent years, several technologies that are changing the business status-quo have been sparked by a wave of digitalization. One of these technologies is the Internet of Things (IoT), a system in which physical objects/things (e.g., sensors, computing devices, machines) exchange data through the internet allowing communication and cooperation among devices (Pelino & Gillet, 2016). Ubiquitous sensing devices – the main driver of the IoT – enabled by wireless sensor network (WSN) technologies, are present in every area of modern day living, affecting both individuals and businesses, by measuring and analysing environmental indicators anywhere and anytime. IoT creates ample opportunities at every level and in every firm, from large-scale multinationals to small and medium enterprises (Lokshina et al., 2018).

According to a recent projection conducted by Statista, the Internet of Things (IoT) has the potential to significantly influence the European Economy. It will bring revenue of approximately 2,133 billion US Dollars during 2020 (Gordon, 2017). Although the application possibilities of Internet of Things are diverse – transportation, healthcare, communication, retail, energy, agriculture and industry (Dai et al., 2019), this dissertation has focused on the use of IoT in industry, more specifically in the footwear segment.

The industrial internet of things (IoT), which involves the integration of IoT into industry, more precisely in manufacturing, has allowed some productive/technical changes, causing organisational consequences and opportunities to seize (Kiel et al., 2017). The implementation of IoT in manufacturing results in completely or partially intelligent, connected and autonomous factories, offering them a chance to become more competitive (Lansiti & Lankhani, 2014; Loebbecke and Picot, 2015). Further opportunities and potential are associated with resource efficiency in terms of energy and material consumption, optimised decision making and flexibility, improved work-life balance (Kiel et al., 2017), among others.

1.1 Problem Statement and Scope

The possible applications of IoT are diverse and provide significant business opportunities for different markets, including manufacturing (Gordon, 2017). Since the Internet of Things has not been deployed in the Portuguese footwear industry yet, this dissertation addresses this gap in our literature and practice. The first objective of this dissertation was to assess which footwear business operations can be leveraged by IoT technology. In order to evaluate this

information, some IoT use cases which have been gaining momentum in IoT deployment investments – manufacturing, retailing, and manufacturing – were analysed (Xu et al., 2014). First, the adoption of Internet of Things in Manufacturing (MIoT) can have a substantial impact in business operations by improving operations and production, reducing machine downtime, improving product quality, enhancing the supply chain and improving customer experience (Zhong et al., 2017). Second, IoT offers retailers the ability to improve the supply chain and logistics management by improving warehouse performance and managing the imperfect information (Schoen et al., 2016; Yan et al., 2016; Tejesh and Roy, 2017). Third, the energy industry has been applying IoT to consume less energy while producing the same service/product (Motlagh et al., 2020). The second objective assessed which IoT solutions are valid for Portuguese footwear SMEs given their economic and business framework. Merging these two objectives enabled to assess the potential benefits and challenges of IoT to Portuguese SMEs.

This dissertation has significant relevance in the Portuguese context as SMEs represent the major contributors to employment in Portugal (INE, 2018) - 99.9% of the Portuguese companies are SMEs (Pordata, 2020). Similarly, footwear SMEs represent 99.6% of the entire Portuguese footwear industry (Direção Geral das Actividades Económicas, 2017). This research paper can shed light on the economic growth opportunities for Portugal given proper deployment within its footwear cluster.

Upfront investment costs and new challenges derived from the interconnectivity of objects and their autonomous evolution (Angelini et al., 2018) have led to the question of whether to invest in IoT. Thus, the third challenge of this dissertation was to demonstrate how Portuguese SMEs in the footwear industry can effectively implement IoT despite all the issues associated with it.

Thereby this dissertation elaborated on the potential operational and productivity benefits and the associated economic impact of adopting IoT technology, as well as the challenges to implement this technology. It examines use cases to provide a framework for footwear industry managers, giving them the necessary tools to evaluate the adoption and viability of IoT in their business.

The dissertation is structured in six chapters. The next chapter defines the theoretical background containing the core academic concepts used through this dissertation. The third

chapter refers to methodology, mainly how the dissertation was conducted, and which methods were used. The fourth chapter contains the data analysis and findings. Finally, the dissertation ends with a conclusion and suggestions for further research, fifth and sixth chapters respectively.

2. Literature Review

2.1 Internet of Things

IoT is syntactically composed by two terms: Internet and things. The first one is associated with a network-oriented vision of IoT whereas the second pushes towards physical objects integrated into a common framework (Atzori et al., 2010). However, when put together, the two terms refer to *"uniquely identifiable objects/things and their virtual representations in an internet-like structure"* (Kassab et al., 2019). In this sense, IoT can be defined as: "*the inter-networking of physical devices, vehicles, buildings and other things*[1]*, embedded with electronics, software, sensors, actuators and network connectivity that enable these objects to collect and exchange data, in real-time or Ad hoc, over the internet to accomplish certain objectives"* (Benamar et al., 2019; Whitmore et al., 2015).

It can be applied in several sectors such as: healthcare, governance, retail, logistics, agriculture, education, automation, manufacturing, city and home management, smart grids, among others (Muralidharan et al., 2018; Saenz et al., 2019; Kim et al., 2017; Gubbi et al., 2013).

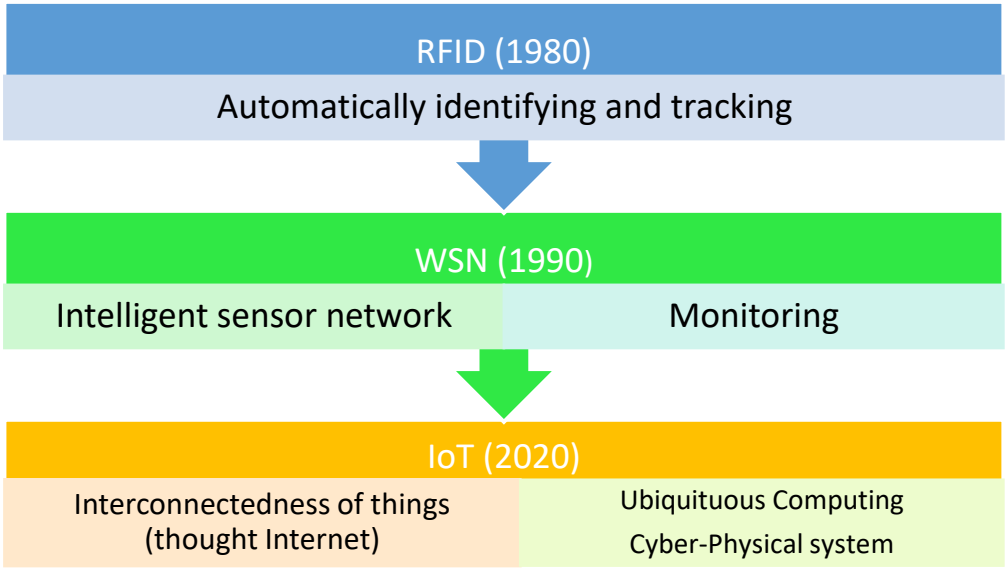
2.1.1 History of IoT

The onset of IoT is intrinsically connected to Radio Frequency Identification (RFID) technology, which is based on microchips that transmits information from the object to a reader through wireless communication. RFID readers allow to identify, track and monitor any object attached with RFID tags (Xu et al., 2014). The Wireless Sensor Networks (WSNs), which interconnect intelligent sensors to monitor devices constitute another foundation technology for IoT (Xu et al., 2014). The improvement of RFID and WSNs were the main catalysts to the emergence of IoT and their applications were widely used in logistics, pharmaceuticals, supply chain management, industrial and traffic monitoring (Ngai et al.,

[1] Also referred as "connected devices" and "smart devices".

2008; Sun, 2012; He et al., 2014). At the turn of the century, the concept "Internet of Things" was officially named. It came to light while large corporations sought to collect benefits from foresight and monitor objects performance (Lianos & Douglas, 2000).

More recently, the advancement of other technologies, such as barcodes, WIFI, cloud computing, GPS, smart phones and even Artificial Intelligence, has been involved in IoT (Uckelman et al., 2011; Li et al., 2013; Wang 2014). The following graphic demonstrates the evolution of IoT until today:



Graphic 1. Evolution of IoT and its main enablers

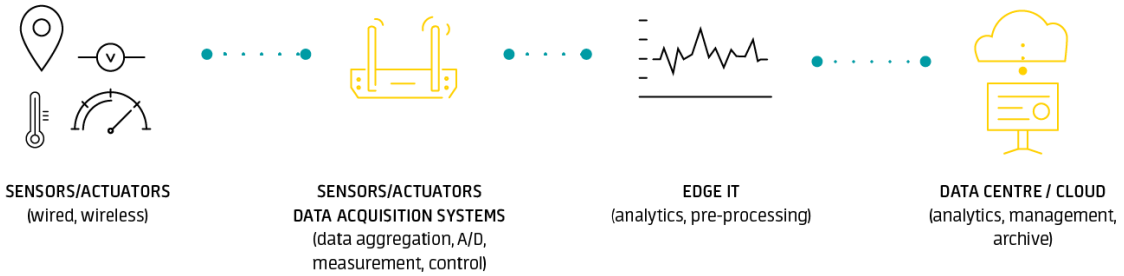
So far IoT has gained strong investments in healthcare, logistics, military, smart home, smart city, surveillance and power grids (Saleem et al., 2019), providing solutions to different scenarios such as intelligent parking, intelligent meter reading and smart hospitals (Zhang et al., 2018; Malik et al., 2018). The rapid deployment of IoT is creating an additional problem as a direct consequence of extra traffic as result from the communication of billions of nodes. Therefore, current research has been investigating efficient ways to transmit data back and forth among devices in network to enhance the routing of the data within the network. (Turjman et al., 2019).

2.1.2 Deployment requirements

The efficient deployment of IoT technology must respect two different sets of requirements: IoT architecture and IoT instruments. Both are described in the following sections.

2.1.2.1 IoT architecture

While every IoT system is different, every foundation respects the four IoT layers namely, networked things/devices, data acquisition, analytics, and data storage (Motlagh et al., 2020,).



Graphic 2. Four layers of IoT technology

The four layers are designed according to each IoT solution, based on the intended IoT application (e.g. predictive maintenance, monitor production, manage inventory). First, the networked things represent the objects embedded with IoT technology (e.g. smart sensors, actuators) being able to sense the environment and gather data (Motlagh et al., 2020). Smart things are dependent on communication protocols – wired internet, WIFI, 3G, 4G, 5G – to communicate and share data among them. The communication protocol is chosen according to the needs of each IoT application (Shancang et al., 2018). The second layer concerns aggregating the heterogeneous data gathered by smart devices. Heterogeneous data is captured in a mix of data formats – analogue signals, sensor readings, device health, metadata, images, video – including structured, semi-structured, and unstructured data (IBM, 2020). At this stage, data is standardised for further analysis. Third, data is pre-processed to filter out duplicates, re-order, aggregate, or normalise the data prior to analysis and sent it to a data centre (IBM, 2020). Finally, the data centre or cloud is designed to store, process, and analyse vast volumes of data for deeper insights. Data is processed and presented on accessible basis to decision making centres (e.g. reports, through dashboards) where it can be analysed and prepared in real-time or ad hoc (IBM, 2020).

2.1.2.2 IoT instruments

The following section outlines the main instruments and the technologies needed to deploy IoT.

Sensors and actuators

Adopting IoT means collecting data from connected objects within the network and sending it back to a data base or cloud. Sensors are required to pick up physical parameters in the outside world or within the object itself (Kelly et al., 2013). There are different types of IoT sensors (wireless sensors or wearable sensing devices), which are developed and used for various applications (e.g. monitor temperature, wear, vibration, among others) (Graphic 3).

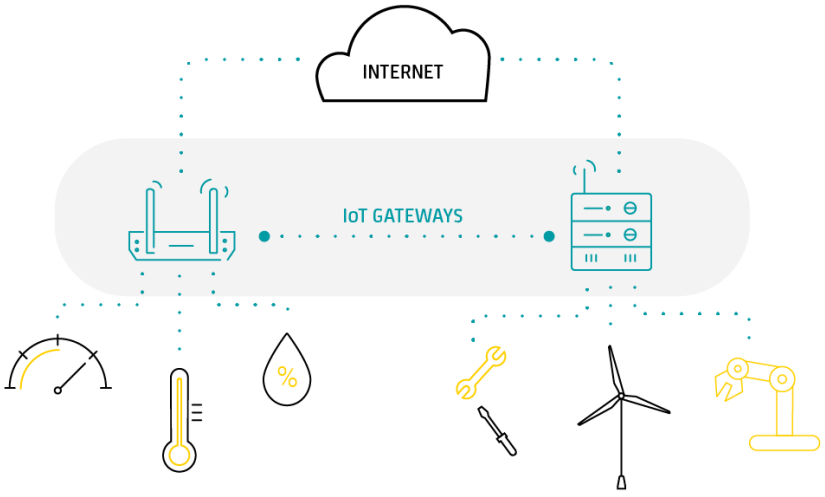
Graphic 3. Examples of IoT sensing applications

Another element of this layer are the actuators. Being in close collaboration with sensors, these devices transform the data generated by smart objects into physical action (Kececi, 2019). Based on the energy sources, actuators are categorised as it follows: *Pneumatic actuators,* which use compressed air for generating motion. As these processes do not need a large amount of motive force, they are used to control those which require quick and accurate response (Nesbitt, 2011); *Hydraulic actuators* using liquids for generating motion. These actuators are used in industrial process control which requires large force and high-speed motion (Motlagh et al., 2020); *Thermal actuators* drawing on heat sources for generating motion. They convert thermal energy into kinetic energy, and motion (Motlagh et al.,2020); *Electric actuators* converting electricity into motion (Kececi, 2019).According*Identification*

IoT systems are composed by several devices, objects and things meaning that IoT solutions need to be prepared to identify different objects and their locations (Al-Fuqaha, 2015). Some of these identification methods include electronic product codes (EPC) and ubiquitous codes (UCode) (Koshizuka & Sakamura, 2010).

Gateways

Gateways are intermediaries between the connected things and the cloud. An IoT gateway device enables routing the data into the IoT system (Graphic 4). They convert the sensor data into formats that can be transferred and used in other systems (e.g. transform video into binary code). They also establish a bi-directional communication between the device-to-gateway and the gateway-to-cloud.



Graphic 4. Gateways linking the IoT components, sensors on the left and actuators on the right side

Communication

An IoT network connects different objects that communicate among them to deliver a specific smart service. IoT communication technologies are fundamental to ensure the constant connectivity among the different IoT layers (Motlagh et al., 2020). Typically, IoT nodes operate using low power technologies such as WIFI, Bluetooth, Zigbee, LTE-M, among others (Table 1) (Al-Fuqaha, 2015). Wireless communication systems connect the sensor devices to IoT gateways and perform end-to-end data transfers among these IoT devices. The

communication technology choice depends on the requirement of the application, namely communication range, bandwidth and power consumption.

Technology \ Parameter	Range	Data Rate	Power Usage (Battery Life)	Security	Installation Cost	Example Application
LoRA	⩽50 km	0.3–38.4 kbps	Very low (8–10 years)	High	Low	Smart buildings (smart lighting)
NB-IoT	⩽50 km	⩽100 kbps	High (1–2 years)	High	Low	Smart grid communication
LTE-M	⩽200 km	0.2–1 Mbps	Low (7–8 years)	High	Moderate	Smart meter
Sigfox	⩽50 km	100 bps	Low (7–8 years)	High	Moderate	Smart buildings (electric plugs)
Weightless	<5 km	100 kbps	Low (Very Long)	High	Low	Smart meter
Bluetooth	⩽50 m	1 Mbps	Low (Few months)	High	Low	Smart home appliances
Zigbee	⩽100 m	250 Kbps	Very Low (5–10 years)	Low	Low	Smart metering in renewable energies
Satellite	Very Long >1500 km	100 kbps	High	High	Costly	Solar & wind power plants

Table 1. Comparison between different wireless technologies (Motlagh et al., 2020; Kabalci et al., 2019; GSMA, 2019; Fraire et al., 2019).

Computation

The IoT system requires a strong computational capacity to collect, gather and analyse data. Computation helps to get technical insights, give accurate responses to the system, and support decision-making (Jaribion et al., 2014). Some hardware – microcontrollers, microprocessors and SOCs – and software applications – OS or Cloud, are required to perform these tasks. Together, these elements constitute the IoT computational "brain" (Al-Faqaha et al., 2015).

Due to its characteristics, the IoT network generates a huge amount of structured, unstructured and heterogeneous data, which goes beyond the capacity of "traditional" methods to store and compute data (Motlagh et al., 2020). Compared to traditional IT, cloud computing[2] – the use of computing resources such as servers, database management, data storage, networking, software applications, and special capabilities such as blockchain and artificial intelligence, over the internet – enhances the computing power and storage capacity (IBM, 2020). Greater cost efficiency is offered since it enables companies to pay solely for

[2] Also referred to simply as "cloud"

the capacity they need and eliminates the ongoing expense of purchasing, housing, maintaining and managing infrastructures. It continually improves performance by regularly updating its infrastructure with the latest computing, storage and networking system (IBM, 2020). Additionally, it eases the data management despite the geographical location (Hamdaqa & Tahvildari, 2012). Another possibility for data processing is Fog computing, which can be considered an extension of the cloud as it expands the cloud at a greater scale, thus supporting a bigger workload (Mahmud et al., 2017). Fog computing uses any device with computing storage and network capability as a fog node, allowing personal computers, industrial controllers, routers, switchers and embedded servers to engage in the computational process (Verma et al., 2014). Enhanced secure services and reduced network traffic and latency are the advantages, providing a faster response with higher security when compared to cloud computing (Atlam et al., 2018).

2.1.3 IoT limitations

This section addresses the limitations of IoT technology.

1. *Smart devices limitations.*

IoT-enabled systems involve a wide range of smart interconnected devices and components (e.g., sensors, biometrics, actuators) which must be capable of sharing information through internet, regardless their location and surrounded environment. Moreover, the heterogeneity of hardware and software, along with the different IoT layers, need to be compatible. The coexistence of different smart components in the IoT network system may create compatibility problems (Chen et al., 2014).

2. *Standardisation and legal issues*

The IoT network system may include smart devices that respect different protocols and architectures (Chen et al., 2014). Different tasks can have different communication protocols, data-aggregation and regulatory standards. Additionally, different tasks can be regulated by different legal entities (e.g. monitoring the health of employees can be regulated both by health and data protection entities). IoT adoption faces the challenge of standardising different protocols, architectures, methods, technologies and it may be supervised by different legal entities (Al-Qaseemi, 2016; Motlagh et al., 2020).

3. *Privacy and Security issues*

The use of IoT and integration communication technologies raises two issues. The first regards the individual rights to maintain confidentiality of personal information when it is shared with an organisation (Prambage et al., 2016; Chow, 2017). Data such as fatigue, productivity or even the health of employees can be gathered by using IoT, thus enabling better decision-making and management (Jayaraman et al., 2017). However, this can constitute a violation of the privacy of the workers. The second issue refers to cyber-security: since all "things" are connected to internet, cyber-attacks are more likely to occur (Poyner & Sherratt, 2018).

4. *Communication limitations*

In IoT, each and every device needs to be connected to a gateway. Therefore, equipment prepared with smart devices need a good internet signal and communication protocols to forward the collected data to the network operation centre. (Singh & Kaur, 2019). Factories represent an infrastructural challenge to internet signal since they have huge metallic structures which block the WIFI signal. Moreover, 4G internet does not make full use of the potential of IoT as it is not capable of quickly and steadily connect and transmit large amounts of data over billions of nodes (Shancang et al., 2018). The 5G internet will resolve these issues being capable of interconnect trillions of devices and transmit large amounts of data (Singh & Kaur, 2019).

2.2 Internet of Things Use cases

The following section covers three industries – energy, retail and manufacture, which have already implemented IoT.

2.2.1 Energy

The European Union is aiming to be climate-neutral by 2050, an economy with net-zero greenhouse gas emissions, which means all parts of society and economic sectors – industry, mobility, buildings, agriculture and forestry – need to adapt to certain constraints (European Commission, 2017). In this sense, all economic agents, including the footwear industry, will need to adapt to this energy paradigm. The role of IoT in the energy sector is designated by the term "Energy Internet of Things" (EIoT), and it describes the IoT applications in the energy management field, from fuel production and extraction, operations, maintenance, to

transmission and distribution, and end use (Minoli & Occhiogrosso, 2018; Motlagh et al., 2020).

Globally, the energy sector has been introducing an energy management system based on IoT to monitor real-time consumption and increase the awareness about the energy performance over the entire supply chain (Tan et al., 2017). It consequently increases energy efficiency consuming less energy while producing the same service/product and consequently diminishing the impacts of fossil fuel use (Connolly et al., 2016; Grubler et al., 2018). By applying IoT, the energy sector can distinguish failures in operations or uncommon changes in energy efficiency, reducing costs with maintenance and environmental impacts (Table 2) (Sigfox, 2020).

	Application	Sector	Description	Benefits
Energy supply	Preventive maintenance	Upstream oil and gas industry/ utility companies	Fault, leakage, and fatigue monitoring by analyzing of big data collected through static and mobile sensors or cameras.	Reducing the risk of failure, production loss and maintenance downtime; reducing the cost of O&M; and preventing accidents and increasing safety.
	Fault maintenance	Upstream oil and gas industry/ utility companies	Identifying failures and problems in energy networks and possibly fixing them virtually.	Improving reliability of a service; improving speed in fixing leakage in district heating or failures in electricity grids; and reducing maintenance time and risk of health/safety.
	Energy storage and analytics	Industrial suppliers or utility companies	Analyzing market data and possibilities for activating flexibility options such as energy storage in the system.	Reducing the risk of supply and demand imbalance; increasing profitability in energy trade by optimal use of flexible and storage options; and ensuring an optimal strategy for storage assets.
	Digitalized power generation	Utility companies & system operator	Analyzing big data of and controlling many generation units at different time scales.	Improving security of supply; improving asset usage and management; reducing the cost of provision of backup capacity; accelerating the response to the loss of load; and reducing the risk of blackout.

Table 2. Application of IoT in the energy sector (Motlagh et al., 2020)

This dissertation analysed exclusively the EIoT adoption for industry.

2.2.1.1 Smart use of Energy in Industry

The deployment of IoT in industry increases energy efficiency while optimising production processes. By monitoring every process, IoT recognizes abnormal energy consumption which are a sign of defective processes (e.g. overconsumption of raw materials) and/or malfunctions (e.g. damaged equipment) (Reitze et al., 2018). This technology enables to reduce production waste and energy consumption while optimising the energy efficiency of equipment installed with smart devices (Motrlagh 2020). Literature suggests that the age of equipment and poor maintenance can lead to high level of energy losses and unreliability (Ramamurthy & Jain,

2017; Immelt, 2015). By monitoring equipment and tracking its conditions, IoT can identify components more susceptible to wear and ensure that they never reach their threshold limits. Ensuring the good conditions of equipment extends their life expectancy and prevents failures that cause energy loss (Kaur & Soon, 2017).

2.2.2 Retail

One of the most prominent fields of applications of IoT is the retail industry (Pantano & Timmermans, 2014). IoT offers retailers opportunities in three different areas, namely supply chain and logistics, new channels and revenue management, and customer experience (Gregory, 2015). This dissertation focused on the first area.

The supply chain and logistics management include several functions such as inventory, location, distribution, routing, purchasing and production (Mostafa & Eltawil, 2016). IoT can improve several of these functions, considering that some IoT solutions have already been implemented. IoT and connected devices help managing issues originated from imperfect information such as the bullwhip effect which describes the risk amplification from the demand side to the supply side due to distorted demand information. It leads to excessive inventory investment, poor customer service, lost revenues, ineffective transportation, misguided capacity plans, and missed production schedules (Asgary & Li., 2016). Since IoT tools help operators to easily trace, track and inspect what is happening in real-time and in any stage of the supply chain, a stronger collaboration can arise and resolve imperfect information, making services more agile, flexible and reducing hazards and disruptions (Schoen et al., 2016; Yan et al., 2016). Real-time data gathered from IoT systems can be analysed and used by decision-making centres, thus providing forecast models resulting in greater accura demand and answering to market dynamics instantly (Yerpude & Singhal, 2017). Furthermore, warehouses contain numerous products meaning that companies need to ensure a fast and accurate identification and pick up (Sun & Lu, 2018). The introduction of IoT in warehouses inproves order fulfilment, enhances picking processes, better inventory tracking improving overall performance and reducing warehouse costs (Tejesh and Roy, 2017; Reaidy et al., 2015). For the same reasons, the introduction of IoT in the industrial process offers not only greater visibility at each stage of the production process but it also improves efficiency and scalability, accurate breakdown prediction, ingredient waste reduction, and performance improvement (Anita & Abhinav, 2017). Moreover, it improves

the inventory management by providing real-time data of inventory hence improving the visibility of demand and preventing stock-out and inventory shrinkage (Qin et al., 2017).

2.2.3 Manufacturing

The deployment of IoT is rapidly evolving, growing and offering several solutions that are transforming various industries including manufacturing (Xu et al., 2014), being described as Manufacturing Internet of Things (MIoT) (Zhong et al., 2017). The goal of using IoT in manufacturing is to improve productivity and reduce costs without compromising quality. It brings production-technical changes but also organisational and administrative changes. (Arnold et al., 2016). The adoption of Internet of Things in Manufacturing can have a substantial impact in the business operations, namely improving operations and productions, reducing machine downtime, improving product quality, enhancing supply chain and improving customer experience (Zhong et al., 2017) Further opportunities and potentials are associated with resource efficiency in terms of energy and material consumption, optimised decision making and flexibility[3], work-life balance improvement (Kiel et al., 2017). In this sense, manufacturing companies have been implementing IoT mainly in five categories (Lade et al., 2017):

1. *Reducing test time and calibration:* Prediction of test results and calibration parameters;
2. *Improving quality:* the self-optimisation of the assembly line allows to identify damage parts or products which do not match quality parameters during production. This allows to correct the procedure or stop that unit production preventing defective products;
3. *Reducing warranty cost:* The gathered data from IoT enables to predict, with a certain amount of certainty, when the product failure is to take place;
4. *Predictive maintenance:* IoT allows to predict when a device or component will reach its failure, thus avoiding unscheduled machine downtime;
5. *Improving Production***:** This includes benchmark analysis across every step of the production process hence identifying causes that are creating bottlenecks, the overall equipment efficiency and cycle time;

[3] Centralised systems may lead to significant time delay and inflexibility to respond changes promptly. Therefore, IoT is leading firms to opt for distributed and decentralised architecture to better deal with these new dynamics.

MIoT is creating factories which are completely or partially intelligent and autonomous, where thousands of processes and quality measures are collected in order to improve quality and efficiency while reducing costs. It provides these corporations an additional tool to stay competitive (Lansiti & Lankhani, 2014; Loebbecke and Picot, 2015).

2.3 The Footwear Industry

The footwear sector is a diverse industry covering a wide variety of materials – textile, leather, plastic, among others – and products from different types of footwear for men, women, and children to more specialised products such as protective and medical footwear (European Commission, 2017).

According to data from World Footwear Yearbook, the footwear production worldwide reached 24.2 billion pairs in 2018 (World Footwear Yearbook, 2019). The Asian continent had 86.2% market share in world production, followed by South America (5%), Africa (3.6%), Europe (3.3%), and North America (1.9%) (World Footwear Yearbook, 2019). China, the export leader, is the origin of almost two thirds of all footwear exports, however, its market share fell by 1.3 percentage points in 2018, showing a downward trend since 2010.

RANK	COUNTRY	PAIRS (MILLIONS)	WORLD SHARE
1	CHINA	9 543	64.7%
2	VIETNAM	1 272	8.6%
3	INDONESIA	406	2.8%
4	GERMANY	314	2.1%
5	BELGIUM	284	1.9%

Table 3. Top 5 worldwide exporters of footwear (World Footwear Yearbook, 2019)

The top 10 footwear consumer countries – China, India, the USA, Indonesia, Brazil, Japan, Germany, Pakistan, United Kingdom, and France – represent 60% of global consumption. China leads the footwear consumption world share (18.4%), followed by India (11.7%) and the USA (10.7%) (World Footwear Yearbook, 2019).

2.3.1 The Portuguese Footwear Industry

The Portuguese footwear industry has been evolving and adapting since the last few decades. During the 1970s and the 1980s the industry grew based on the low labour costs and on scale-economies based on large volumes. In the 1990s, several buyers and producers of footwear moved their operations and orders from Portugal to Asia and Eastern Europe (Silva, 2019). Despite these challenges, in 2018, the footwear sector accounted for 2.8% of the Portuguese GDP, and represented 6.7% of all jobs in Portugal. It produced more than 80 million pairs of shoes making approximately 2 billion euros, representing 3.4% of the total national goods exported (APICCAPS, 2019). It employs approximately 40,000 people in almost 1,500 companies. The footwear industry is particularly relevant in the North, where most companies are based, displaying two major production centres: one in Felgueiras and Guimarães; the other in Santa Maria da Feira, São João da Madeira and Oliveira de Azeméis. Both centres are estimated to be about 50/60 kilometres from Porto. A third centre is located in Benedita, 90 kilometres from Lisbon, having a smaller expression (APICCAPS, 2019).

Internationally, Portugal remains the 6th largest leather footwear exporter worldwide. The Portuguese footwear exports are mainly targeted to European markets, possessing substantial market shares there: Denmark (11%), United Kingdom (6.7%), France (5.1%), Spain (4.3%), and Germany (4.1%) (APICCAPS, 2019).

POSITION	COUNTRIES	MILLION €
1	FRANCE	395
2	GERMANY	351
3	NETHERLANDS	269
4	SPAIN	176
5	UNITED KINGDOM	123
	TOTAL	1 902

Table 4. Major markets of Portuguese footwear exportations

2.3.2 Portuguese Footwear SMEs Business model

The following paragraphs address the Portuguese footwear SMEs, macroeconomy framework, stakeholders, and their current business model.

The national footwear sector, including SMEs, underwent expansion from the late 1970s until the late 1980s. During this phase, which correspond to the first and second integration of

Portugal in the European Economic Community (EEC), large multinational companies set their production in Portugal or subcontracted Portuguese footwear manufacturers. At the time, the Portuguese footwear industry was oriented towards mass production and low-cost products (DGAE, 2017). During the 1990s, several Asian countries entered the global market offering fewer operational costs to footwear companies. It resulted in a wave of displacement of footwear companies established in Portugal to the Asian continent. The Portuguese footwear industry suffered a great setback when China entered the World Trade Organization in 2001 (DGAE, 2017; Interview C). The characteristics of Asian industries – accessible technology, high rate of human labour, low implementation costs – along with lower wages and costs, justified the displacement of footwear firms.

This new reality presented a new paradigm to the remaining Portuguese footwear SMEs. The business migration towards Asia, specially China, took a significant amount of footwear suppliers and the biggest orders. This new paradigm led Portuguese footwear SMEs to their actual business model: customization and high added value. These firms moved from a business model based on mass production and low-cost products to highly customised products with high added value (Interview A, B, and C). The lack of competitiveness of Portuguese footwear companies to secure big orders due to smaller prices charged by companies established in Asia, moved their business focus towards small and micro orders. Portuguese SMEs are now addressing a market segment which focus on high product customisation and higher product quality (Interview A, B, and C).

This new paradigm has brought new challenges to the Portuguese footwear SMEs. These firms produce low quantities of high customised products which require a high rate of human labour. Such factors hinder automation and result in high production costs, culminating in low profit margins (Interview A, B, and C). Despite the effort to automate and sophisticate several tasks and processes, these firms face significant obstacles concerning the lack of financial and technical resources to acquire the best equipment and technologies in the market (Interview C).

The Portuguese SMEs working in the footwear industry are split in two major footwear areas: footwear manufacturing and the manufacture of footwear components. Footwear manufacturing encompasses the manufacture of footwear in different materials – leather, rubber, plastic, textiles, wood, among others whereas the latter regards the production of every part of shoe components – soles, shoe uppers, insoles, heels, toecaps, among others

(DGAE, 2017). Despite the recent emergence of Portuguese footwear brands and collections, most SMEs work on an outsourcing basis with foreign companies (DGAE, 2017).

The Human Resources in this sector, in general, are not very qualified, however footwear managers and Portuguese footwear associations – APICCAPS and CTCP – have been doing an effort to up-grade the qualification of the workers (Interview C). The Footwear Technological Center of Portugal (CTCP) and the Portuguese Footwear, Components, Leather Goods Manufacturers' Association (APICCAPS) are the most important stakeholders in the Portuguese Footwear Industry. Both associations have been playing a key role in the modernisation and internationalisation of the Portuguese footwear industry, including SMEs. They represent an essential partner for SMEs since they promote networking, technical and financial support (Interview C).

2.3.2 IoT & Portuguese footwear industry

This industry has invested in Industry 4.0 technologies in order to digitise and modernise production and selling methods (Silva, 2019). APICCAPS and the Footwear Technological Center of Portugal (CTCP), in a partnership with the Portuguese government, launched the FOOTure 4.0 programme which explores the opportunities created by Industry 4.0. The programme defined four strategic priorities: first, create ways of interacting with the customer in a digital and network context; second, improve flexibility, customer response time, business intelligence and sustainability; third, qualify the sector for industry 4.0 by making it more dynamic, innovative and capable of creating new businesses; fourth, improve the intelligence and image of the sector (APICCAPS & CTCP, 2019).

So far none of the Portuguese footwear companies, including SMEs, applied IoT solutions in their business (APICCAPS, 2020). However, it has been estimated that this technology will have an impact on businesses. IoT solutions allow to control production in real-time to produce an unlimited number of different footwear models at the same time (Silva, 2019).

3 Methodology

3.1 Research Design

This dissertation aims to identify potential benefits generated by the adoption of IoT for Portuguese footwear companies. This chapter elaborates on the methodology to answer the following research questions:

1. What are the use cases and associated potential for Internet of Things in the Portuguese footwear SME industry?
2. How can Portuguese footwear SMEs, effectively implement IoT in their businesses?

A qualitative method was used to evaluate the associated potential of different use cases and address the first research question. First, IoT use cases of leading corporations in three different industries – manufacturing, retailing, and energy – were examined to analyse the potential applications, best practices, and outcomes of IoT projects. Second, 7 IoT use cases were examined to evaluate the potential operational, production, and economic impact for Portuguese footwear SMEs. They are based on the interviews with IoT experts, the IoT supplier, and Portuguese footwear SMEs professionals. The aim was to present the potential of different IoT use cases, considering the technical and economic framework of footwear SMEs and the limitations of the technology.

In research question 1, a semi-quantitative method was used to measure the importance of the limitations of the technology and in research question 2 the importance of the implementation challenges based on qualitative components. First, parameters were chosen from interviews, literature review. Second, these parameters were assessed using a method of scaling. Third, the weight of each stakeholder group was established according to its importance in the subject.

The second research question was developed under a qualitative method. It is presented an IoT implementation plan based on the interviews with IoT experts and footwear stakeholders. The results of research question 1 were taken into consideration. The objective was to match the characteristics of Portuguese footwear SMEs with IoT technology requirements, providing a successful method to implement an IoT solution.

Both research questions only considered Portuguese firms in the footwear industry employing less than 250 people and having a total turnover under 50 million euros, hence respecting the European Commission standards (European Commission, 2017).

3.2 Data collection

Primary data and secondary data were used to answer both research questions, englobing literature review, interviews and reports. As a primary method of data collection, 10 semi-structured expert interviews were held with three different stakeholders: IoT experts, IoT suppliers and footwear professionals working in Portuguese SMEs. The interviews lasted between 25 and 70 minutes and were held via phone, email or video call. IoT experts were the first to be interviewed, having their answers been used to build the interview guides for IoT suppliers and footwear professionals in combination with literature reviews and reports. The interview guidelines were divided into three parts. First, a brief set of introductory questions to collect information about the company and the participant. Second, for IoT experts and IoT supplier cases, it was asked the technology requirements, enablers, challenges, and the inherent economic impact of developing and implementing an IoT solution. The footwear professionals were asked about the characteristics of the Portuguese footwear industry and the reality of Portuguese SMEs, including the willingness and capacity to adopt an IoT solution. The last set of questions were open questions to collect data about subjects which were not considered during the elaboration of the guides.

The secondary data were collected from the literature review and additional reports. It was given priority to A source academic journals in the field of technology and management, as well as IoT consultancy projects.

Table 5. Footwear interviews

Footwear Professionals Interviews						
Interview	**Name**	**Position**	**Company type**	**Company**	**Annual Revenue (2019)**	**Number of employees**
A	Luís Claro	IT Team Leader	Footwear	DesignMore & WalkMore	2M & 3M	16 & 11
B	-	Senior Economist	Footwear	ISI Soles	10 M	95
C	Pedro Castro	Project Manager	Footwear	Aloft	5.5 M	95

Table 6. IoT interviews

IoT Experts and IoT Supplier Interviews					
Interview	**Name**	**Position**	**Company Type**	**Company**	**Annual Revenue (2019)**
D	Duarte Filipe	Maintenance Engineer (responsible for digital transformation)	Manufacturing	Navigator	€1,688 b
E	Emre Dikmen	Technical and managing partner of Unilever's digitalization projects	Manufacturing	Unilever	€53,715 b
F	Diogo Ribeiro	Process Control and Automation Manager	Manufacturing	Heineken	€18,383 b
G	Bruno Espírito Santo	Head of Automation & IoT	Energy	EDP	€14,333 b
H	Juan Blanco	IoT & Blockchain technician	Energy	CEPSA	€21,158 b
I	Eduardo Brandão	Infrastructure & IoT Architect	Retail	SONAE	€5,710 b
J	Carlos Pereira	Managing Partner	IoT supplier	EQS	€18 M

4. Results and Discussion

This chapter presents and analyses the empirical data from a business perspective. The objective of the following sections is to answer the first research question: *What are the use cases and associated potential for Internet of Things in the Portuguese footwear SME industry*. The second research question, *How can Portuguese footwear SMEs efficiently implement IoT in their business? is* answered on section 4.3.

4.1 IoT Use Cases

In order to obtain a clear understanding of the potentialities associated to IoT solutions, the following section examines why leading corporations have implemented the technology and its impact on their businesses. The selected use cases provide insights which enable the development of use cases for Portuguese footwear SMEs presented in section 4.2.

Navigator

Navigator is an integrated forest producer whose end products are pulp, paper, tissues, and energy. The company is the largest manufacturer of uncoated wood-free printing and writing paper in Europe, and the sixth in the world. The IoT project started in 2018 with the objective to gather data of critical equipment and move from reactive maintenance to predictive maintenance. The company possesses old industrial equipment still having good performance and long-life expectancy. The IoT technology was introduced to start monitoring close to real-time, the conditions of these assets, from the conditions of each component inside these machines (e.g., engine) to its processes (e.g. temperature and vibration). The data gathered enabled the company to establish patterns which can be used to predict future failures. Although this IoT solution required a significant temporary financial investment in hardware, the company has decreased its downtime costs. The capacity to predict future machine failure prevents serious malfunctions and breakdown time, as well as all the associated costs with production stoppages and higher reparation costs. Although there are traditional technologies that can solve the same issues (e.g., devices originally built with sensors), they would require the acquisition of new equipment. The acquisition of IoT hardware and software allowed the company to keep using and monitoring their old equipment with a relatively small investment, when compared to traditional technologies. The immaturity of IoT represents the main obstacle, the company cannot find a solution which fits its needs 100% in the market. Additionally, communications represent a big challenge that still need to be overcome,

regarding the WIFI signal inside factories and the 4G technology capacity to transmit high volumes of data.

Unilever

Unilever is a multinational consumer goods company. Its products include food, energy drink, ice cream, tea, cleaning agents, beauty and personal care products, and it is the largest producer of soap in the world. The company is using IoT to collect reliable data and to control different processes (e.g. control temperature, machines vibration). The firm developed an IoT solution which is divided into two concepts and architectures: shop floor integration (e.g., production processes, machines, robots, workers) and data management systems (e.g., addressing the systems of Unilever such as server, cloud, and edge devices). The IoT communications base, WIFI, allowed the company to eliminate the considerable cabling costs and to monitor equipment placed in rough environments. On the shop floor the company is using IoT technology to monitor its equipment (e.g. pumps, compressors, components, among others) and processes. The gathered data, close to real-time, enables the company to set production, energy consumption and equipment status and patterns. The technology enables the company to take a closer look over its assets such as the conditions and energy consumption of each component inside the industrial machines. The data gathered with IoT has been helping to diminish the risk of equipment failure, energy consumption waste, product defects, and transformed human work force into automation, as well as to reduce all the associated costs.

Heineken

Heineken is one the largest beer producers in the world. It has developed several IoT solutions all over the world, which are not homogenous in terms of maturity and objectives. The firm has adopted IoT in sales, customer service, maintenance and production monitorisation. Beer factories possess an enormous variety and quantity of machines and components, each with a different expected lifetime and wear. In Portugal, Heineken has given priority to IoT maintenance and monitoring production projects. The IoT allows the company to gather more and more accurate data in real-time, regarding the efficiency and the condition of each individual component and process. The gathered data has given Heineken the opportunity to establish patterns and make future predictions concerning the lifetime expectancy and wear of each component. Having the ability to monitor each component and plan maintenance allows

factories to anticipate failure, prevent downtime, and sending the defective component for reparation instead of sending an entire machine. Additionally, IoT is allowing to reduce production waste and increase productivity. By monitoring production in real-time (e.g., temperature, fermentation, among others), Heineken can automatically correct the values and avoid losing batches that do not meet the quality standards. Financially, IoT has significantly been reducing costs with maintenance, reparation, production stoppage, and eliminating production inefficiencies and waste. The greatest challenge that Heineken has been facing is the lack of the maturity of the IoT. The firm has been facing the obstacle to find experienced IoT suppliers that could meet all its needs and requirements.

CEPSA

CEPSA is a multinational oil and gas company, which extracts, refines, and sells oil and gas. It has several IoT projects, each in a different state of maturity and addressing different issues. The IoT projects vary from activity to activity – oil exploration, refineries, energy distribution, work safety – and all follow the same purpose: collecting bigger quantities and reliable data. The company decided to implement IoT solutions for two reasons: cost reduction and the flexible architecture of IoT. It is cheaper to monitor equipment and processes with IoT technology when compared to traditional technology (e.g., devices that already possess sensors). Additionally, IoT architecture flexibility offers CEPSA the opportunity to use the same technology and standards to address different issues and tasks. The firm is monitoring production, employees, and machines at different work environments such as refineries, retail stores, and drilling rigs using the same technology. The IoT is also an important enabler to other technologies (e.g., advanced analytics, AI, among others) which cannot be achieved with traditional technology. CEPSA has been using IoT to improve the efficiency of production processes, reduce production waste, increase work safety, and predict equipment failure. The adoption has both decreased costs and increased profits. Some of those economic benefits are tangible – less consumption of raw materials, downtime, reduce waste – while others are intangible – work safety.

EDP

EDP is a multinational, vertically integrated utility company. It is present throughout the electricity value chain and in the gas commercialisation activity, being the fourth largest wind energy company in the world. The company has adopted IoT for two reasons. First, with the

objective to collect larger amounts and reliable data about the grid status in real-time. The collected data is used to predict several events, at any given time in the grid, namely consumption flows, anomalies, failures, voltage and current levels. Second, IoT technology offers the necessary flexibility to be applied in a wide variety of tasks and activities which have different architectures. Moreover, it is given the possibility to apply the same standards to everything (e.g., connecting different devices through WIFI). IoT is also an important enabler to other technologies projects at EDP (e.g., advanced analytics). It has been a key element to maximise efficiency and reduce costs. Even though some processes have kept the same operational costs, IoT is allowing to perform the same tasks with less employees who were transferred to other departments or demanding tasks. Additionally, by moving from reaction to prediction, the company has been able to anticipate anomalies and prevent the worst-case scenarios in each situation (e.g., equipment failure, electrical failure, blackout).

SONAE

SONAE is a multinational company managing a diversified portfolio of business in retail, financial services, technology, shopping centres and telecommunications. SONAE MC addresses the food retail market covering a wide range of business segments: hypermarkets, convenience shops, cafeterias and restaurants, animal products and services, and bookshops. The firm implemented IoT technology in retailing to collect larger amounts of reliable data in real-time. It has three different IoT projects. First, it is using IoT technology to establish consumption patterns (e.g., product preferences, number of trolleys inside shops and their taken routes). Certain brands pay SONAE to stand out their products inside shops as some sections and shelves are more valuable than others. The reliable data gathered with IoT proves which are the most visited sections and shelves inside shops and in turn that is used for marketing purposes. Second, IoT enables a fast technical-customer support response. By gathering information in real time, product and equipment anomalies (e.g., food condition, freezer failure) can now be instantly detected (e.g., avoiding selling expired products or losing perishable goods when equipment fails). The third IoT project concerns the transportation of consumer goods in individual thermic boxes. Each box has different temperatures which are being remotely monitored and controlled with IoT technology. The firm is developing two other IoT solution which are not well developed. First, SONAE wants to monitor and control the energy usage at shops and their equipment (e.g., freezers) to reduce energy costs. Second, it wants to apply IoT technology to track and pick the products at shops and warehouses. By

adopting IoT, the firm has increased its productivity, profitability, as well as cost reduction. All these IoT solutions enabled the automation of specific tasks (e.g., monitoring product availability on shelves) allowing the company to deliver the same service quality using less resources (e.g., human resources, time)

Table 7. Motivations of IoT implementations

Industry	Firm	Collect new data	Flexibility	Automate processes	Increase productivity	Cost savings
Manufacturing	Navigator	X				X
	Unilever	X		X	X	X
	Heineken	X			X	X
Energy	EDP	X	X	X		X
	CEPSA	X	X			X
Retailing	SONAE	X		X	X	X

The table above describes the different reasons which motivated the stated companies to implement IoT solutions. Depending on the goal that the IoT project wants to achieve and the feasibility of the project, IoT offers a wide set of opportunities (Interview D, F, G, and I). However, the presented table, along with literature review, suggests that the major IoT opportunities result from the potential to collect new data and reduce costs. Regardless the industry, all firms implemented IoT with the purpose of collecting new data and reducing costs. This technology enables to collect large amounts of data on many different areas (e.g., energy, logistics, production, maintenance, among others) and collect new insights (e.g., power consumption, vibration, temperature). Reliable information is the key element of IoT (Interview D, E, F, G, H, I, and J). It allows corporations to check their assets condition (e.g. wear of components) and production/operational processes (e.g., find bottlenecks, detect

production waste) (Interview D, E, F, G, H, and I). IoT enhances the ability of companies to increase productivity and reduce production and operational costs (Interview D, E, F, G, H, and I). By monitoring and tracking processes, organisations can take a closer look over their procedures and optimise them (e.g., reduce energy and raw materials overconsumption, reduce downtime, reduce the number of defective products). Table 7 suggests that IoT offers a great chance to reduce costs. Another reason for the implementation of IoT was the fact that it reduces human effort by automating tasks normally done by human labour (e.g., detecting product availability on shelves, detecting vegetation approaching high voltage pylons), thus removing eventual human errors from the process (Interview G and I). Finally, organisations in the energy business implemented IoT due to its flexibility. IoT enables different technologies, procedures, and equipment to operate under the same protocols and standards. Therefore, it permits to reduce the technical complexity of having a broad technology portfolio within the company and its associated financial costs.

4.2 Potential value of applying IoT

The objective of the following section 4.2 is to analyse seven IoT use cases in order to assess the potential added value of IoT for Portuguese footwear SMEs. The limitations of the technology have been assessed and taken into consideration.

4.2.1 Potential operational and production gains

The associated operational and production gains of the seven IoT use cases are as it follows (Zhong et al., 2017; Kiel et al., 2017; Farhni et al., 2020; Interviews A, B, C, D, E, F, G, H, and I;)

1. *Safety:* IoT technology can enhance safety at the workplace by tracking the activities of the employees and their location within the facilities (e.g., signal that staff is moving towards dangerous parts of the facility, turn off equipment when reaching dangerous levels, among others). A safer workplace enables to reduce costs with accidents at work, namely sick leaves (e.g., hiring a replacement and training him/her) and decrease insurance costs;
2. *Inventory management:* IoT can leverage automated asset tracking and reporting in real-time. Corporations can remotely account, locate, and assess the condition of their assets, which can range from handled devices to raw materials, and large industrial equipment. This real-time transparency allows the logistics team to manage the

material flow more accurately and order raw material and other inputs closer to the date they are needed, reducing the inventory and its inherent costs (e.g., eliminating the bullwhip effect);

3. *Production visibility:* IoT is constantly monitoring assets and processes. The availability of materials, work-in-progress, condition, inefficiency, and malfunction of each component and process can be assessed in real-time or close to it. The higher the visibility over assets and processes, the greater the opportunity to detect inefficiencies and anomalies: production waste (e.g., product flaws), overconsumption of energy, bottlenecks. With greater visibility over the processes, comes the opportunity to use resources more efficiently (e.g., raw materials and energy) and to lean processes (e.g., solve bottlenecks);
4. *Maintenance:* IoT identifies the condition of equipment and predicts when a certain component will fail. Instead of replacing a machine part after a certain period of time, organisations can extend its lifetime by measuring its conditions. It allows the company to plan maintenance in advance decreasing the reparation and downtime costs;
5. *Remote connectivity:* IoT leverages remote monitoring, data collection and control. Remote access to machines reduces the necessity to be physically present, especially reducing travelling costs;
6. *Energy efficiency:* IoT connectivity provides the energy profile of equipment and components being monitored. It detects energy peaks of consumption and it keeps machines operating at their peak efficiency. Abnormal energy consumption is normally a sign of equipment malfunction;
7. *Procurement transparency:* IoT enhances the procurement optimisation by using real-time information on inventory and production capacity, determining the exact quantities that must be ordered while providing the data to improve negotiation strategies (e.g., buying raw materials when prices are low).

The following table summarises the operational and production gains as it assesses the potential economic impact of each use case based on footwear SMEs operational costs (Farhni et al., 2020; Interview A, B and C) (Appendix 1).

Table 8. Potential operational, production and economic gains

IoT applications	IoT use case	Potential operational and production gains	SMEs operational costs example (per year)	Potential economic impact (per year)
Safety	Workforce tracking	Decrease work insurance costs up to 10% Intangible gains (e.g. human life/health)	€8,000 with insurance costs	8,000×10%=€800
Inventory management	Manage and reduce inventory	Decrease inventory from 10% to 35% and its inherent costs	Inventory =750,502	750,502×10%= 75,050.2 to 20,000×35%= 262,675.7
Production visibility	Waste reduction Find inefficiencies, malfunctions, lean processes	-20% waste Productivity increased from 15% to 25%	€10,000 with product defects costs	15,000×20%=€3,000
Maintenance	Maintenance-cycle increase Predictive maintenance: reduce downtime probability	From -10% to -15% maintenance costs Up to 5%-point overall equipment effectiveness	€71,578 with maintenance costs	71,578×10%=€7,157.8 to 171,578×15%=€10,736.7
Remote connectivity	Remotely monitor and control processes	From -10% to -40% service costs (mostly travels)	€26,248 with travels costs	26,248×10%=€2,624.8 to 26,248×40%= €10,499.2
Energy efficiency	Leverage energy	Increase energy	€197,460 with energy	

	consumption efficiency	efficiency up to 40%	costs	197,460×40%=€78,984
Procurement transparency	Optimise procurement strategy	From -2% to -5% with raw material costs	€2,932,000 with raw material costs	300,000×2%=€58,640 to 300,000×5%=€146,600

The previous table proves that different use cases bring different operational and production gains. Along with Table 7, it is possible to conclude that the main gains concern cost savings.

4.2.2 IoT limitations

Once understood how IoT can bring operational and production gains, it is necessary to assess the main limitations which can hinder an IoT solution. The four potential limitations are as it follows.

1. *Scalability issues:* The increasing size of the IoT project bears a greater number of devices augmenting the complexity pertaining to collecting, storing, processing, analysing data (Xu et al, 2014; Kamble et al., 2019). The bigger the scale of an IoT solution, the greater the challenges for the IoT network and communications. IoT systems may become overloaded with data and communications may not stand a greater number of connected devices (Interview D).
2. *Lack of internet infrastructure*: Poor internet connectivity and unreliable electricity supply constitute two critical challenges to IoT adoption (Luthra et al., 2018). IoT requires internet and electricity to ensure the functionality and connectivity of smart services. Low internet penetration and issues with continuous supply of electricity jeopardise the IoT reliability since it creates information blackouts (Interview D, F, and G).
3. *Compatibility issues*: Challenges in integrating IoT technologies with existing legal systems, and the heterogeneity of technologies and device usage arise compatibility problems (Alaba et al, 2017; Kamble et al., 2019). Incompatibility among software, hardware, machinery, and equipment, prevents the connectivity that IoT solutions require to deliver reliable data (Interview D and F).
4. *Cyber-Security*: the opportunity to connect devices and control business processes through internet, increases the risk of suffering cyber-attacks. Threats such as overwriting false data, accessing sensitive data, and sabotages can paralyse the

networks (Kamble et al., 2019; Interview A, C, E, G, H and I). Judicial laws should provide guidance on efficient network usage and define clear restrictions on sensitive frequency bands (Bandyopadhyay & Sen, 2011).

A frequency analysis was created to assess the degree of importance of each IoT limitation. The greater the value, the greater the importance of the limitation. All respondents were asked to list the IoT major limitations.

The weight of importance of the stakeholder groups was decided as it follows. IoT experts were given priority since they have the technological know-how and the experience regarding the limitations of the technology. It was given moderate preference to the IoT supplier due to his IoT knowledge and involvement in several IoT project implementations. Nonetheless, as a seller, the data may be biased (over evaluated or devaluated). Finally, footwear SMEs professionals have a deep knowledge concerning the footwear industry and the SMEs framework. However, they do not possess a strong IoT background as the IoT experts and the IoT supplier do. In this sense, the weight of importance for the limitations of the technology is 50% for the IoT experts, 30% for the IoT supplier, and 20% for the footwear professionals.

Table 9. IoT limitations

Limitations	**IoT experts**	**Footwear professionals**	**IoT supplier**	**Total limitation importance**
Scalability issues	4	4	4	(4×0.5) +(4×0.2) +(4×0.3) =4
Lack of IoT infrastructures	2	3	2	(2×0.5) +(3×0.2) +(2×0.3) =2
Cyber-security issue	4	4	4	(4×0.5) +(4×0.2) +(4×0.3) =4
Compatibility issue	3	4	3	(3×0.5) +(4×0.2) +(3×0.3) =3.2
Weight of importance of each stakeholder	**50%**	**20%**	**30%**	

1 – 4 Limitation importance

1) Low importance
2) Medium importance
3) High importance
4) Huge importance

As it can be seen from the analysis in Table 9, the lack of IoT infrastructures is the least important limitation with a 2 degree of importance. Elements such as good internet connection and reliable electricity supply are elements without which the IoT solution does not work. Nonetheless, it was mentioned by IoT experts and the supplier that it is possible to overcome this issue unless the IoT programme requires real-time analysis. Close to real-time solutions, can have smart sensors saving the collected data in their memory and be programmed to send it from time to time (e.g., once every hour) or when the internet connection /energy is re-established (Interview D and E).

The compatibility and integration of different technologies, devices, and IoT layers was recognised as an important issue, with a 3.2 degree of importance. The technology and the IoT supplier service are not mature enough bringing constraints regarding the compatibility between hardware and software. IoT suppliers often offer IoT software without the correspondent hardware, or vice versa. Therefore, companies have to search and find the related compatible hardware/software in the market (Interview F). However, thanks to intensive collaboration between the IoT suppliers and the firms that are implementing IoT, this issue can be mitigated (Interview J). A reliable compatible system guarantees that the necessary data are being collected and arriving at their destination (e.g. cloud, data base).

The last criterion took into consideration the cyber-security and the scalability issues, both with a degree of importance of 4. Regarding cyber-security, the opportunity to connect several business devices and control business processes through internet, increases the risk of suffering cyber-attacks. The larger the number of devices and processes connected through internet, the greater the chance of suffering a cyber-attack. Without a proper IoT security protocol, hackers can access sensitive data and sabotage processes. It is imperative to give top priority to this threat since it can tear down the processes that depend on IoT technology (Interview A, C, E, G, H and I). An access control protocol and stronger user authentication

can help to ensure that only authorised users are able to gain access to the IoT system (Interview H).

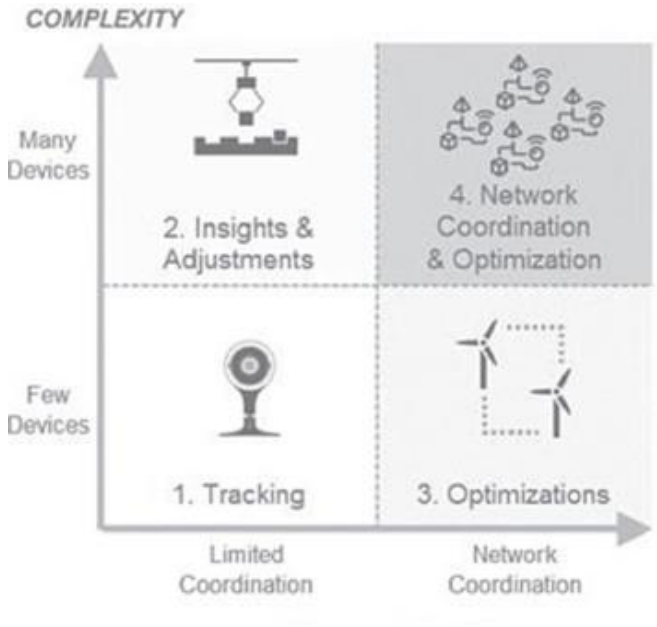
Concerning the scalability issue, an IoT solution can be reliable and efficient in a small scale but unfeasible at a larger scale. As the scale increases so does the network and communication challenges. For instance, an IoT prototype may easily gather information and ensure communication among 20 devices yet the system may be impractical with 100 devices due to the amount and size of data collected, as well as the communications capacity to connect so many devices. The costs to ensure a reliable solution could surpass the benefits (Interview D, F, and I).

The operational and production added value in section 4.2.1 depends on the ability of all stakeholders to overcome these IoT limitations. Additionally, the IoT potential for Portuguese footwear SMEs is also dependent on the economic and technical framework of these companies. The next section evaluates the feasibility of each IoT use case.

4.2.3 Projects feasibility

There are two fundamental factors that may inhibit the projects feasibility for Portuguese footwear SMEs, namely the economic and technical requirements of IoT solutions (Interview D, F, H, I, and J). The technical requirements focus on the technical resources available on the organisations, involving their capacity to convert the use cases into working systems: data analysis, data mining, database design, programming, establishing a wireless mesh networking, and user experience (Interview D, E, F, G, H, and I) . The economic feasibility determines the viability of each project regarding the ability of footwear SMEs to bear the implementation costs. Since the Portuguese footwear SMEs are decapitalised and do not have financial capacity to make significant investments on complex IoT solutions, the degree of feasibility is dependent on the project simplicity and affordable implementation costs (Interview A, B and C).

For the purpose of gauging the level of complexity of each IoT use case, the following levels are presented, in ascending order of complexity (Rossman, 2016).



Graphic 5. Levels of IoT projects complexity (Rossman, 2016)

Level 1, Tracking: it is the basic connected-device scenario. It concerns tracking objects/things and people, collect the data and send it to the cloud.

Level 2, Insights and Adjustments: Level 2 IoT solutions provide sensor-based analytics which provide data to set adjustments on basic events and scenarios. At this level, the IoT system is capturing production data, feeding them into production and yielding reports, as well as applying the pre-established rules/parameters. However, the data collected does not create real-time adjustments or optimisations.

Level 3, Optimizations: It concerns complex data science, forecasting, and real-time adjustment scenarios or processes. This level includes the actuators which play a crucial role in optimising the processes (e.g., controlling the temperature).

Level 4, Network coordination and optimization: This level aggregates all the three previous levels, adding the accuracy of insight and the data collection. A greater interaction among different devices provide additional data and insights which are correlated, resulting in additional data.

A frequency analysis was created to assess the feasibility of each use case based on the level of complexity and implementation costs. All respondents were asked to assess the feasibility of IoT. Based on their insights, a scale was built according to the four levels of project

complexity. The implementation costs were estimated by the IoT experts and the IoT supplier (Appendix 2).

Table 10. Use cases feasibility

IoT applications	IoT use case	Technical requirements	Economic requirements
		Project complexity	Implementation cost
Safety	Workforce tracking	1	1
Inventory management	Manage and reduce inventory	1	1
Production visibility	Waste reduction Find inefficiencies, malfunctions, lean processes	2	2
Maintenance	Maintenance-cycle increase Reduce downtime probability	4	4
Remote connectivity	Remotely monitor and control processes	3	3
Energy efficiency	Leverage energy consumption efficiency	3	4
Procurement transparency	Optimize procurement strategy	2	1

1 – 4 scale of project complexity

1) Tracking (simple)
2) Insigths & adjustments (medium)
3) Optimizations (complex)
4) Network coordination and optimization (very complex)

1 – 4 implementation costs

1) Low implementation cost
2) Moderate implementation costs
3) High implementation costs
4) Huge implementation costs

Table 10 suggests that complex IoT projects (optimisations and network coordination and optimisation) tend to have higher implementation costs. The exceptions are the procurement transparency and the energy efficiency. Given the economic and technical framework of Portuguese footwear SMEs, projects related to maintenance and energy efficiency seem to be out of reach (Interview D, F, C, I, and J). IoT projects concerning the monitoring, tracking and data collecting for process improvements (level 1 and 2) present low implementation costs and are relatively easy to implement (Interview D, F, G, and I). The use cases in safety, inventory management, and procurement transparency have a greater implementation feasibility since they present low implementation projects and low project complexity. The remote connectivity is at an intermediary stage as it is a complex IoT solution (optimisation) and requires a high financial investment.

4.2.4 Assessing the IoT potential

The following table presents the answer to the first research question. It states the potential operational and production gains, its potential economic impact, and the feasibility of each project.

Table 11. The potential of IoT technology for Portuguese footwear SMEs

IoT applications	**IoT use case**	**Potential operational and production gains**	**Potential economic impact (per year)**	**Feasibility**	
				Project complexity	**Implementation cost**
Safety	Workforce tracking	Decrease insurance costs up to 10% Intangible gains (e.g. human life/health)	Minus €800 insurance costs	Simple	Low
Inventory management	Manage and reduce inventory	Decrease inventory 10% to 35% and its inherent costs	Minus [75,050 – 263,676] units in inventory and its inherent cost	Simple	Low

Production visibility	Waste reduction Find inefficiencies, malfunctions, lean processes	-20% waste Productivity increased 15% to 25%	Minus €3,000 with defects costs	Medium	Moderate
Maintenance	Maintenance-cycle increase Reduce downtime probability	-10% to -15% maintenance costs Up to 5%-point overall equipment effectiveness	Minus [€7,157 - €10,736] with maintenance costs	Very complex	Huge
Remote connectivity	Remotely monitor and control processes	-10% to -40% service costs (mostly travels)	Minus [€2,624 - €10,499] with service costs	Complex	Moderate
Energy efficiency	Leverage energy consumption efficiency	Increase energy efficiency up to 40%	Minus €78,984 with energy costs	Complex	Huge
Procurement transparency	Optimize procurement strategy	-2% to -5% with raw materials costs	Minus [€58,640 - €146,600] with raw materials costs	Medium	Low

As it is presented in Table 11, IoT brings several advantages for Portuguese footwear SMEs, especially regarding cost reduction. Even though every IoT solution could add value to footwear SMEs, the use cases presenting greater implementation costs and a degree of complexity are very unlikely to be implemented on footwear SMEs (Interview D, F, G, and I). In this sense, the use cases presenting a greater potential for Portuguese footwear SMEs, given its economic impact and feasibility, are the procurement transparency, production visibility, inventory management, and safety.

4.3 Successful IoT adoption

On the basis of the primary and secondary data collected, the following sections demonstrate how Portuguese footwear SMEs can effectively implement IoT. This is done by focusing on the main deployment barriers and the collaboration among the main stakeholders. An implementation plan is provided.

4.3.1 Implementation challenges of Portuguese footwear SMEs & Enablers

The implementation of IoT in Portuguese footwear SMEs faces several challenges, as described below.

1. *High adoption costs*: the implementation of IoT projects requires high-end technical and infrastructure support. Their implementation in industry involves a vast range of sensing and actuating devices, requiring significant financial investment, mainly in hardware (Kamble et al., 2019; Interview A, B, C, D, E, F, G, H, I, and J). Additionally, depending on the financial investment, the return on investment can take a long time, increasing the payback period (Luthra et al., 2018).
2. *Lack of human skills availability*: IoT solutions require highly trained professionals to develop and implement IoT applications. Technical and functional skills are needed to adapt the IoT system to each process and equipment, as well as to develop a user-friendly system (Ryan & Watson, 2017; Kamble, 2018).
3. *Lacking a clear-defined use case*: an IoT implementation project requires a well-established guidance which can be found on use cases. They demonstrate the potential usage of the technology, pointing out its limitations and added value. It contributes with insights regarding the implementation process (Interview D, E, F, G, H, and I)
4. *Lack of awareness of footwear managers concerning IoT*: only a few percentage of Portuguese footwear managers are aware of the potentialities of IoT technology (Interview A, B, and C). Companies, especially their executives, will not make significant implementation investments as they are unacquainted with the potentialities of IoT (Interview D, F, E, and I).

A frequency analysis was created to assess the level of importance of each implementation barrier. According to the insights of all respondents, a scale from 1 to 4 was created. The weight of importance from the stakeholder group towards the IoT implementation challenges

was decided as it follows. IoT experts and footwear professionals were given the same importance. IoT experts have overcome and experienced the implementation constrains of their IoT projects. Portuguese footwear SMEs professionals have the know-how regarding the footwear industry, being able to identify the main challenges for this industry and SMEs. Finally, the IoT supplier has in-depth knowledge of the technology and its implementation. However, as a seller, its values may be biased. Therefore, the weight of importance for the challenges of the technology is 40% for IoT experts, 40% for Portuguese footwear SMEs professionals, and 20% for the IoT supplier.

Table 12. IoT Implementation challenges of Portuguese footwear SMEs

Implementation challenges	**IoT experts**	**Footwear professionals**	**IoT supplier**	**Total barrier importance**
High adaptation costs	4	4	4	(4×0.4) +(4×0.4) +(4×0.4) =4.8
Lack of human skills availability	2	3	1	(2×0.4) +(3×0.4) +(1×0.2) =2.2
Lacking a clear-defined use case	4	4	4	(4×0.4) +(4×0.4) +(4×0.4) =4.8
Lack of awareness	4	3	4	(4×0.4) +(3×0.4) +(4×0.2) =3.6
Weight of importance of each stakeholder	**40%**	**40%**	**20%**	

1 – 4 Degree of importance

1) Low
2) Moderate
3) High
4) Very high

The implementation barriers can be overcome or mitigated by the enablers which are the Portuguese footwear associations and Portuguese/European funds.

The barrier having the smallest importance is the lack of human skills, scoring 2.2. IoT requires a team comprised of a mix of experts across IT and operations to work together. The necessary backgrounds – technical, operational, management, industrial, among others – are needed (Interview D, E, F, G, H, and I). However, each IoT programme needs to have a mix of experts possessing deep technical knowledge – IoT hardware, IoT software, IoT communications, analytics – and members that have an intimate understanding of the industry and the business itself. This role is commonly given to executives, establishing a bridge between the technology and the characteristics of the company and industry in which it operates (Interview I). If the company develops an in-house IoT solution, it will need to hire or train the necessary human resources, which is not feasible for most Portuguese footwear SMEs (Interview A, B, C, D, E, F, G, H, and I). In an outsourced solution, the technical IoT experts are within the hired IoT supplier, hence they should be considered partners rather than service providers (Interview D and F). In this sense, besides the footwear professionals, the stakeholders considered that it is not critical for Portuguese footwear SMEs to have all the necessary human resources within the firm. These companies can work in straight collaboration with the IoT supplier who supplies and guarantees technical assistance.

The lack of footwear SMEs professional awareness regarding IoT was considered the second least important barrier. Portuguese footwear associations – APICCAPS and CTCP – play a major role in educating and increasing the awareness of Portuguese footwear managers regarding the use of Industry 4.0 technologies by Portuguese footwear managers. These associations have been a key element in shaping the organisational and cultural paradigm of national footwear firms towards digitalization and innovation. They find use cases and demonstrate the potential associated to them. These associations, in close collaboration, launched in 2018 the FOOTure 4.0 programme with the objective to stimulate and support the adoption of Industry 4.0 technologies. The programme involves more than 70 entities, including companies, start-ups, universities, innovation centres and scientific and technological entities. It is ruled by four axis: customer experience innovation, intelligent manufacturing, qualifications, and leadership (APICCAPS, 2019). Moreover, the ecosystem of partners is changing with the arrival of new Portuguese/European programmes such as COMPETE 2020, which emphasises the digital transformation of SMEs (COMPETE 2020, 2020).

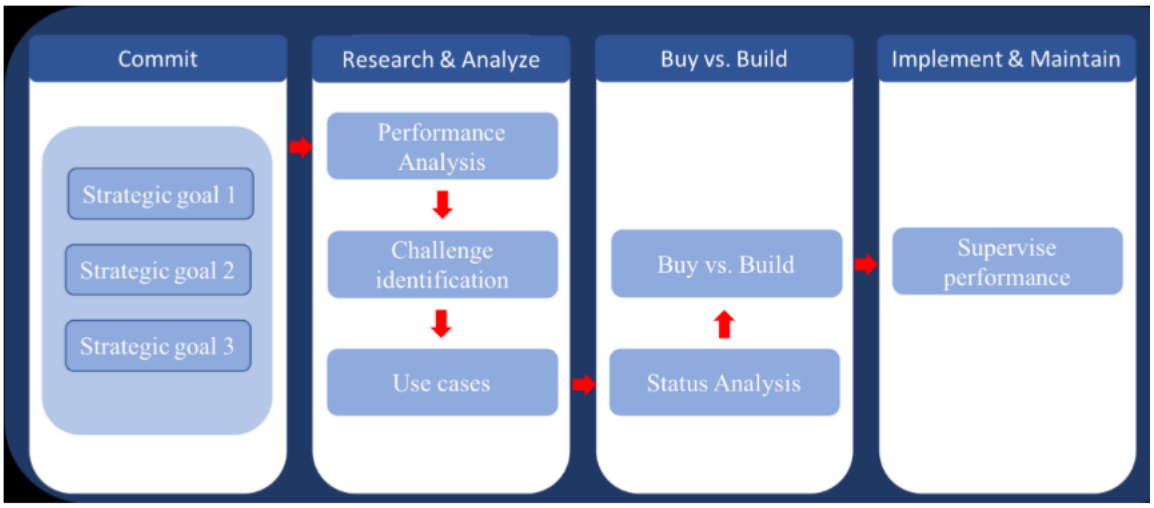
All the stakeholders considered the lack of a clear-defined use case and the implementation costs as being the major deployment barriers, both with a degree of importance of 4.8. There was unanimous agreement, among IoT experts, that finding a clear-defined used case is the most important element for a successful IoT adoption (Interviews D, E, F, G, H, and I). In order to derive value from the vast amount of structured and unstructured data generated from connected equipment, organisations must have the correct system and technologies to ensure the technology is given the intended usage (e.g. collecting and processing the intended data). When an issue is identified, the next step is finding the correspondent use case. It provides information regarding which technology best fits the need, the necessary hardware, software, human resources, implementation procedures, and technology weaknesses.

Additionally, IoT is a technology in development entailing significative costs. However, different IoT solutions and different implementation strategies have different costs. The gathered data suggest two different implementation strategies: an in-house solution or an outsourced solution. In an in-house solution, companies develop their IoT solution by acquiring and developing the necessary technical and human resources within the company. In an outsourced IoT solution, firms hire an IoT supplier (e.g. subscribe an IoT platform and buy the hardware) thus developing their IoT solution in cooperation with the IoT supplier. Complex IoT solutions, meaning IoT projects which fit very specific issues of an organisation, and large-scale programmes are more expensive and harder to implement (Interview D, F, I, and J). In contrast, a simple IoT solution is relatively cheap and easy to implement (e.g., monitoring environment, processes). A simple IoT solution does not require a significant financial investment as seen on section 4.2.3. The IoT supplier market offers several options for each IoT programme. Companies can subscribe IoT platforms free of charge – Crosser, Kuzzle, among others, that offer the necessary tools to develop a basic IoT solution free of charge. Other alternatives are the IoT platforms such as AWS IoT (Amazon) and Azure (Google), which do not charge anything until a specific number of messages is reached or the message size does not surpass the defined kilobyte size (appendix 3). These platforms offer many IoT modalities, and prices, charging according to the amount of data collected and transmitted. There are other IoT suppliers which provide the necessary hardware and software, charging the usage time or information generated throughout the collected data (Interview D, F, G and I). Additionally, the Portuguese footwear associations and the European/Portuguese funds provide financial support for companies that wish to move towards digital transformation, including IoT.

There was unanimous agreement among the interviewed footwear professionals, that the adoption of this new technology is only a matter of time (Interview A, B, and C). The key to a successful implementation involves smooth cross collaboration between the footwear SMEs, the IoT supplier, the Portuguese footwear associations, and Portuguese/European funds. The relationship between footwear SMEs and IoT suppliers must be reciprocal in terms of sharing costs, benefits, and failure risk. By sharing these factors with the IoT supplier, footwear SMEs are ensuring equal commitment and increasing the probability of a successful implementation (Interview F).

4.4.2 Implementation plan

In order to reach the operational and production gains mentioned in section 4.2.4, developing the right implementation plan is crucial (Interview D, E, U, F, G, H and I). The following implementation plan of the technology represents a suggestion on how Portuguese footwear SMEs may successfully implement IoT in their business.



Graphic 6. Implementation PLAN (Schmidt, 2019 ; Arvidsson et al., 2014)

Commit: The commitment phase consists of two steps. First, in order to implement IoT successfully, it is essential that organisations adapt their processes and organisation according to the technology specificity. The resistance of the organisation to accept and make the necessary changes is often the reason for the implementation failure of new technologies (Chang, 2006). Several footwear workers have been producing shoes and shoe components the same way for the last decades, expressing reluctance to new methods and technologies (Interview B). However, footwear workers have to start being trained to adapt and work

together with IoT (Interview B, C). Second, it is necessary that organisations tie the usage of IoT solutions with strategic goals, making IoT a key enabler of those objectives (e.g., implement IoT to decrease maintenance costs by 10%). An IoT solution which does not present a clear goal will fail (Interview D, E, F, G, H and I).

Research and Analysis: Organisations, especially their executives, need to analyse the issue that they want to solve (e.g., reduce product defects) and analyse the possible alternatives available. The questions and challenges raised at that point serve as a basis to identify a clear-defined use case. It must provide information on how IoT can fit the problem and add value, as well as refer some of the challenges and limitations associated to the technology (Interview D, F, G and I). At this stage, the major objective is to conclude if IoT is the best technology to solve the issue and assess the resources the company (Interview I).

Buy or Build: Once it was determined that IoT is the best technology to address the issue, the use case provides important insight regarding the project necessary resources. Firms need to analyse their capacity to develop an insourced solution or outsourced solution. The available budget, the advantages and disadvantages of each strategy must be analysed. An IoT outsourced solution does not require the total acquisition of all the necessary resources (human and technical), lowering the initial investment. Moreover, IoT is permanently evolving in terms of hardware and software, meaning that IoT solutions need to be constantly upgraded. In this sense, the IoT experts and the IoT supplier suggested that an outsourced solution is the one that best fits Portuguese footwear SMEs.

Implement and Maintain: a proof of concept must be done to implement IoT. Pilot tests are launched so as to test the theoretical ideas stated in use cases. Unlike the examination of use cases which take on average a few months to analyse, pilot tests should take a year or two in order to fully demonstrate the proof of concept (Interview I). The pilot test should be first launched in small-scale (e.g., launched in one production line) and gradually expanded and adjusted. The technology must be gradually expanded in case the results are satisfactory. An IoT implementation is an ongoing process since it needs to be continuously adjusted and updated (Interview D, H, G and I). As mentioned, a successful IoT implementation depends on four different stakeholders: IoT supplier, Portuguese footwear SMEs, Portuguese footwear associations, and Portuguese/European funds. Their collaboration is crucial to overcome the IoT limitations of the technology and the implementation challenges associated to Portuguese footwear SMEs, mentioned on sections 4.2.2 and 4.3.1 respectively.

Furthermore, corporations should constantly measure the performance of their IoT solution (e.g., analyse whether the solution is meeting the strategic goal or it can be improved) and compare it to the process performance without IoT.

5. Conclusion

This dissertation endeavoured to present the potential advantages, limitations, and challenges, to implement IoT technology on Portuguese footwear SMEs. In line with literature review, primary data suggest that the key element of IoT is the opportunity to collect larger amounts of new reliable data. These data, when transformed into information, allow to check the condition of different assets (e.g., workers, equipment) and processes (e.g., production), enabling the processes improvement (e.g., decreasing production waste) translated mainly in cost reduction. The findings obtained reveal that IoT can bring operational and production opportunities for Portuguese footwear SMEs, i.e., increase work environment safety, better inventory management, promote an efficient energy consumption, reduce production waste, find production inefficiencies and malfunctions, increase maintenance cycle and reduce downtime, remotely monitor and control processes, and optimise the procurement strategy. Financially, these gains result in cost reduction related to work insurance, maintenance, travelling, energy, and raw-material acquisition and decrease of inventory units, and production waste.

The associated potential of each IoT use case is dependent on the capacity of Portuguese footwear SMEs to make the required financial investment and acquire the necessary technical resources. In this sense, the IoT use cases which presented lowest implementation costs and lowest project complexity (the procurement transparency, production visibility, inventory management, and safety) present a greater feasibility for footwear SMEs.

The successful implementation of IoT is intrinsically dependent on cross cooperation among Portuguese footwear SMEs, IoT suppliers, Portuguese footwear associations, and Portuguese European funds. This interconnection is crucial to minimise the technology limitations and the implementation challenges inherent to these firms. IoT can be implemented on footwear SMEs with a proper implementation plan, englobing a clear-defined use case.

6. Limitations

The research is not without its limitations. Given the stage of maturity of the technology, mainly large companies have been implementing IoT solutions. This dissertation used mostly qualitative data, based on lessons and insights learned from the interviews to analyse the production and operational benefits for SMEs. Reliable information regarding the SMEs using IoT was not found. This element could have affected the range of IoT potentialities for Portuguese footwear SMEs, as well as the feasibility and impact of the use cases. Moreover, production and operational costs may vary from company to company, among Portuguese footwear SMEs, resulting in different operational and production gains from those assessed in this dissertation.

This dissertation was developed during the Covid-19 pandemic crisis, which limited the data collection, the collaboration with Portuguese footwear associations, and footwear companies, closed due to public-health concerns. The sample size of Portuguese footwear SMEs is rather small to generalise the findings across the whole industry.

Furthermore, the use cases were selected in the retailing, manufacturing, and energy industries, being that the inclusion of other industries (e.g., transport) could have improved the range of potentialities and the accuracy of the research, regarding the IoT potential for footwear SMEs.

Due to research design approaches, namely interviews, the results are likely to suffer from recall and post-hoc rationalisation bias. In order to measure the full potential – advantages, disadvantages – of IoT for Portuguese footwear SMEs, a more quantitative analysis should be conducted.

Although the present dissertation identifies that the adoption of IoT brings efficiency gains, it is undefined regarding its added value. Since IoT implementation costs vary from application to application, project scale, organisational models of firms, typology of equipment and processes used, and implementation plans, the underlying research does not generate insights about the potential implementation costs and consequently potential return on investment.

As mentioned in literature review, IoT can have an impact in almost every human and business domain. Due to time constraints only 7 IoT use cases were analysed, being that this study only estimates a small portion of the full potential that IoT may generate. Further

research should add additional use cases and factors (e.g., capital requirements, implementation costs, gross profit margins, among others) to assess the full potential of IoT for Portuguese footwear SMEs.

8. Final notes

"*The implementation of IoT in Portuguese footwear SMEs is not a question of if, but a question of when. The society is moving towards IoT and that includes footwear SMEs as well"*

Pedro Castro, project manager at Aloft

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9. Annex

Appendix 1

The following balance sheet belongs to a Portuguese footwear SME which have 95 employees and an annual profit of 5.5 million euros (2018). It presents the liabilities use to compute the economic impact. The following liabilities were uses: *energia e fluidos* (energy costs), *Inventários* (Inventory), *Custo das mercadorias vendidas e matérias primas consumidas* (Raw-materials consumed), *Deslocações e Estadas (*travel expenses), *Conservação e Reparação +Ferramentas e utensilios de desgaste rápido* (Maintenance costs). The costs related to work insurances (€8,000 per years) and defective products costs (€3,000 per year) derive from an estimation of the company.

Demonstração dos resultados por naturezas					
				Média do setor 2018	
Rendimentos e gastos	2018	2017	Var. 2018/ 2017	dimensão: Pequenas empresas	Total do setor
Vendas e serviços prestados	5 179 512,64	4 321 389,11	20%	4 315 762,76	928 908,63
Subsídios à exploração	2 716,45	17 920,40	-85%	3 803,62	1 330,16
Ganhos / perdas imputados de subsidiárias, assoc. e emp. conj.	0,00	0,00	-	2 200,82	251,75
Variação nos inventários da produção	87 171,25	191 710,71	-55%	10 143,42	1 590,06
Trabalhos para a própria entidade	0,00	0,00	-	3 858,23	619,86
Custo das mercadorias vendidas e das matérias consumidas	2 932 051,19	2 672 529,60	10%	2 179 796,35	444 139,83
Fornecimentos e serviços externos	447 053,53	422 803,69	6%	637 149,42	139 054,75
Gastos com o pessoal	1 127 765,22	933 615,63	21%	1 072 102,32	255 164,87
Imparidade de inventários (perdas / reversões)	0,00	0,00	-	703,02	80,42
Imparidade de dívidas a receber (perdas / reversões)	0,00	-54 726,09	100%	20 370,27	3 470,67
Provisões (aumentos / reduções)	0,00	0,00	-	0,00	539,75
Imparidade investimentos n/ deprec./amortizáveis (perdas / reversões)	0,00	0,00	-	0,00	0,00
Outras imparidades (perdas / reversões)	0,00	0,00	-	0,00	209,12
Aumentos / reduções de justo valor	0,00	0,00	-	-54,14	-5,77
Outros rendimentos e ganhos	19 991,17	7 744,79	158%	57 649,94	11 970,16
Outros gastos e perdas	15 841,24	62 358,96	-75%	81 799,62	18 635,89
Resultado antes de depreciações, gastos de financiamento e impostos	**766 680,33**	**502 183,22**	**53%**	**401 443,65**	**83 369,54**
Gastos / reversões de depreciação e de amortização	272 263,56	233 186,65	17%	221 075,35	44 657,41
Imparidade invest. deprec./amortizáveis (perdas / reversões)	0,00	0,00	-	0,00	0,00
Resultado operacional (antes de gastos de financiamento e impostos)	**494 416,77**	**268 996,57**	**84%**	**180 368,30**	**38 712,13**
Juros e rendimentos similares obtidos	0,00	0,00	-	245,50	47,86
Juros e gastos similares suportados	5 493,82	3 517,98	56%	18 664,17	5 033,05
Resultado antes de impostos	**488 922,95**	**265 478,59**	**84%**	**161 949,62**	**33 726,95**
Imposto sobre o rendimento do período	14 329,29	22 492,96	-36%	43 137,86	9 993,44
Resultado líquido do período	**474 593,66**	**242 985,63**	**95%**	**118 811,77**	**23 733,51**
Resultado das atividades descontinuadas (líquidas de impostos) incluído no resultado líquido do período	0,00	0,00	-	0,00	0,00

Fornecimentos e serviços externos			
Exercício referente a:	**2018**	**2017**	**Var. 2018/ 2017**
Subcontratos	540,92	-	-
Serviços especializados	80 984,92	98 278,01	-18%
Trabalhos especializados	35 946,78	34 275,90	5%
Dos quais: pagamentos a trabalhadores colocados através de agências	-	-	-
Publicidade e propaganda	5 351,66	1 233,01	334%
Vigilância e segurança	1 000,04	383,47	161%
Honorários	1 830,00	1 090,00	68%
Comissões	3 808,40	28 912,75	-87%
Conservação e reparação	33 048,04	32 382,88	2%
Outros	-	-	-
Materiais	48 382,89	64 689,10	-25%
Ferramentas e utensílios de desgaste rápido	38 530,64	51 124,86	-25%
Livros e documentação técnica	-	-	-
Material de escritório	6 167,56	6 282,15	-2%
Artigos de oferta	3 684,69	7 043,95	-48%
Outros	-	238,14	-
Energia e fluidos	197 460,30	174 973,35	13%

Ativo corrente

Inventários	750 502,38	547 268,80	350 281,60
Ativos biológicos	0,00	0,00	0,00
Clientes	1 788 328,76	707 552,14	543 257,89
Adiantamentos a fornecedores	0,00	0,00	0,00
Estado e outros entes públicos	35 029,71	28 199,55	0,00
Acionistas / sócios	0,00	0,00	0,00
Outras contas a receber	50 938,99	111 364,60	0,00

Deslocações, estadas e transportes	69 943,68	47 347,49	48%
Deslocações e estadas	26 248,89	16 008,06	64%
Transportes de pessoal	-	-	-
Transportes de mercadorias	42 260,86	31 339,43	35%
Outros	1 433,93	-	-

Appendix 2

The following implementation costs were estimated by the IoT experts and the IoT supplier.

Implementation cost in an industry already implementing IoT solutions			
Investments	**Percentage cost of total budget**	**Project complexity**	
		Example of a basic solution	**Example of a complex solution**
Cost	-	≤ €15,000	≥ €200,000
Hardware	70%	€10,500	€140,000
Design & Develop the software	15%	€2,250	€30,000
Integration and testing	15%	€2,250	€30,000

Implementation cost in a new industry			
Investments	**Percentage cost of total budget**	**Project complexity**	
		Example of a basic solution	**Example of a complex solution**
Cost	-	≤ €27,000	≥ €200,000
Hardware	30%	€8,100	€60,000
Design & Develop the software	60%	€16,200	€120,000
Integration and testing	10%	€2,700	€20,000

10. Interviews

Guide of the interviews done to IoT experts

In order to answer both research questions, the following information was requested:

1- Why did the company implement IoT? What was your main goal, or what problem were you trying to solve?
2- What type of IoT projects are being adopted by the company?
3- Could not that problem be solved with "conventional" technology?
4- What did the firm want to achieve in: short term; and long term?
5- Regarding the implementation of IoT, was it a gradual or fast implementation?
6- In case of a gradual implementation, could you explain a little bit what you done?
7- After implementing IoT, did your cost decrease/profits increase?
8- What do you consider as being the required hardware and software to implement IoT?
9- In your opinion what is the most fundamental element in the entire IoT system?
10- Did the introduction of IoT affected the modus operandi of the company?
11- What type of different experts are needed to implement IoT?
12- What do you consider as being the biggest risk associated with implementing IoT?
13- In your opinion do you think that IoT could be adopted by footwear SMEs?
14- What do you consider to be the biggest challenge for these companies in order to successfully implement IoT?
15- Do you have any advice for the footwear SMEs that want to introduce IoT?

Guide of the Interviews done to Portuguese footwear professionals

In order to answer the second research question, the following information was requested to Portuguese footwear professionals working is SMEs:

1. Do you think that the Portuguese footwear SMEs are aware of Internet of Things - what the technology is and what it could benefit them?
2. In your opinion, what is the degree of digitalization of Portuguese footwear SMEs, from 1 to 5. Being 1, not digitalized, and 5, very digitalized? Explain.
3. Is it possible for Portuguese footwear SMEs to introduce IoT? Explain why.
4. What are the particularities of the (Portuguese) footwear industry?
5. How could these companies apply IoT and in which departments?
6. What are the eventual challenges that these companies may face to implement IoT?
7. Could IoT reduce costs or increase profits? How?
8. What are the potential benefits that IoT could bring to Portuguese footwear SMEs?
9. Do you see any disadvantage that the implementation of IoT may bring to these companies?

Summary of IoT expert interviews

Interview A: DesignMore & WalkMore. Luís Claro

Focusing on the financial, technical and digital reality of Portuguese footwear SMEs. The question is, in Portugal, can footwear SMEs implement IoT?

Luís: Portuguese footwear SMEs can implement IoT. A successful implementation depends on the organization of each company. Without a structured path and an objective goal in mind, companies will not collect reliable data, meaning that the IoT project will fail. IoT will not solve issues linked to structural problems of these enterprises such as disorganization, outdated processes and lack of vision. Moreover, SMEs are much more risk-averse when comparing to bigger companies since failure may end in bankruptcy. In other words, when adopting a new technology which requires significant investments in hardware and software, SMEs must ensure that the return justifies the investment. Different companies have different structures and different ways of doing things. Therefore, each firm must identify how IoT would add value in its case. Although IoT can be implemented in several departments –

production, logistics, customer service, maintenance, among others – it must adapt to each specific case. When a company finds a specific issue, it must analyse if it has the necessary tools and conditions to implement IoT.

Particularities of the Portuguese footwear industry: Low level of automated processes and highly dependent on human labour → First, people working in this field, from managers to operators, tend to be reluctant to change well established processes. Second, this industry receives mostly small order quantities which are not standardized (e.g. different colours, materials, sizes, seasonality). Thus, this industry must cope with an enormous diversity of orders which unable automatization in most cases. The orders received by the Portuguese footwear companies do not allow to create scale or to create stock since companies do not know if they will be able to sell it.

IoT Barriers: First, initial investment in hardware, software and other technical and human resources. A great percentage of Portuguese footwear companies would need to take debts to invest in IoT. Second, IoT maintenance costs. Third, unwillingness of workers and managers to implement the technology (risk-aversion and mindset).

Economic effect: Depending on the application it can help to reduce costs, or increase profits, or both. Portuguese footwear SMEs are highly dependent on human labour and people tend to commit more errors than machines. IoT would allow us to monitor, control, and improve the human processes, thus reducing production waste, accidents and the associated costs. Reliable data, offers managers the possibility to take better decisions, hence avoiding bad decisions resulted from the lack of information (e.g. overproduction, ordering the right amount of raw materials). IoT provides reliable data which allows firms to improve processes and consequently increase productivity or reduce cost, as an example by reduction defects we will be cutting on the energy, human resources, and raw material costs since we are not spending valuable resources. Additionally, we can relocate these resources and use them in further tasks or production processes. Another example related to IoT economic advantages concerns the inventory and warehousing. Another example of how IoT can help us, concerns the inventory and warehousing management. Monitoring the products stored in warehousing would allow us to manage better our stock. The IoT would push us into another level of information where we would be able to know the exact location of a specific product in the warehousing, when it was produced, on which machine, which batch of raw materials used, among others. The IoT has a tremendous potential in a wide variety of tasks and departments.

IoT potential operational benefits: Increased supervision and control of processes; Reliable information to improve processes and support decision making; Have a clear vision of processes in real-time, or close to it; Possibility to connect different devices, processes and platforms; Possibility to lean processes; Greater proximity between clients and the factory, enabling clients to customize products remotely and access the production stage; Possibility to create algorithms and patterns, enabling better forecasts.

IoT disadvantages: Destruction of technical jobs (while it creates skilled jobs). Cyber-attacks.

Luís own opinion regarding IoT: In my opinion most of the Portuguese footwear companies, including SMEs, are aware of the existence of IoT. However, many of these companies do not fully realize the potential that IoT can have in several business domains. There has been an important movement towards the digitalization of the Portuguese footwear, handled by footwear associations that clarify and encourage the investments in new technologies. Despite being aware of IoT, many firms have difficulty to establish the link between their business and the technology.

Interview B: ISI Soles. Patricia Covita.

Focusing on the financial, technical and digital reality of Portuguese footwear SMEs. The question is, in Portugal, can footwear SMEs implement IoT?

Patricia: Yes, it is possible. Since it is costly and a slow process, I do not see most of the footwear SMEs investing on IoT now. Many of these companies are not aware of what is IoT, especially what this technology can do for them. Implementing a new technology which is not well mature yet, brings additional constrains that most SMEs cannot bear. As an example, in ISI Soles we are trying to implement an IoT based idea. We want to create an app where customers can check the status of their orders at real-time (e.g. check how many soles are ready). However, we have been facing several barriers regarding computer programming. We have already worked with two different software providers, but we have not managed to have an effective system. Therefore, being a SME is not an impediment to implement new technologies, including IoT, but firms need to bear in mind that they may not find a solution in the market that suits their needs. Our case shows that the technology must be adjusted to the company itself which takes time and money.

Particularities of the Portuguese footwear industry: First, the Portuguese footwear industry is highly dependent on human labour. Second, small orders and highly customized products. Third, large amount of orders goes mainly to the Asian continent. The Portuguese footwear industry cannot compete with it because our companies do not have the exact same incentives that Asian, mostly Chinese, companies have (e.g. government aid). Moreover, SMEs do not have the capacity to satisfy large amounts of orders that certain brands need. In this sense, the challenge for the future of the Portuguese footwear industry is to be able to increase diversity, customization, and faster production processes, while it automates and scales its production. The implementation of IoT would contribute to solve these issues as it enables to increase customization, reliability, and streamline processes. For example, costumers could make their shoes online and send their order instantly to the assembly line. Hence, factories would be capable to streamline processes and respond faster.

IoT Barriers: First, lack of awareness among footwear managers regarding IoT. Second, significant financial investment. Third, adjust the technology to the existing systems and equipment, which is slow, costly, and difficult to do. Fourth, workers mindset, it takes time for workers to get used to new processes and rules.

Economic effect: IoT will mostly result in increased profits. It gives firms the chance to gather data in real-time on processes and equipment. Such data can be used to improve processes (e.g. eliminate production waste) or enhance decision making (e.g. manage raw-materials stock). By reducing inefficiencies and attenuate imperfect information, footwear SMEs could increase their productivity.

IoT potential operational gains: The greatest potential behind IoT is the data accuracy. The greater the data accuracy is, the better the decision making and consequently the greater the overall effectiveness (e.g. accurate forecasts, lean processes).

IoT disadvantages: First, the initial financial investment. Second, the maintenance costs.

Patricia own opinion regarding IoT: In my opinion, being a footwear SME is not an impediment to implement IoT however not all SMEs have the required financial capacity to invest in programming, which is an essential part of IoT and the most expensive one as well.

Interview C: Aloft. Pedro Castro

Focusing on the financial, technical and digital reality of Portuguese footwear SMEs. The question is, in Portugal, can footwear SMEs implement IoT?

Pedro: Yes, definitively. Although footwear SMEs do not have the necessary resources, within the companies, to invest in IT research, they can work in close collaboration with the Footwear Technological Center of Portugal (CTCP) and the Portuguese Footwear, Components, Leather Goods Manufacturers' Association (APICCAPS). These two associations have the objective to modernize and to make the Portuguese footwear industry competitive. Both associations are constantly analysing new business opportunities and used cases. When they find business opportunities they contact and transmit their findings to the Portuguese footwear companies. Generally, footwear companies are not proactive in terms of developing new technological projects, but cases of success are quickly replicated by other firms. For instance, in Aloft we developed a Virtual Reality (VR) project in collaboration with the technological center of Universidade de Aveiro. Since it was a success it was rapidly copied by other companies in the sector.

Particularities of the Portuguese footwear industry: First, high dependence on human labour. Second, decapitalized companies. The great majority of people explain this as a result of the lack of educational background and vision of the footwear managers. However, this does not correspond to the reality. In 1995 all the productive processes of our company were automated. Today, in 2020, we have a couple of robots and we have handmade processes which used to be done by robots 25 years ago. The factor that explains the automation setback is not the education of the manager but all the political and economic changes that happened in the world. Thirty years ago, European companies did not have to compete with Asian companies. Meanwhile, Asian countries entered in the global market and started offering favourable conditions to their firms, which we cannot compete with. For example, those footwear firms receive state aids (e.g. government pays the travels and stays of potential clients), have different wage policies and work safety concerts, which are illegal in Portugal. The turning point to the Portuguese footwear industry was when China entered in the World Trade Organization (WTO). When the big orders migrated to the Asian continent, the Portuguese footwear industry remained with the orders that Asia did not want: the micro orders. While three decades ago, it was economically viable to automate processes, today this industry faces a new reality: low order books requiring customized products (e.g. different colours, sizes, materials and models). Thirty years ago, Portuguese footwear companies used

to have large amounts of standard orders which enabled us to use the same mold at least for 6 months. We used to weld the molds to the machines, now we change them 17 times per days. Back then, they had orders which justified automation not only for its quantities but also because they could produce the exact same product during a year or two. Thus, the biggest difference between the Portuguese footwear industries and other manufacturing industries (e.g. automobile) is the low order books which prevents bigger automation rates, hence requiring more human labour. In this industry, the profit margin is very low, each component produced results in gains of cents.

IoT barriers: First, significant financial investment in hardware, software and new equipment. Second, difficulty to merge old systems and old equipment into an IoT system.

Economic effect: IoT has an amazing potential to reduce costs in our business. Now, our quality control is done when the product is finished, we only detect defects at the end of the production process. By implementing IoT we can do our quality control during the production process. This technology provides more information on the productive process such as, what were the machine parameters during the production of a specific lot, when it was done, which batch of raw materials were used and how they were applied. More and better information, analysed in real-time, gives us the opportunity to detect anomalies (e.g. detect changes on machines temperature which influence the colour tone) and correct them during the production process. By doing this we are preventing all sorts of wastes and its inherent costs (e.g. raw materials, energy, human resources). In Aloft, with the RFIDs, we can know which employee/machine did a certain component, yet we cannot control the parameters of the processes (e.g. temperature, vibration). For instance, we have the resources to find out which machine is producing defects, but we don't know what is causing those errors, until we open it. With IoT, we can know which machine is falling, why and correct the situation in real-time.

IoT potential operational benefits: Gather larger amounts of reliable data will help SMEs to improve processes such as, reduce defects, support decision making, decrease the rate of human errors, manage inventory and stock, among others. In other words, the technology can increase the overall effectiveness of the company. In this sense, the introduction of IoT will reduce costs which in turn will increase the profit margins of these firms. By increasing their margins, they are mitigating all the problems stated above.

IoT Disadvantages: cyber-attacks.

Pedro own opinion regarding IoT: Every technology brings advantages and disadvantages. In case of IoT, the benefits outweigh the disadvantages. Implementing IoT is inevitable, not only to the footwear industry but to all other industries and society as well.

Since the biggest orders migrated to Asia, the European footwear industry, including the Portuguese industry, are having difficulties to generate significant profit margins. Without good profit margins, companies cannot hire the best skilled workers, acquire the best equipment available in the market or invest in several components. Due to this issue, most of the Portuguese companies will not have all the resources to developed and adopt an IoT solution alone. This is where APICCAPS and CTCP play an important role, with their technical and financial help, SMEs will be capable to introduce an IoT project. Portuguese and European funds are also very important (e.g. Portugal 2020, FOOTURE, among others) must be used in close collaboration with these associations. Without a common European policy, it will be very difficult to preserve this sector in all Europe. All European companies are migrating to China because they have greater opportunities, higher profit margins, and government incentives to produce there.

Interview D: Navigator. Duarte Filipe

Focusing on the experience to develop, adopt, maintain an IoT solution and the respective operational and economic added value. Assess the feasibility of different IoT solution for Portuguese footwear SMEs.

Implemented IoT solution and its goal(s): The company has several industrial equipment. Some of these machines are very old but still have a good performance and a long-life expectancy. In this sense, we decided to start monitoring in real-time the condition of these assets, giving us more accurate information about the temperature and vibrations of these machines. In our IoT solution, the implementation of smart sensors in critical equipment gave us the opportunity to check the conditions of these critical machines, in real-time or very close to real-time. It offers us the possibility to forecast future trends of these machines such as predict future failures.

IoT advantages: Conventional technology already has similar solutions to those presented by IoT. However, conventional solutions require the acquisition of new machines/equipment. On the other hand, IoT allows the company to continue using our current equipment, which still works perfectly well, while investing only in IoT sensors. In our case, it didn't make sense to make a huge investment in new equipment (e.g. electrical engines) when we could spend less than one third in IoT sensors. Therefore, conventional technology doesn't work in our case for two reasons: first, it is much more expensive; second, it didn't allow us to keep our equipment which is still in good conditions.

Implementation process: The Navigator has been adopting IoT gradually. In order to implement IoT, the first step was to identify the problem that we wanted to solve. The problem was identified when we were implementing a pilot project related to predictive maintenance. We had a problem related to the quantity and accuracy of the data that we were gathering. Thus, we decided that we needed to develop an IoT project. The second step was to analyse the IoT solutions provided by the market and consider if it fitted our requirements. For that, after analysing the market, we contacted a few IoT suppliers and we tested their IoT solutions. This second step is a continuous process. Even when we found an IoT solution that fitted our issue, we kept looking (and we keep doing it) for a better solution because this market is evolving very fast. We are currently in the third step; we are now expanding the IoT project to more factories of Navigator. When we decided that certain requirements were being accomplished, that our IoT solution was solid enough, we started to recommend it to other factories. However, it is very important to keep in mind that this project is evolving and adapting itself every day to better IoT solutions that fit our problem. IoT projects are a continuous process.

Economic impact of IoT: According to our data, IoT is going to have a direct impact in the costs of the company during the first stage of the implementation. IoT bears a significant investment in hardware, however this is temporary. When the investment is done, IoT will allow us to significantly reduce costs, mostly coming from downtime and reparations. Since IoT is giving us more and better data about the conditions of machines, we can predict when it is going to breakdown. By doing that we are preventing downtime, which means that all the costs associated with production stoppage will fall drastically. Moreover, IoT allows us to reduce costs in every equipment which is being monitored. Since this technology gives us information to predict failures, it helps us to prevent serious breakdowns as well. In other

words, by knowing the conditions of every machine we can repair or change a component in advance, avoiding a much more serious breakdown. We are saving money with reparations that could be more serious and expensive, breakdowns, and preserving our current assets.

IoT key element: One of the key elements of IoT are communications. The company may have premium hardware devices, yet without a good communication protocol the system won't work. In my opinion communications are the key element of IoT, not because the other elements are not essential but because this is the most difficult topic to build and develop. For example, without a proper WIFI connexion nothing will work, which is an obstacle to factories with their huge metallic structures. Additionally, the Internet 4G does not seize the entire potential of IoT, due to its connexion speed and exchange data capacity limitations.

IoT associated risks: The main obstacle now results from the immaturity of IoT. That is, when the problem is identified, the company starts looking in the market for a solution that fits its issues. Nevertheless, the market does not provide solutions which fits 100% the issues that it is addressing. The Navigator faces this problem as well, we are moderately satisfied with our IoT solution, but we know that there is room to do much better. That is why we are working in straight collaboration with our IoT suppliers, giving them feedback so that we could improve together our IoT solution.

There is also another problem that we face related to communications. We introduced IoT in an industrial environment where we have big metallic structures, preventing a good WIFI signal. Since the equipment, that is being monitored, is scattered along the factory and the internet connexion is not good, the company would need to make a significant investment in gateways to receive the gathered data in real-time. We are currently using internet 4G, however we are very interested in introducing the next internet generation, the 5G. We believe that 5G is going to solve most of these problems, since this technology has an industrial segment which focus on the latency and penetration rate. 5G allows us to increase the latency, meaning that sensors will store data and send it from time to time (e.g. every 10 min), thus allowing us to receive all the gathered information.

Implement IoT in Portuguese footwear SMEs: In my opinion these companies can implement IoT solutions. However, we must have in mind that the entire process of developing an IoT used case for a SME is completely different from those made for large companies. The financial availability to make big investments is not the same. Nevertheless, a basic IoT

solution is not that expensive anymore. A company does not need to develop their own IoT solution, unless it wants something complex. In other words, simple solutions as installing sensors to gather data and track products sounds feasible. On the contrary, complex projects such as predictive maintenance or improve processes (e.g. decrease temperature, autocorrection) will require significant financial and technical resources.

Firms have several IoT suppliers in the market with whom they can work with. The IoT market its evolving, there are several suppliers that don not charge for hardware rental, charging the amount of data that firms collect or the amount of information that they are getting from that data. This "outsourcing" of IoT means that companies do not need to make a significant investment in hardware. The IoT supplier has its revenues from the software usage (e.g. usage time, data gathered, or information generated). In my opinion, this type of IoT project could be a good solution to the footwear companies because it is an industry which is not as automated as other industries. In other words, footwear companies will not need to make huge investments in hardware and would be charged according to their rate of usage.

The second challenge may be the lack of vision of the administration. The company may have all the necessary resources to implement the technology but if it does not have a clear idea of what it wants to achieve, the IoT programme will fail. These programs must come-up from the head of the company, it is impossible to successfully implement IoT if the administration is not sure what issue is addressing and what objective it wants to achieve with the technology. For instance, in our case, IoT is an enabler to reach other technologies. There is no room for experiences.

My best advice for these companies, before anything else, is to identify the problem that they have. The company must ask itself if it has a problem and what is the problem. This is very important because firms cannot implement IoT just to improve production, reduce any sort of waste, or even cut costs. These examples are a direct result of a well identified issue which in this case was solved by implementing IoT. Additionally, companies must analyse if IoT is the best tool to address that problem. IoT may not be the best solution and sometimes the solution to the identified issues do not even require technology.

It is also important that the firm follows closely the IoT market, not only because the market is evolving fast but also because there may exist other suppliers that would better fit the necessities of the company.

Interview E: Unilever. Emre Dikmen

Focusing on the experience to develop, adopt, maintain an IoT solution and the respective operational and economic added value. Assess the feasibility of different IoT solution for Portuguese footwear SMEs.

Implemented IoT solution and its goal(s): In Unilever we can basically divide the IoT systems into two individual architectures: shop floor integration (e.g. source of data collection, machines, processes, robots, among others) and data management systems (e.g. server, cloud, edge device, among others). Our initial point was to gather newer data from existing systems. Therefore, we started to monitor condition of our systems like pumps and compressors to gain valuable output that has an impact on maintenance work. Additionally, we started to monitor power and source consumptions of our machines more closely. For instance, we used to measure electricity consumption of the whole machine, now we can measure the consumption of each individual components within the machines.

IoT advantages: IoT suits our necessities for several reasons. First, we believe that the main benefit of the IoT systems, regarding to shop floor integration, is its wireless communication infrastructure. It allows us to eliminate the cabling cost which is considerably high in large scale installations. Conventional sensors require communication cables or at least analog signal carriers installation to transmit measured signal. Moreover, rough environments sometimes difficult cable installations. Thus, IoT sensors helped us to extend our arms into factory easily. Second, battery powered IoT devices also provide easier installation by eliminating external power source installations. Comparing the existing monitoring and controlling devices, that are well established in the automation market, IoT device data management systems are more capable when it comes to web-based communications. Additionally, it enables further developments on web platform, and it is very agile regarding its adaptation of updated web-based technologies.

Implementation process: Unilever is gradually implementing IoT. The installation of IoT systems are not that complex, yet it still requires modifications and updates in order to align the existing systems and the IoT systems. In other words, the adoption of IoT naturally forces us to make installations gradually. In our case, the first step was to modify and adapt our systems in order to support the IoT technology (e.g. database modifications, convention and supporting standards, among others). Then, we started to gather data that could be treated

later. Nonetheless, this is still being done because the technology is not mature enough, meaning that we need permanently to track, analyse and tune our IoT processes. This programme remains a gradual process, since we are gradually expanding the technology to other factories and machines.

Economic impact: We have decreased repair costs and we also created an opportunity to track our detailed consumptions, thus enabling further savings.

IoT key element: All the elements are fundamental, the IoT project must have all hardware components and it should support remote firmware updates.

IoT associated risks: the biggest risk regarding IoT implementation are the cyber threats. Before IoT, most of the factories and industrial plants were not connected to the internet. Only the offices of the factory used to have an internet connection and it was managed by the IT department of the corporation. Now, IoT creates the possibility to connect everything to internet, thus increasing the vulnerability to cyber-attacks which can be very expensive.

Implement IoT in Portuguese footwear SMEs: In my opinion they can implement an IoT solution. There are several applications, objectives, project scales, and methods to implement IoT. This means that there are IoT solutions for every type of companies and applications. Besides the cyber-security issue, which is transversal to all companies, SMEs probably have an additional challenge concerning the financial investment. However, once this issue has been overcome, these companies will face the exact same challenges that big companies face. An IoT application does not need to be very complex and expensive, meaning that a SME could implement an affordable IoT solution. Most of the SMEs are using CCTV systems that can be remotely accessible. Gathering data from a machine or a process using IoT is the same thing. Being that the process is similar, SMEs could convert their CCTVs into an IoT system by using a web-based platform. In this sense, IoT projects such as monitoring and gathering data sound feasible for these firms. My advice is, if the company wants to try a specific IoT solution for the first time, it should analyse well the used case it is based on. The best option is to look for proven history of a similar IoT solution and just then launch their pilot test.

Interview F: Heineken. Diogo Ribeiro

Focusing on the experience to develop, adopt, maintain an IoT solution and the respective operational and economic added value. Assess the feasibility of different IoT solution for Portuguese footwear SMEs.

Implemented IoT solution and its goal(s): we are adopting IoT in maintenance and production, mostly regarding the filling lines. Beer factories have an enormous quantity of machines and components with different expected lifetime and wear. In this sense, our objective is to have a closer picture regarding the condition of these machines. This is being done with one thing in mind: reduce costs and reach predictive maintenance. We can save a lot of money if we have an accurate estimation of when and how these machines will fail.

IoT advantages: IoT suits our needs because it is cheaper in comparison with the alternatives and gives us information about the conditions of every component inside a machine. Conventional technology offers a solution which is more expensive and does not fit 100% our issues.

Implementation process: IoT was gradually implemented. The adoption of IoT at Heineken, in equipment or processes, must respect always the following steps. First, search and analyse a used case which has similarities with the objective that the company wants to achieve. Second, launch a pilot test in one production line, equipment or process. Third, evaluate the results obtained which may take a year or two, depending on the complexity of the project. This step is not static, meaning that during this time there are several adjustments being made to the initial set up. Fourth, when the results are satisfactory enough, the company can start to progressively expand the IoT programme to other equipment, processes and factories. Its mandatory to keep tracking the pilot test because when we start expanding the technology to other production lines or equipment, the initial result may change. For example, the pilot test may have been a success, however when we start expanding, we will have a greater number of devices and machines connected to WIFI. It is very different to have 20 devices connected to WIFI and expanded it to 60 devices, which may potentially affect the data collection.

In other words, our tests are done on small-scale since they are expensive. The main issue here does not concern gathering data, this is the easiest part. The difficulty stands in addressing and treating the generated data.

Economic impact of IoT: IoT has an enormous potential when it comes to reducing costs. As I mentioned before, Heineken has been given priority to IoT projects related to maintenance because, given the characteristics of this business, maintenance allow us to save a lot of money. IoT allows us to gather more and better information of each components inside machines. This technology offers us the possibility to check the actual condition of a component (e.g. engine wear), regarding it lifetime expectancy and wear, thus we can plan the maintenance before it breaks. This brings us several financial advantages. First, we can predict downtime which avoids having the production line stopped for hours. Second, since we know which component is in bad conditions, the factory does not need to send an entire machine to reparation because we already know which part has to be repaired. Before IoT, we used to have an annual check up to several machines and engines, now some of these machines are examined every 4 years. Thus, saving us a lot of money in maintenance check-ups which are normally expensive.

Additionally, IoT allows us to reduce waste and increase productivity. The factory is monitoring its production processes close to real-time. Thus, we are now able to monitor environmental elements regarding the beer production such as, temperature and fermentation. This means that Heineken can now automatically correct values which does not correspond to its production standards. For example, if temperature increases/decreases or the beer gets very diluted, the entire batch will not correspond to our quality patterns, meaning that we cannot sell it. At the end of the production of each batch, our quality control department used to check if the beer was good to be sold, now we can do the quality control during the production process. Some of these processes are programmed to auto correct itself when values are incorrect, meaning that we will not produce bad beer and spend money in its production. With the help of IoT we can control different production processes close to real-time, thus allowing us to eliminate production waste.

IoT key element: All IoT elements or components have the same importance. There are elements that may offer biggest challenges than others (e.g. communications), however if we remove one element of the systems it will not work. For example, a company may have the best hardware and software available in the market, but if does not have capable human resources to assure its functionality, the system will fail.

IoT associated risks: One problem that Heineken has been facing regarding IoT is the lack maturity of the IoT suppliers. Since this is a recent technology, they lack in experience. IoT

suppliers are one of the most fundamental keys to implement IoT, normally they experienced other IoT projects denoting more experience and information. Nonetheless, this not always happen, being that their solution is not good enough to fit the necessities of the company. One of the greatest obstacles that we face in Heineken is the fact that we cannot find one IoT supplier that fits our requirements both in hardware and software. We have been having troubles to find "two in one", thus a supplier which satisfies us both with a good hardware and software solutions.

The WIFI connexion can represent another risk being that without internet, IoT does not work. In our case we managed to solve this problem, most of our devices are connected to gateways by cable. There are parts of the factory which for specific reasons cannot have cables (e.g. silos) and where the signal is weak. For these situations, the company decided to introduce a different type of sensors that can store data up to two days and send the information via WIFI once the connexion is re-establish. This type of sensors is a good solution to prevent losing data when WIFI is down, but it is also a good tool for environments where WIFI signal is good. The connexion may be lost for several reasons such as, electrical breakdown or internet supplier failures, thus it is good to assure that the firm does not lose any data.

Implement IoT in Portuguese footwear SMEs: In my opinion SMEs may have difficulties to implement the IoT, mostly related to their business focus. One difference between SMEs and big companies is that the second ones are at a stage where they do not want to produce greater quantities, they want to optimize the production while SMEs want to increase their business and production. SMEs also pay attention to efficiency and costs reduction, but their greatest focus is to grow and earn market share. One the other hand, big companies want to increase their market share not by producing greater quantities, but by having more efficient production processes.

Moreover, I think that their dimension could be a serious problem. The IoT is a recent technology meaning that it is not as affordable as other technologies. Therefore, SMEs may not have the required financial capacity to invest in complex IoT solutions. As well as that, SMEs cannot give the same economy of scale to IoT as big companies can. For instance, Heineken has several production lines to which it can apply the IoT, whereas SMEs may have just a few. This means that the cost to introduce IoT will be higher to SMEs in comparison with big companies because they cannot scale their investment. In addition, the payback of

IoT technology is slow and sometimes it does not happen because it fails, we must have in mind that IoT is not overdeveloped yet.

However, this does not mean that I think that SMEs cannot introduce IoT. On the contrary, I think they can, and it would be good for them. My point is that they will not be capable to implement IoT solution as complex as the ones implemented in big companies. For example, projects such as predictive maintenance and predicting forecasts requires an advanced IoT solution, thus requiring huge financial and technical investments. This technology is already at a good stage of development in our country (Portugal) thus these firms will not find big issues to start monitoring the environment (e.g. humidity, temperature, among others) or tracking processes. On the contrary, if these companies want to address a problem that it is very particular to them and it is not widespread in terms of IoT, it may face the same problem that Heineken is facing. When the IoT solution becomes complex it is difficult to find just one IoT supplier that could fit the issue. Therefore, the company has the hard work to find different IoT suppliers that are compatible in terms of hardware and software, which is a very hard task.

On the other hand, there are IoT solutions that are not that complex and expensive which would have a good Return of Investment index. For instance, IoT solutions refereeing to monitoring and gather data. These basic solutions are not that expensive, since the company can pay his IoT suppliers according to their usage time. This option allows SMEs to use and apply IoT since they do not need to scale their IoT programme.

Another problem that is very common is the lack of a good WIFI connexion that could compromise the entire IoT system. However, there are plenty ways to solve this issue, it depends on each IoT solution and scale of the project.

My advice to these companies is to always do the proof of concept of their IoT solution by verifying if their theory has a practical potential before start implementing the technology. It is very important to develop their own proof of concept. Even if the IoT solution has already gave proofs in other similar companies and processes, this does not mean that the same will happen to the company. Different companies have different structures, equipment, and production processes, this is to say that every company needs to adjust IoT to their reality and needs. In other words, these companies need to have a proof of concept which copes these differences.

Interview G: EDP. Bruno Espírito Santo

Focusing on the experience to develop, adopt, maintain an IoT solution and the respective operational and economic added value. Assess the feasibility of different IoT solution for Portuguese footwear SMEs.

Implemented IoT solution and its goal(s): EDP adopted IoT technology for two reasons: collect larger amounts of reliable data and move from reaction to prediction. Few years ago, EDP only knew which equipment was connected to the grid. Now with the automatization and digitalization of processes, the company needs to gather more information about the grid. More and better data means that the company can predict several events such as, the voltage level and level of current, which circuit will have various micro-producers, or the number of electrical vehicles in the grid. In this sense IoT is helping us to be proactive, in real-time or close to it, while predicting anomalies that may occur in the grid.

Additionally, IoT is in our point of view a good tool to connect different devices due to its flexibility. It offers standards which can be widely used by different objects and things. Therefore, we are using the IoT standards to develop new projects. With this technology, EDP does not need to have several vertical platforms, each corresponding to one type of sensors and procedures, because IoT gives us the possibility to apply the same standards to everything. This technology allows us to have a horizontal platform, this is, apply the same standards to different uses.

IoT advantages: Despite we could have other technology to intermediate communications, IoT is the only that can connect different things throughout a single system. Thus, its capacity to collect large amounts of reliable data and the opportunity that it offers to standardize different things and processes made it the best choice for us.

Implementation process: The IoT is itself a gradual process because it is a technology that is evolving fast, meaning that we must adjust our IoT solution frequently. In this sense, it was a gradual implementation. Our implementation process started with a used case. The first step is to identify what is the problem (e.g. find what is causing power outages in a specific circuit). The second step is to determine possible ways to solve it. The used cases are the best source to find this answer since it gives us information on how a similar issue was solved. It gives us

the information of what technology should be used, what are the necessary equipment, and it give us important hints on what we should do. The fourth step is to test that solution, this should start as a small-scale project, by launching a pilot test. Once the pilot has been tested and adjusted, this takes some time, the company can expand gradually its adoption. It must be noted that this process is a gradual and continues process that never ends, even at EDP we keep adjusting and improving our IoT solution. Additionally, it is fundamental to have a cost-benefits analysis.

Economic impact of IoT: IoT is a good tool to streamline processes and increase efficiency. Giving the fact that IoT gives us the opportunity to be proactive and predictive, we can now plan and address issues in advance. By predicting events we can move from reaction to proactivity, which is a good method to reduce costs. In some domains we were not able to reduce costs, but we created a more efficient environment. For example, some tasks continue to have the same operational costs, however IoT allowed us to streamline processes meaning that we are now capable of performing the same activities with less employees. These employees can now be transferred to other departments or tasks which require more effort. In other words, when we maximize efficiency, even if the operational costs remain the same, we are reducing costs because we can produce more with the same resources that we have.

IoT key element: In my opinion the most fundamental element in IoT is its standards. This technology connects different thigs, objects, and devices, therefore we need a common standard so that these different things may interact and exchange data. The innovation that IoT brings is that it unifies different protocols in one. This standardization opens a window opportunity to develop new used cases.

IoT associated risk: The biggest risk associated to IoT technology is the cyber-security.

Implement IoT in Portuguese footwear SMEs: In my opinion these companies can implement IoT technology. There are different IoT solutions and different ways to introduce it, thus IoT can be implemented in an enormous variety of tasks and in different scales. The market already provides open-source platforms, free of charge, which can improve the optimization of a simple IoT solution. There are several IoT suppliers in the market which offer free access to their platforms, being that it is possible to develop many projects there. In case the firm is looking for more complex IoT projects, it will need to pay in order to unlock other tools in these platforms.

The biggest risk of an IoT implementation is the lack of a structured plan and a clear roadmap to introduce this technology. The used case is one of the most important elements in the implementation process. It gives us the prerequisites of the technology, how it works, and it provides important hints on how to apply it. An IoT solution without a detailed roadmap and a detailed plan concerning its implementation will fail. The question that companies should ask at this point is "what are the processes that we want to improve?", this question will be the main point of their entire IoT solution. The challenge it is not implementing the IoT since there are plenty ways of doing it. The objective of the company should not be the IoT implementation to be more efficient and reduce costs. On the contrary, this should be the outcome of their implementation. The company must identify an issue that it wants to optimize (e.g. monitor production lines wear, monitor when it is the best time to buy raw material, among others) and then apply the IoT to reach its objectives.

My best advice to these companies is if they want to implement IoT, they should respect three steps. First, identify which issue it wants to address. Second, find the correspondent use case and learn how to solve that issue. They could conclude that IoT is not exactly what they are looking for or that there are better alternatives to address the issue. Third, structure an IoT implementation plan and a roadmap.

Interview H: CEPSA. Juan Blanco

Focusing on the experience to develop, adopt, maintain an IoT solution and the respective operational and economic added value. Assess the feasibility of different IoT solution for Portuguese footwear SMEs.

Implemented IoT solution and its goal(s): CEPSA is in the oil and gas industry meaning that we already had sensors and actuators before IoT. Traditionally these sensors and actuators were used to maintain processes. Now, we are using these sensors and IoT not only to monitor processes in real-time but also to gather data that could not be gathered before. The greater the amount of data and its accuracy, the greater is our knowledge about the processes.

CEPSA has several IoT projects, each in a different state of maturity and addressing different issues. Thus, the IoT project varies from activity to activity – oil exploration, refineries, energy distribution, safety – all following the same purpose which is gather more and better

data so to improve processes. In this sense, we are developing projects from monitoring work environment, people, and machines till predictive maintenance.

IoT advantages: If our objective was to connect things, we could have done it with traditional technology. Nonetheless, IoT brings two innovations: the costs of doing it and it is more flexible that conventional technology. The first point in favour of IoT is that it is cheaper than other technologies when it comes to monitor things and gather data. Moreover, IoT is an important enabler to other technologies (e.g. advanced analytics, AI) that cannot be achieved with traditional technology. The second point is related to IoT flexibility, it creates the opportunity to use the same technology and standards to address different issues, for example from monitoring a machine until monitoring people.

Implementation process: The technology has been gradually implemented in our business. This happens because IoT is an ongoing process. Before implementing and expanding the technology we must assure that it works, being that in our case we are implementing it in rough environments (e.g. refineries). Additionally, we need to make sure that everyone in the company trusts the technology and understands it, which should be done step by step.

The company always follow the same guidelines in regards IoT adoption. First, we look for used cases related to our issue, which gives us information on how to proceed. The second step is to implement the theory into practice, in at small scale and test it. It will probably need some adjustments, or it may require a different approach. The final step is to expand the technology gradually and to keep monitor its results.

Economic impact of IoT: The adoption of IoT has both decrease costs and increased profits. IoT carries several economic benefits, some are tangible while others are intangible. IoT allows us to improve our processes and to be more efficient which can be quantified in some activities. In CEPSA, IoT is helping us to optimize processes such as to reutilize raw material during production. This resulted both in costs reduction and increased profits because the company not only succeeded to reduce raw material consumption and its inherent costs, but it also accomplished to produce more with the same resources. However, there are intangible benefits which are very difficult to be quantified. For example, IoT has been helping us to reduce accidents at works which is very difficult to quantify in euros. To do that you would need to quantify health, the employee knowledge and his productivity.

IoT key element: Every IoT system must respect the three "Is" layer, namely: instrumentation, communication and intelligence. Instrumentation concerns the required hardware and software, such as the required sensors, actuators, gateways or cloud. Regarding communications, firms must set communication protocols which establish how different components communicate and exchange information between them and the data base. The last layer, intelligence, concerns human resources to develop, introduce and monitor an IoT project. However, it is fundamental that each IoT solution adapt these three layers according to their specific use case. For instance, in CEPSA we needed to adapt communication according to the environment where we are applying IoT. Inside factories we were able to connect everything by fiber optic internet whereas in refineries we have sensors placed in much rougher environment, thus we relied in mobile communications.

IoT associated risks: There is one issue that is applicable to all industries and sectors applying IoT, namely the cyber-security. The greatest the preponderance of internet in the business, the greatest the damaged caused by cyber-attacks. Having processes fully automated and connected to internet means that any cyber-attack can have catastrophic repercussions.

The second obstacle concerns the IoT maturity. Since this is a recent technology companies may face unexpected adversities to implement it. In theory their plan can work, but when put into practice it may fail due to plenty reasons (e.g. rough environments). Thus, it may take several attempts in order to successfully implement an IoT solution. The best way to tackle this problem is to hire people with good IoT skills in order to decrease the failure rate.

Implement IoT in Portuguese footwear SMEs: In my opinion footwear SMEs can implement IoT. As I mentioned, the IoT is very helpful when it comes to develop automation and have a greater visibility of the processes. The more the current processes are automated, the greater the potential of Internet of things for the company. Although the footwear industry may have different production processes comparing to the oil and gas industry, it will need to address similar issues that we face in our industry. Thus, the constrains may vary a bit but at the end the footwear industry will have to implement the same three layers of IoT that we implemented. Obviously, the footwear industry has its own specificities which will require some adaptations, but the constrains will be similar. Yet, the financial capacity may be the biggest difference between our company and a SME. In this sense, a healthy footwear company meets all the requirements to implement IoT, depending on their objectives. There are smart devices which are easy to install, do not require heavy investments and have cheap

maintenance. The key point is to confirm if the improvements worth the financial investment. Increase production and efficiency may not justify a significant financial investment. In conclusion, a simple IoT project – monitoring processes, collect data, and track assets – sounds feasible while a more complex solution may be out of range due to financial reasons.

My advice to this companies is, before anything else, to put their efforts into the used case. It is an error to implement IoT in order to improve processes (e.g. improve analytics) without analyse the used case first. It gives important information regarding the technology and how it can help the company to reach its goals. A good used case should be the core of an IoT strategy because it says which direction the company should follow namely, what are the pain points to focus on, what are the required hardware and software, which human resources are needed and how should data be stored and treated

Interview I: SONAE. Eduardo Brandão

Focusing on the experience to develop, adopt, maintain an IoT solution and the respective operational and economic added value. Assess the feasibility of different IoT solution for Portuguese footwear SMEs.

Implemented IoT solutions and its goal(s): we implemented IoT in order to gather more information and in real-time. We have several IoT projects such as, establish buying patterns (e.g. number of trolleys in stores and it taken routes), detect anomalies (e.g. food condition and machines) and gather the statistics on equipment usage (e.g. equipment failure). The innovation with IoT is that it allows us to gather data in real time, resulting in costumer and technical support in real-time as well. Moreover, the gathered data is being used for marketing purposes. Each section and shelf have different costumer exposures; thus, brands pay us to stand out its products in the most visible surfaces. IoT permits us to collect data which proves what are the most visited sections and shelfs. We can use this information for marketing purposes.

Additionally, the company has an IoT project in logistic regarding the transport of consumer goods. The legislation imposes perishable goods to be transported at low temperatures. This means that every time a customer buys its goods online, we need to send a refrigerated van regardless of the quantity ordered. Now with IoT, we can have thermic boxes and control it

temperature in real-time. The company can now rent normal vans, which are cheaper, helping us to reduce costs.

We have two more IoT projects, which are not yet as developed. One concerns the monitorization of energy in stores (e.g. freezers). The main objective is to reach predictive maintenance, thus allowing us to tackle malfunctions in advance and avoid losing the goods. The second, is tracking and picking of products so a costumer or an employee can know precise location of the different products.

IoT advantages: we are using IoT because it is the technology that best suits our needs and requirements for two reasons. The first reason it is it flexibility. For instance, we can track products with video analytics, but we cannot pick products with it, whereas IoT enables both activities. The second reason is that the IoT solution is less expensive when compared to a traditional technology solution regarding monitorization.

Implementation process: All the IoT solutions were implemented gradually. The company use to have different IT teams dealing with new technologies, mainly Industry 4.0 technologies. One of these teams focused on IoT. In SONAE every new technology must go through three stages: proof of concept, pilot test and roll out. Thus, the first step was to analyse used cases, so to know which IoT projects would be both feasible and add value to the business. The proof of concept tests the used case not to demonstrate if a technology is good, but to demonstrate its feasibility. The second step is to confront use cases with the reality. Unlike the examination of use cases, which take only a few months to analyse, pilot tests may take a year or two in order to fully proof the concept. While the proof of concept examines the theory, the pilot test analyses the theory into practice. This stage adds new variables and issues such as, work environment, architecture of the company, equipment used, among others. The third step is to roll out the technology while gradually expand it to other stores or equipment.

However, the company had two different IoT strategies. One, IoT solutions which emerged from business necessities/issues (e.g. thermic boxes). The second, IoT solutions which were initially promoted by the IT team (e.g. improve delivery time after an online purchase). The main lesson to take out from these strategies is that an IoT project that does not emerge from a use case is much more complex and requires more effort. When an IoT solution emerges from business necessities, the company knows what it is dealing with and it has a clue on how IoT

can add value. On the contrary, IoT solutions that do not emerge from use cases have the added task of finding out how their experiment may add value to the company. We faced this problem at SONAE, the company successfully developed an IoT solution which did not follow a use case (improve delivery time after an online purchase). The solution was completely developed by our IoT team (Altilabs) and it works perfectly well, being implemented in two stores. However, since this solution did not emerge from a business necessity it is much more difficult to assess its benefits to the business. Thus, we do not expect to expand this IoT solution beyond those two stores.

Economic impact of IoT: Our IoT solutions are allowing us to increase productivity, profitability and to reduce costs. Each IoT solution – gather buying patterns, monitor equipment, monitor track and picking of products, use thermic boxes, use data for marketing purposes – are helping the company to optimize its processes. Monitor track and picking of products helps to increase productivity because it saves searching time, while thermic boxes allow us to reduce costs with refrigerated vans. In this sense, all these IoT solutions are making our processes more efficient which means we can do the same with less resources (e.g. time, human labour). Thus, IoT not only helps to reduce costs but it also increases productivity and profitability as well.

IoT key element: IoT has three elements without which it does not work namely, human skills, the IoT platform and hardware, and the use case. If we take out one of these elements the IoT programme will not work, thus I cannot pick one. Every project needs human skills (e.g. engineers, programmers), people who know how to implement and cope with the technology. Without a platform and the required hardware all the technical elements are missing. Finally, an IoT solution that does not follow a use case, does not have an implementation strategy and clear goals. Since IoT is a recent technology the company may not find a proper use case, meaning that the IoT project will require more effort and face more obstacles (e.g. find which hardware best fits the environment and needs).

IoT associated risk: The biggest risk associated with IoT is the cyber-security issue. An IoT system means that the company has more processes being done throughout internet, thus the damage of a cyber-attack is bigger for companies using IoT.

Implement IoT in Portuguese footwear SMEs: Technologies like IoT are normally easier to implement in bigger companies because they have more financial and human resources.

However, nowadays a basic IoT programme can be implemented nearly without costs. Moreover, the technical skills required by a specific IoT solution can be found in a consultancy project, outside the company. In this sense, if a footwear SME finds a use case, it can acquire the required technical resources outside the company. The most crucial element to successfully implement IoT comes from a good use case. Develop an insource project, does not determine a successful implementation of an IoT system. Since SMEs normally do not have the same financial and technical capacities as big companies do, I think they should look for a an IoT partner.

The biggest challenge that these companies will face is to find a good use case. SMEs can implement an IoT project with resources found within the company or they can work with an IoT supplier. A successful implementation of IoT does not depend on the technology itself but in the use it is given. The company can acquire all the necessary tools to implement an IoT solution but if it does not have a good use case, which says why IoT suits their needs and how it deals with the issue, the solution will not work.

My advice is to look at IoT as an enabler to reach a specific objective and not to look at it as an inevitability. The used case will set if the company really needs to implement IoT or not. The IoT does not solve all the problems and sometimes companies do not even need to introduce technology to solve the issues. Companies have two options to implement IoT, first, build a team which focus on IoT use cases and analyse how the technology could add value to their business; second, the company identifies an issue and then analyses use cases to see if IoT can solve that problem.

Interview J: EQS. Carlos Pereira

Focusing on the potential IoT solutions for Portuguese footwear SMEs and its potential economic impact. The main questions are: can Portuguese footwear SMEs implement IoT solutions? If so, what are the estimated economic impact.

Carlos: Yes, footwear SMEs can implement IoT solutions. IoT offers a wide range of possibilities, enabling its usage in several domains and industries. Depending on the scale, certain IoT solutions require significant financial investment, thus SMEs may not be capable to afford it. However, there are cheaper and simpler solutions which could be adopted.

Everything which concerns installing sensors just to gather data it is relatively easy and cheap to install. On the other hand, specific issues or complex solutions are costly and time consuming. As an example, predicting the future - forecasts and maintenance - require advanced analytics.

There are several factors that influence the economic impact, namely the scale of the solution, the IoT application itself, the objective, the KPIs, the industry, the organization of the company, equipment and processes, among others. In this sense, the economic impact of each IoT application tend to vary a lot within the same IoT application and industry.

Based on the EQS data, and the specifies of Portuguese footwear SMEs, the following values were provided:

- Increase production productivity 15% to 25%
- Decrease waste costs 20% to 40%
- Decrease inventory 10% to 20%
- Increase safety at work while reducing the costs with accidents.
- Decrease maintenance costs between 30% to 60%
- Decrease energy consumption up to 50%
- Improve forecasts by increasing effectiveness 10% to 40% (resulting in costs reduction, increased productivity, or both)
- Bring closer different departments and enhance decision making can result in increased overall effectiveness 15% to 35%