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**Mestrado em Gestão de Informação**

Master Program in Information Management

## **The Impact of IoT in Brick-and-Mortar Stores**

How IoT and Customer Analytics are boosting  
customer engagement

Helena Margarida Ferrão Soares

Dissertation presented as partial requirement for obtaining  
the Master's degree in Information Management, with a  
specialization in Knowledge Management and Business  
Intelligence

**NOVA Information Management School**  
**Instituto Superior de Estatística e Gestão de Informação**

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NOVA Information Management School (NOVA IMS)

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## DEDICATION

*Dedico este trabalho ao meu pai, que me  
e ensinou a querer sempre mais da vida e  
me proporcionou os meios para o alcançar.  
Obrigada, Pai.*

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## RESUMO

O cliente tem sido o centro do retalho durante muitos anos. De forma a responder à procura, e conseqüentemente às expectativas do cliente, os retalhistas têm inovado e se adaptado a novas tecnologias com o decorrer do tempo. Com a proliferação da *Internet of Things* nos negócios dos retalhistas surgiu a oportunidade de capturar mais dados sobre o comportamento do consumidor dentro das lojas de retalho físicas. Conseqüentemente, a possibilidade de beneficiar de *customer analytics* cresceu exacerbadamente, visto que anteriormente os retalhistas conseguiam mapear o percurso do cliente apenas online. Para além disso, as lojas físicas ainda acrescentam valor ao retalho, tendo em conta que garantem fatores únicos e exclusivos que as distinguem perante o consumidor. Todavia, a necessidade de readaptação para não atrasar o negócio é uma constante devido à evolução contínua das expectativas do consumidor.

Nesse sentido, o estudo apresentado tem o objetivo de perceber se e como os retalhistas estão a beneficiar do uso de *IoT* nas lojas de retalho físico para impulsionar o *customer engagement*.

Assim, tendo por base o tema da investigação, recorreu-se a uma metodologia de carácter quantitativo, sendo que os dados primários foram recolhidos através de um questionário realizado online direccionado a empresas de retalho que operam em Portugal.

Através de uma amostra de 20 inquiridos foram obtidos resultados que permitiram desenvolver uma perceção geral do impacto da implementação da *IoT* nas lojas físicas destas empresas. Estas descobertas revelaram a vontade dos retalhistas de compreender o percurso do cliente dentro das suas lojas com o intuito de solucionar e melhorar a organização das mesmas, a fim de responder às expectativas dos clientes. No entanto, a integração desta tecnologia em lojas física ainda é recente e, como tal, várias inovações têm sido introduzidas lentamente também com o objetivo de dinamizar a experiência do cliente e criar diferentes pontos de contacto.

## PALAVRAS-CHAVE

Retalho; *IoT*; lojas físicas; *customer analytics*; comportamento do consumidor; envolvimento do consumidor; experiência do consumidor

## **ABSTRACT**

Customer has been the centre of retail businesses for many years. In order to answer their demand, and therefore their expectations, retailers have been innovating and adapting to new technologies over time. With the dissemination of Internet of Things into retail businesses, the opportunity to collect more data on customer behaviour inside brick-and-mortar stores come into sight, and subsequently, the prospect to perform customer analytics expands disruptively. Prior to this, retailers were only able to get a full view of the customer journey in online settings. In spite of this, brick-and-mortar stores still hold value for the customer regarding specific sentiments that are still exclusive from physical environments. However, the need to adapt to not fall behind urges, since customer expectations are growing and what is valued today might not be tomorrow. Considering this, the research presented has the objective of understanding if and how retailers are leveraging IoT in brick-and-mortar stores to boost customer engagement.

With that in mind, the research was conducted through a quantitative research method where the primary data was collected through an online survey directed to retail companies operating in Portugal. With a sample of 20 respondents, the results allowed to grasp a general understanding of the impact of IoT implementation in brick-and-mortar stores. These findings revealed a preference for understanding the customer journey inside the stores to address some spatial-related aspects in order to deliver customers' expectations inside the store. However, this technology is yet to mature in a retail environment as other novelties have been slowly introduced to also dynamize customer experience and create different points of engagement.

## **KEYWORDS**

Retail; IoT; brick-and-mortar stores; customer analytics; customer behaviour; customer engagement; customer experience

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## LIST OF ABBREVIATIONS AND ACRONYMS

<b>AI</b>	Artificial Intelligence
<b>AR</b>	Augmented Reality
<b>CAE-Rev.3</b>	Classificação Portuguesa das Atividades Económicas - Revisão 3
<b>e-commerce</b>	Electronic commerce
<b>e-retailing</b>	Electronic retailing
<b>e-Wallet</b>	Digital wallet
<b>IoT</b>	Internet of Things
<b>IoT-commerce</b>	Internet of Things commerce
<b>IP</b>	Internet Protocol
<b>IPSO</b>	IP for Smart Objects
<b>LAN</b>	Local area network
<b>m-commerce</b>	Mobile commerce
<b>NFC</b>	Near Field Communications
<b>ORION</b>	On-Road Integrated Optimization and Navigation
<b>POS</b>	Point of Sale
<b>RFID</b>	Radio-Frequency Identification
<b>SRT</b>	Smart Retail Technology
<b>UHF</b>	Ultra-High Frequency
<b>uID</b>	Ubiquitous Identifier
<b>UPC</b>	Universal Product Code
<b>WA</b>	Web Analytics
<b>WISP</b>	Wireless Internet Service Provider
<b>WSAN</b>	Wireless Sensor and Actuator Network

## 1. INTRODUCTION

The first chapter aims to identify the main problem to be tackled in this dissertation. Also, to ensure a proper basis, the relevance of the subject and its background are analysed. Furthermore, the objectives and outline are established allowing a feasible quantification and understanding of the work extension.

### 1.1. BACKGROUND AND PROBLEM IDENTIFICATION

In recent years, Internet of Things (IoT) has been becoming a trend within business and technology. In spite of that, it is not a new concept. The concept goes back to 1999 and it was introduced by Kevin Ashton, being its main objective to link information captured in the physical world to the Internet under the premise of “promoting the communication between anything from anywhere at anytime through context-aware applications” (Ali et al., 2015, p. 37). IoT’s massive growth urges organizations to acquire these technologies in order to upgrade their decision-making process through the collection and analysis of great amounts of data generated – Big Data (Côte-Real et al., 2019). Although it went under great improvements, offering sensors and communications technologies, the implementation of IoT applications in business models is still a challenge for many companies as they lack IoT and analytic capabilities to extract vital information and differentiate their businesses (Gartner, 2017). Nevertheless, its disruption is noticeable since it is integrated into many businesses from manufacturing and finance to health care and automotive. McKinsey forecasted that by 2025, IoT applications will impact the economy up to 11,1 trillion dollars per year (McKinsey Global Institute, 2015).

As a result of this digital age, customer’s expectations expanded due to massive usage of Internet for tasks such as shopping, socializing or just researching. Hence, the need to combine virtual and physical aspects became a critical factor to achieve a successful strategy in a business. In order to accomplish this and seize the opportunity, the value proposition must be restructured so the digital component can be integrated. “Using information and analytics, organizations can reshape the customer value proposition on three levels by enhancing, extending or redefining the value of the customer experience” (Berman & Ragna, 2011, p. 7). In view of that, the retail industry faced great changes, enabling at the same time different purchase channels to keep up with modern customers. Under those circumstances, the number of online stores increased widely as well as smartphone applications to answer that revolution. With these new technologies available, the traditional brick-and-mortar stores landed the omnichannel concept in an attempt to overcome the barrier between online and offline shopping. “Customers expect consistent, uniform, integrated service and experience, regardless of the channel they use” (Piotrowicz & Cuthbertson, 2014, p. 8). While this is yet to be an exceeded concern for retailers, the lack of integration in many aspects of the business still exists such as pricing, brand building or even the experience they are trying to sell (Piotrowicz & Cuthbertson, 2014).

Regardless of the fact e-commerce use has increased over the past couple of years, physical stores still hold important features valued by customers that are yet to be caught by the Internet. On that matter, trust is still a concern for customers regarding online shopping. Alongside human interaction and the necessity to “feel” the product, these factors play a major role in the purchase decision, as they all add a unique value to customer experience, unable to match by e-commerce (Blázquez, 2014; Oliveira et al., 2017; Piotrowicz & Cuthbertson, 2014). Admittedly e-commerce offers accessibility, but brick-and-mortar deliver an experience. “Experience per square foot will be the new retail metric to measure success.”(KPMG, 2018, p. 4). In order to improve customers’ experience is necessary to understand their behaviour to keep them engaged. Since digital channels became more and more popular as previously mentioned, track customer engagement within this channel became a critical factor to perceive consumer’s needs. With Web Analytics (WA) that task was within reach as the seller became able to track visits and what the consumer was watching and when (Järvinen & Karjaluoto, 2015). By examining each step made until conversion (or not), the WA user is able to identify how small changes can affect the conversion rate and the website traffic, and gather enough information to outline customers profile based on their navigation path and previous orders (Dale Wilson, 2010). As a result, researches and frameworks about this topic increased greatly in order to understand and implement better this concept (Huang & Van Mieghem, 2013; Järvinen & Karjaluoto, 2015; Pîrvu & Anghel, 2019; Terragni & Hassani, 2018). Also, companies started to shift their businesses in the attempt to attract and satisfy more customers and consequently capture profit by taking advantage of insights gathered.

Conversely, customer insights in traditional stores have been collected in the point of sale (POS) from several years through UPC (Universal Product Code) barcode scanning which has been helpful to understand customers but within certain boundaries, since it does not provide information about the clients’ path prior to that moment. Information such as what products they search and interact with but do not buy is not disclosure with this technology. However, this was the start of data-driven models in retail and “it would not be an exaggeration to say that the advent of scanning technology made possible much of the retail technology innovation that has followed” (Inman & Nikolova, 2017, p. 8).

## **1.2. STUDY OBJECTIVES**

IoT applications and evolution of customers’ expectations are shifting businesses as has been previously noted. Henceforth, the main objective of this research is to assess how IoT potential is being applied in brick-and-mortar stores in order to impact customer engagement. Therefore, the main research question of this dissertation is the following: *how IoT implementation in brick-and-mortars stores is impacting customer engagement?*

Additionally, the research conducted will be also focused on answering secondary questions presented in Table 1.1, alongside the literature references that support them.

Table 1.1 – Research Questions and Objectives

Research questions	Research objectives	References
(1) Which sensors do retailers consider more effective to collect customer data inside stores?	To identify the most effective sensors for collecting relevant customer data inside a store.	(Fraden, 2010; Holdowsky et al., 2014)
(2) Which type of customer analytics are being carried with the data collected?	To determine which type of analytics are being preferred to gather valuable information about customers.	(Adi et al., 2020; Sathyanarayanan, 2012)
(3) How are insights gather being used to improve customer engagement?	To establish how the information collected is turning into actions to improve customer engagement.	(Inman & Nikolova, 2017; Marr, 2016; Polacco & Backes, 2018; Sridharan, 2014)

### 1.3. STUDY RELEVANCE AND IMPORTANCE

Sensors represent a key technology that enables the Internet of Things. The implementation and usage of sensors in current technology has been increasing over the years, where its range of implementation can vary into multiple aspects, from industrial practice and automotive control into daily basis operations and smart cities (Caggiano et al., 2017; Chang & Kalawsky, 2017; Overmeyer et al., 2018). Nevertheless, it is possible to state a trend of evolution of this concept. Its implementation is starting to grow since companies and entities understand a new methodology is available to extract vital data that can aid the process of decision making. “The cost of an accelerometer has fallen to 40 cents from \$2 in 2006.” (Holdowsky et al., 2014, p. 3).

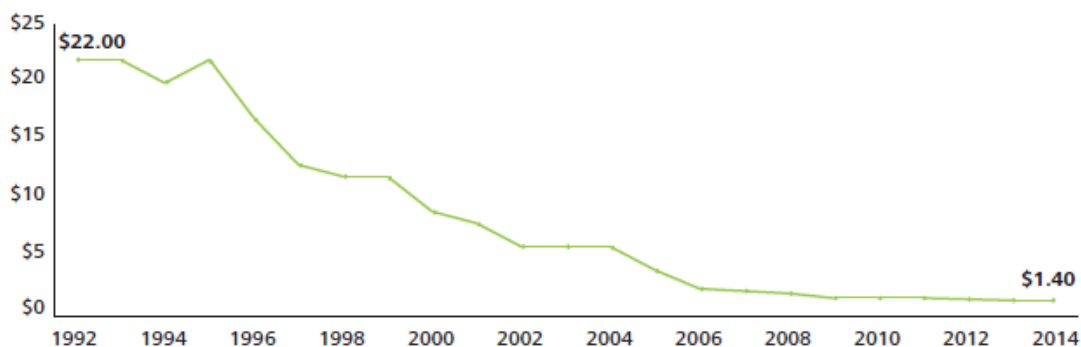


Figure 1.1 – Sensor price over time (Holdowsky et al., 2014)

Figure 1.1 shows the price tendency regarding the price of a sensor over time, this variable has evidently dropped over the years, allowing an affordable entry on this IoT

revolution. With the evolution of components, it is possible to see a trend where Moore’s Law<sup>1</sup> can be applied. Though the concept of the sensor suffers multiple evolutions, its purpose remains unchanged: “Generates an electronic signal from a physical condition or event” (Holdowsky et al., 2014, p. 3).

The potential of IoT goes further than simply connecting physical devices to the Internet. With the number of devices rising and its positive impact on the economy, it portrays a desirable opportunity for many industries, as it can increase their efficiency, reduces cost and rises profits (Gartner, 2017; McKinsey Global Institute, 2015). As a result, 91% of the investments made in IoT lead to a cost reduction (Hogan et al., 2016).

Even though IoT dissemination was quick in many sectors such as manufacturing or supply chains, as this technology is being used to drain the need for human resources and replace them to reduce costs, in retail these practices are under a more deliberated approach. With smartphones, social media and traditional stores many channels are available to fit clients’ needs. Regarding online purchases, e-commerce is rising, and it is expected to reach 17.5 % of the total global retail share by 2021. In that view, traditional stores are expected to reach 82.5%, therefore keeping the majority of sales, which means they are still a preference for customers (Figure 1.2) (Statista, 2017).

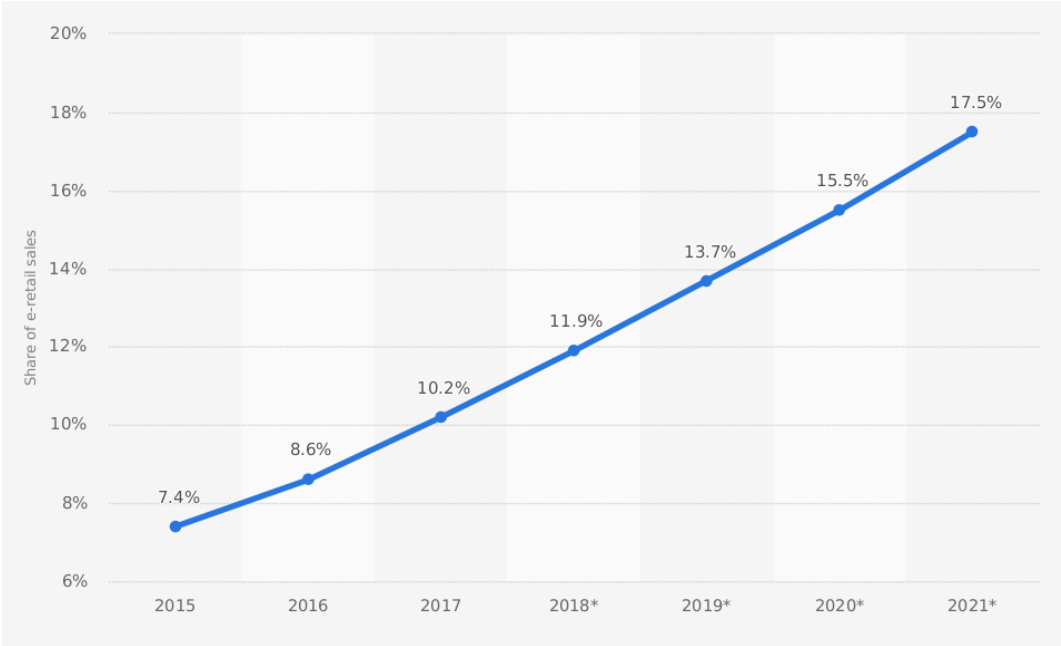


Figure 1.2 – E-commerce share of total global retail sales from 2015 and 2021 (Statista, 2017)

Moreover, with advanced analytic capabilities, retailers began to be able to go further than the POS. On the one hand, online presence allowed retailers to know the customer

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<sup>1</sup> Moore’s Law represents the capacity of computers and microchips doubles every 18 months, in an exponential growth.

path: their searches for specific products, the number of clicks, and the remaining interactions made in that platform. Through that data analysis retailers start to acquire customers insights about the client behaviour in the whole shopping experience (Mangiaracina et al., 2009). On the other hand, the conditions change regarding physical stores, as the digital world expanded. IoT is already entering retail with the purpose of simplifying the customer path within a store. Amazon Go makes use of IoT to improve the customer experience by making their trip to the grocery store faster without the hassle of lines (Polacco & Backes, 2018). Additionally, Costa Coffee created a vending machine with cashless payment options and interactive digital signage that allow the vendor to remotely control the temperature, monitor the machine and also gather data to base campaigns (Intel, 2013). Alongside this implementation urges the possibility of acquiring more data about the customer behaviour inside stores, and therefore the chance to extract new and crucial insights for business performance. According to trends defined by KPMG in 2018, “customer experience will overtake price and product as the key brand differentiator by the year 2020” (KPMG, 2018, p. 7). Focused on customer-centricity more than ever, it is important to understand how IoT can be effectively applied in order to enhance analytics capabilities and how it can shift business models toward a sustainable competitive advantage.

#### **1.4. DISSERTATION OUTLINE**

The composition of this dissertation entails five segments described in this section.

The *Literature Review* is divided in three main topics. The first introduces Retail and its evolution throughout the years, focusing on the main challenges faced by trying to keep up with the digital transformation. Secondly, the concept of IoT is stripped down in order to analyse its progress and its contributions in different fields. Different applications are introduced as well as the different sensors released and its functions. Finally, the last unit refers to analytics, emphasizing on customer analytics and how it relates to IoT.

The *Methodology* section establishes and describes the research methodology selected and its appropriation to this research. It describes the survey setting in order to reinforce and validate the research topic.

The *Results and discussion* section is focused on analysing the questionnaire outputs in the context of the literature reviewed. Therefore, it presents the research findings.

The *Conclusion* section sums up the main topics regarding IoT implementation inside physical stores. It is at this stage that research questions are answered.

The *Limitations and recommendations for future works* section explains the barriers met to accomplish this dissertation and suggests future research in this field of study to expand its contribution to society.

## 2. LITERATURE REVIEW

This chapter intends to explore the main concepts relevant to the study from an academic perspective. As Webster & Watson (2002, p. 13) stated “a review of prior, relevant literature is an essential feature of any academic project. An effective review creates a firm foundation for advancing knowledge”. In that view, the second chapter regards the literature review of topics of relevance for the study, namely, Retail Evolution, Internet of Things, and Analytics.

### 2.1. RETAIL EVOLUTION

What started with simple transactions inside physical stores has suffered major changes compared to what is known today as retail. Innovation is a key factor to stay afloat in the market. It “is one of the main mechanisms for organizations to improve their competitiveness and ensure their long-term survival” (Domínguez-Escrig et al., 2019). Throughout the years, retail has been evolving in order to keep up with the latest technologies and keep profiting. Hence, the interest in topics such as retail design, POS technologies and customer technology acceptance has been expressed in many studies (Clodfelter, 2010; Inman & Nikolova, 2017; Pantano & Viassone, 2014; Quartier et al., 2019).

The digital era brought up a tremendous transformation in the industry considering the many technological opportunities that arose in both ends of the chain, i.e., for both customer and retailer. This constant reformulation of the environment that revolves around society reflects on customers’ expectations and therefore on their behaviour as they expect more from every innovation launched. The digital world opened access to a vast amount of information, thus the shopper searched for more reasoned purchases. Automation eased the purchase process and offered more control over it, regardless customers started to strive for an even faster and effortless process. This progression is incremental as one evolution does not disregard its prior, and that is the value that brick-and-mortar stores still hold in the retail industry. A study performed by Quartier, Claes & Vanrie (2019) gathered retail experts in Europe concluded that one of the most valued competencies in a retail designer is the capability of transition seamlessly across channels by merging digital and physical environments. Furthermore, this study also reinforces that retail’s future is bound by brick-and-mortar stores, since spatial design skills still hold a major role in this field. Physical stores are still perceived as an “effective competitive weapon” (Rigby, 2011), as they can counterweight with unique features that e-commerce (electronic commerce) cannot match. However, the traditional policy is not enough anymore, customers do not distinguish brick-and-mortar stores as the only way to get their goods. Reliability and the ability to test products, combined with a personalized and more enjoyable experience, can be decisive factors to whether or not leave home.

The customer experience is simply the customer reaction to every interaction with products, brands or retailers that can consequently influence the value of services or

products (Flacandji & Krey, 2020). Therefore, the adoption of technologies has a vital spot in this transition to enhance the dynamic of the purchase process by enabling more engagement points in this process (Ferracuti et al., 2019; Rigby, 2011; Verhoef et al., 2015).

The entrance into the online channel led by the Internet was a fundamental requirement as customers behaviour evolved and greater expectations were shaped. The opportunity of selling and buying products online unveiled the concept of e-commerce which portrayed the prospect of shopping everywhere with an online connection (Clarke III, 2008).

The quick dissemination of digital channels increased the popularity of multichannel strategies as both traditional and online retailers began to feel the need pursue new channels in order to compete by signing their presence in both fields. Neslin et al. (2006, p. 96) described “**multichannel customer management** as the design, deployment, coordination, and evaluation of channels to enhance customer value through effective customer acquisition, retention, and development”. However, the lack of integration due to the independence of channels from each other portrayed some difficulties regarding the management of the different channels used, in terms of clients, resources allocation and strategy coordination across channels (Neslin et al., 2006; Verhoef et al., 2015). The lack of cooperation between co-workers would lead to the application of different strategies and, in worse scenarios, incompatible ones. This would mostly result in selling the same product for different prices, isolated marketing campaigns for each channel, difficulties in profiling customers across channels, unrelated experiences provided, among other barriers. A clear division was established that would emphasize channels over brands (Piotrowicz & Cuthbertson, 2014).

Alongside the massive digitalization, these new digital channels were brought into sight and reformed retail business models through different devices. For instance, the massive use of smartphones and the introduction to mobile apps led to the extension of e-commerce umbrella with m-commerce (mobile commerce) enabling a growing multitude of shopping experiences providers, therefore, exceeding the limitations of e-commerce until then (Clarke III, 2008). As the multichannel was not considered sufficient, the omnichannel approach was a natural progression (Verhoef et al., 2015). In 2013, the MIT Sloan Management Review stated that “the distinctions between physical and online will vanish, turning the world into a showroom without walls” (Brynjolfsson et al., 2013, p. 24). Later Verhoef, Kannan & Inman (2015, p. 176) labelled “**omni-channel management** as the synergetic management of the numerous available channels and customer touchpoints, in such a way that the customer experience across channels and the performance over channels is optimized”. Table 2.1 summarizes the main differences between the two concepts, namely, multichannel management and omnichannel management.

Table 2.1 – Multi-channel versus omni-channel management (Verhoef et al., 2015, p. 176)

	<b>Multi-channel management</b>	<b>Omni-channel management</b>
<b>Channel focus</b>	Interactive channels only	Interactive and mass-communication channels
<b>Channel scope</b>	Retail channels: store, online website, and direct marketing (catalog)	Retail channels: store, online website, and direct marketing, mobile channels (i.e., smart phones, tablets, apps), social media. Customer Touchpoints (incl. mass communication channels: TV, Radio, Print, C2C, etc.).
<b>Separation of channels</b>	Separate channels with no overlap	Integrated channels providing seamless retail experiences
<b>Brand versus channel customer relationship focus</b>	Customer – Retail channel focus	Customer – Retail channel – Brand focus
<b>Channel management Objectives</b>	Per channel	Cross-channel
<b>Objectives</b>	Channel objectives (i.e., sales per channel; experience per channel)	Cross-channel objectives (i.e., overall retail customer experience, total sales over channels)

Over the years, more researchers witnessed this natural evolution and advocated the necessity of integrating physical and digital notions (Balaji & Roy, 2017; Bèzes, 2019; Miller, 2015). Rebecca Miller (2015, p. 2) claimed that “the future is less likely to be a rejection of one or the other than a smart integration of what’s possible” calling this urge of merging “phygital”. Bèzes (2019) suggested that the connected store is nothing more than a smart store where digital meets physical and the freedom that customers are given in their shopping experience might come with the cost of their privacy being breached. Nevertheless, **smart retailing** arose as the mean to fully achieve the omnichannel strategy and level up the advantage taken by integrating smart retail technology and inevitably by gathering and exploring data. Roy (2018, p. 147) defines smart retail technology (henceforth, SRT) as “an interactive retail system which delivers retail services to consumers through a

network of smart or intelligent objects and devices”. These objects’ “smartness” concerns their capability of interconnect with each other in order to sense the environment and generate, share and interact with real-time data autonomously (Haque et al., 2013; Romero et al., 2020).

Although e-commerce broadened the opportunity in terms of channel selection and customer interaction with retailers and other customers, smart technology launched an even more interactive environment. The new devices embedded with sensors made possible the interaction with products, brands, retailers and other customers in real-time inside a store, improving not only the customer experience but also operations efficiency. The Table 2.2 summarized by Roy et al. compiles the main differences between electronic retailing and smart retailing.

Table 2.2 – Key differences between e-retailing and smart retailing (Roy et al., 2017, p. 258)

<b>Attributes</b>	<b>E-retailing</b>	<b>Smart retailing</b>
<b>Space</b>	Digital	Bridging digital and physical
<b>Core technology</b>	Websites	Innumerable sensors, smartphones, and apps
<b>Nature of interactivity</b>	Between customers and webstores; customer to customer	Customer to retailer Customer to customer Customer to products (brands) Products (brands) to retailers Machine to machine (touchpoint to touchpoint)
<b>Service provision</b>	Always-on services	Always-responsive services which is context specific

IoT emerged in every device and consequently SRTs entered brick-and-mortar stores collecting more data on customers and dynamizing their path. The innovation marched even further entering customers’ houses and adding a new asset to the online retail umbrella. IoT-commerce became a reality where automatic repurchase of groceries, smart voice assistants and smart appliances are no longer a distant idea. It was defined by Bayer (2020, p. 6) as “the purchasing of products and services online via the use of IoT devices whose technical features afford new opportunities to retail customers”. Assistants like Alexa connected to a network of smart appliances allow the user to be notified of his grocery’s shortages, for example, and to purchase them through voice commands.

### 2.1.1. Retail Technology Review

In order to stay relevant, retailers need to keep updating their business models while going hand-to-hand with the massive technology progression by integrating it in a strategic and profitable way (Renko & Druzijanic, 2014).

The first device that clearly impacted the purchase process was the **UPC barcode scanner** since it enabled more efficient transactions by recognizing products faster while generating real-time data. The first sale supported by this technology was in 1974 and the item sold was a pack of chewing gum. This pioneer idea was followed by many other devices. In 1992, the **self-scanning checkout unit** was one of them. It provided a faster way of shopping and discarded the need of a cashier, as the client started to be responsible for scanning, bagging and paying.

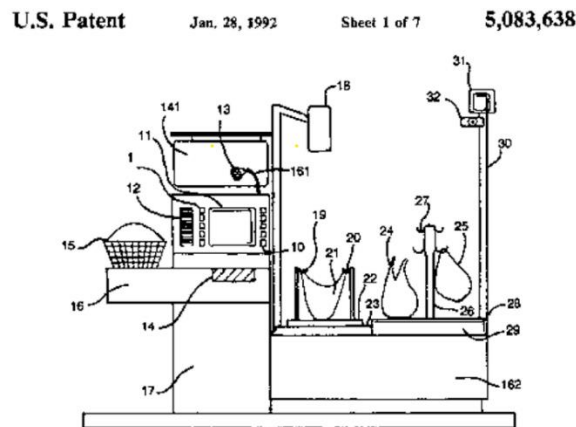


Figure 2.1 – Self-checkout sketch from original patent 5,083,638 (Inman & Nikolova, 2017, p. 11)

Also, **location-based marketing technologies**, that are highly used nowadays, are not recent, as in 1988, a videocart was introduced by Malec and Moser with a digital display that would play specific content according to the cart location inside the store. Other equipment such as in-store coupons dispensers, or network of monitors inside a store focused on advertising products made use of this technology. Retailer Walmart was one of the firsts to apply these monitors, initiating the Walmart Smart Network (Inman & Nikolova, 2017).

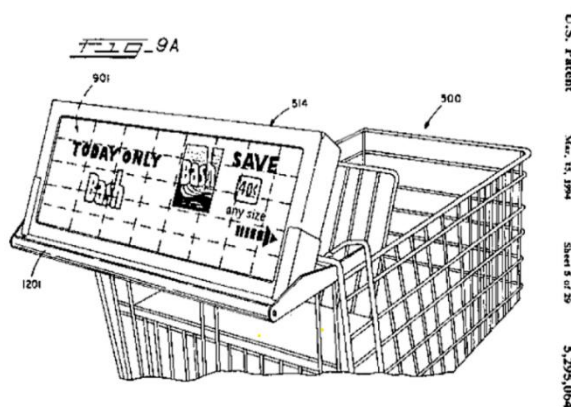


Figure 2.2 – Videocart sketch from original patent 5,295,064 (Inman & Nikolova, 2017, p. 9)

The mass technological development led to a wide introduction of electronic component-based equipment in brick-and-mortar stores like **smart shelves** with weight sensors that are being installed to provide better stock management and avoid discontentment from buyers since products searched are always available. **Store traffic counter systems** have been launched to cut wait time in lines, by counting the numbers of clients in store in order to have enough cashiers available. These devices provide real time data that allows companies to perform predictions regarding the busiest months, days or even hours in stores. QueVision is the platform used by Kroger which uses infrared sensor to perform this task. Reports suggests that QueVision has cut the waiting time to half a minute and customers satisfaction was obviously improved along with revenues. Moreover, **digital price tags** with beacons that more than being laboursaving and less time consuming, allowed retailers to use proximity-based communication to connect with customers by sharing advertisements in their mobile applications, functioning basically as call to action activated by the location of the customers. **Loyalty cards** based on a customized pricing system allowed to extract purchase information, enabling the process of data integration between physical stores, and therefore, establishing prices and promotions in view of the customers interests though data mining techniques (Inman & Nikolova, 2017).

Online shopping prompt likewise new technologies due to the necessity to understand clients in this environment and answer their needs. **Cookies** are commonly used these days in online retail to collect customer data in order to identify customer demands. Also, **chatlines** intended to establish a connection with customers by helping them in the shopping process. While the previous entails human interference, **chatbots** depend on AI (Artificial Intelligence) technology and disregard this interaction (Roggeveen & Sethuraman, 2020).

Beyond data collection, data analytics boost businesses and became a decision breaker in the innovation path. Companies start to learn clients' perceptions of their services or products faster through social networks but also in meaningful ways due to data mining techniques, particularly text mining, or AI. These make possible to follow customers' online print regarding their business-related interests. **Social media listening** is more than tracking impressions, it focuses on learning what it is being said concerning the brand or its competitors in social media, like brand references, specific keywords, sentiments or even potential leads, and how to react to that information. It allows a brand to enter in discussion with clients or potential ones, connect and reply to their doubts and concerns. The focus is always giving the customer what he wants even if he does not know what it is yet. In this matter, **recommendation systems** help the user by using historical client's data and machine learning techniques to decrease selection complexity for the client. Brands and retailers with the insight gathered can provide personalized recommendations like a specific movie on Netflix or a product that might be complementary to a previous purchase on Amazon (Ducange et al., 2019; Marchand & Marx, 2020; Roggeveen & Sethuraman, 2020). In the same prospect, **visual search technology** allows the user to complete a search by using

images, so if the client aspires a red shirt he passed by somewhere, he can use H&M app to take a picture and search for something very similar or if he is lucky that same shirt (Roggeveen & Sethuraman, 2020).

With such tools buyers can gather information easily and make a more knowledgeable and faster decision regarding the purchase. To keep up the process efficiency and provide a seamless transaction between online and physical retail, companies started to provide **click and collect** services and **automated curbside pickup** (Target and Walmart) which allow customers to lose less time with shopping and avoid lines and sidestep unnecessary contact with other people (Piotrowicz & Cuthbertson, 2014; Roggeveen & Sethuraman, 2020).

In physical stores, **Scan and Go** implementation highlighted the usage of sensors and deep learning algorithms inside a store as clients are able to scan products as they take them from shelves and also pay with their smartphones. When Walmart tried to put this in motion back in 2013 and 2014, the results were not encouraging as the customers showed preference in a device provided by the retailer rather to use their own phones (Inman & Nikolova, 2017; Polacco & Backes, 2018). Soon, Amazon expanded this concept under the chain Amazon Go, with the Just Walk Out technology, as the client only needs to leave the store after picking its groceries since he is charged directly on his Amazon account. This made **contactless checkout** the next evolution phase in self-checkout. In terms of data extraction, it symbolized a great evolution for brick-and-mortar stores as retailers became able to monitor which items were placed back on shelves and by which customers, therefore, taking a step further on understanding customer behaviour inside stores (Polacco & Backes, 2018).

Meanwhile new portable technologies are highly used such as smartphones and tablets alongside with mobile apps ensuring this new retail evolution phase, the omnichannel retailing, focused on overcoming barriers between different channels (Verhoef et al., 2015). **Mobile applications** were embedded with a new set of tools that provided a seamless experience between the offline and online channel and enhanced the client experience inside a store, namely automatic payment, item searching, online purchasing and item comparison. Moreover, these apps allowed to identify customers preferences due to RFID (Radio Frequency Identification) systems that enable bar code reading (Inman & Nikolova, 2017; Pantano & Viassone, 2014).

Following these developments, it is noticeable that retail is driven by consumers desires in an endeavour to satisfy them. The efforts described reveal how investments are shifting into smart retail technology to make customer experience more enjoyable and accentuate the position and future of physical stores in complementarity with online stores (Adapa et al., 2020; Rigby, 2011). In that sense, IoT-commerce alongside the smart house concept allows companies to go further in the quest for the most seamless experience possible. Many brands like Samsung, Whirlpool and LG comprise a variety of **product-base IoT** such as smart fridges that allow the user to add items to his shopping list and order them online or

smart washing machines that track the number of times laundry is done in order to notify laundry detergent shortages, for example (Bayer et al., 2020). In addition, **automatic replenishment services** were introduced to work with these devices, like Amazon Dash Replenishment that lets the user set up the device in order to automatically order specific products when they are needed, for example ink cartridges for printers when the ink levels are low. Optionally, the Dash Smart Shelf reorders whatever the user puts on it when it detects a shortage on the product through weight shifts (Berthiaume, 2021; Goode, 2021). Additionally, to upgrade the offer, all those products and services can be requested through voice control commands by using gadgets integrated with AI virtual assistants like Echo devices with Alexa by Amazon or Google Nest devices with Google Assistant by Google (Roggeveen & Sethuraman, 2020). The client has now the freedom to manage its needs inside its own house whenever and wherever is more convenient without opening a screen and without a single touch (Bayer et al., 2020).

In the transportation sector, IoT-commerce made rise companies like DriveNow, Cooltra, Smoove and others, which offer vehicles on various locations that people can easily use, once they register on their app. Usually these applications allow the user to find cars, scooters or bicycles near him and consequently unlock them so they can travel. The client is billed according to different metrics like time or travelled area, which are tracked by sensors installed on the vehicle (Bayer et al., 2020).

Considering that this dissertation is focused on the application of IoT inside brick-and-mortar stores and how customer data is being and can be collected inside physical stores, Table 2.3 presents front-end SRTs that brick-and-mortar stores started using to fill the void on the subject of data availability and collection, while some also dynamize and enhance directly the customer experience making them stand out as a more desirable option to cope with customer churn (Roy et al., 2018). These represent a step forward in matching the insight delivered by online retail stores but more important, they provide a seamless experience between physical and digital concepts.

Table 2.3 – Front-end SRTs implemented in brick-and-mortar stores

Path-to-purchase	Name	Description / Details	Applications	Existing literature
Pre-purchase	Geofencing	Location-based service which uses sensors installed in stores to track RFID, Bluetooth and Wi-Fi fingerprinting in order to collect mobility data inside a store and analyse path patterns.	<ul style="list-style-type: none"> <li>▪ Shopping Centers;</li> <li>▪ Museums.</li> </ul>	(Kim & Lee, 2018; Kirkpatrick, 2020; Ren et al., 2017; Stavrou et al., 2019)
Pre-purchase	Mobile Applications	Stores mobile apps work in different settings. They can notify customers regarding stores nearby, deliver specific content relevant to the customer location inside the store or give indications regarding product location.	<ul style="list-style-type: none"> <li>▪ Walmart;</li> <li>▪ Starbucks;</li> <li>▪ Costco.</li> </ul>	(Roggeveen & Sethuraman, 2020)
Pre-purchase	Virtual showroom	A technology that enables to visualise how products will look like in specific site like customers' houses.	IKEA Place is an app that use AR technology so the user can see how IKEA solution would look on his house.	(Pantano & Vannucci, 2019; Roggeveen & Sethuraman, 2020)
Pre-purchase	Smart fitting room	Interactive mirrors that sense the garments usually through RFID tags and allow users to request different sizing, colours or even different	<ul style="list-style-type: none"> <li>▪ Mango;</li> <li>▪ Ralph Lauren.</li> </ul>	(Beth Osborne, 2018; Hilary

		clothes or accessories recommended by the device according to their previous selection.		Milnes, 2016)
Pre-purchase	Virtual trial room (AR)	Devices supported by AR technology that represent virtual space or objects around the user. These devices are also known as magic mirror and this technology is used inside stores through digital screens but also in mobile apps and online so the customer can try their garments at home.	<ul style="list-style-type: none"> <li>▪ Kinect fitting room used in a Timberland campaign in Moktow Gallery, Warsaw, Poland;</li> <li>▪ Memory mirror by MemoMi;</li> <li>▪ ModiFace mirror at MAC and Sephora allows customers to see how makeup products would look like on their faces.</li> </ul>	(Grewal et al., 2020; Pantano & Vannucci, 2019; Roggeveen & Sethuraman, 2020)
Pre-purchase	RFID tags	RFID tags are attached to the products and allow them to be sensed inside the store. Therefore, through the RFID readers products position inside the store can be determined, allowing for instance to understand the customers journey and prevent thefts.	H&M implemented RFID tags in their clothes paired RFID readers in the ceiling in order to control stocks better.	(Jocovski, 2020; Renko & Druzijanic, 2014)
Pre-purchase	Robotic shopping assistant	Robots that help customers with products location inside the store, check inventory, and answer to other questions the client might have.	LoweBot is at Lowe's entrance and uses smart laser sensors and computer vision to guide customers and assess stocks.	(Roggeveen & Sethuraman, 2020)
Pre-	In-store cameras and	Images recorded are for many purposes like	Sephora stores in Malasya	(Kirkpatrick,

purchase stage	video analytics	counting clients, track waiting lines and client's path in order optimize the efficiency of the store design.		2020)
Purchase stage	Wearable technology	Smart devices such as smart watches that integrate online and physical retailing.	<ul style="list-style-type: none"> <li>Wear OS through Google Pay allows to pay in physical stores using NFC;</li> <li>Apple Pay and Apple Watch.</li> </ul>	(Roggeveen & Sethuraman, 2020)
Purchase stage	Contactless Payment	Payment systems that use RFID or NFC or QR codes. It makes possible to pay in any POS terminal just by tapping or holding credit cards, wearables or smartphones above these devices.	<ul style="list-style-type: none"> <li>Companies like Visa and Mastercard produce contactless creditcards</li> <li>Banks applications like Mbway allow to scan a QR code to proceed with payment.</li> <li>SwatchPAY! by Swatch and Caixa Geral de Depósitos is a watch connected to a credit card that allows contactless payment through NFC.</li> </ul>	(Caixa Geral de Depósitos, n.d.; Mastroberte, 2021)
Purchase stage	Contactless Payment (biometrics authentication)	Payment system that uses computer vision to recognize clients through their exclusive biological features such as fingerprints.	Amazon One uses palm signature to allow clients to pay by hovering their hand.	(Robinson-Jacobs, 2020)
Purchase stage	Smart cart technology / Smart Trolley	Device that scans products once they are inserted and the cart. The number of	Amazon Dash Cart available at Amazon Fresh stores even allow to	(Jeff Helbling,

		interactions is limited, making the process simpler and faster.	leave the store without waiting for payment, as the buyer is automatically charged through its Amazon account.	2020; Renko & Druzijanic, 2014; Roggeveen & Sethuraman, 2020)
Purchase stage	Digital Wallet (e-Wallet)	Online payment services that allow to make online transacting. The user can deposit money in these wallets or affiliate it with a bank account. They can be used in online purchases or in stores through smartphone and wearables.	<ul style="list-style-type: none"> <li>▪ Apple Pay;</li> <li>▪ Google Pay;</li> <li>▪ Samsung Pay;</li> <li>▪ Garmin Pay.</li> </ul>	(Roggeveen & Sethuraman, 2020)
Purchase stage	Scan and Go	This technology allows the client to scan their items with a mobile app during their journey through store, and in the end cut time in lines by also paying through the app.	<ul style="list-style-type: none"> <li>▪ Scan, Bag, Go by Kroger;</li> <li>▪ Scan and Go by Walmart;</li> <li>▪ Pingo Doce &amp; Go allow users to register products not only by using phones camera but by proximity using NFC communication.</li> </ul>	(Grewal et al., 2020; Inman & Nikolova, 2017; Maria Salgueiro, 2019)
Purchase stage	Just Walk Out Shopping	This technology is an upgrade of Scan and Go, introduced by Amazon in their own stores, and it allows the user to leave the store after picking their groceries since he is automatically charged in its Amazon account. It pairs sensors, with computer vision technology and deep learning algorithms to make this possible.	<ul style="list-style-type: none"> <li>▪ Amazon Go Grocery;</li> <li>▪ Amazon Go stores offer ready to eat meals;</li> <li>▪ Continente Labs.</li> </ul>	(Filipe Pacheco, 2021; Nick Statt, 2020; Polacco & Backes, 2018)

## 2.2. INTERNET OF THINGS

Internet of Things emerged as a solution to connect physical “things” in order to ease the comprehension and processing of the physical environment through information systems. Therefore, Internet of Things can be defined as an assortment of technologies that enables the interconnection between physical items through the use of sensors and actuators, fully connected to the Internet (Atzori et al., 2010; Dijkman et al., 2015). There are three main visions that defined IoT, according Atzori, Iera & Morabito (2010): things-oriented, Internet-oriented and semantic-oriented (Figure 2.3).

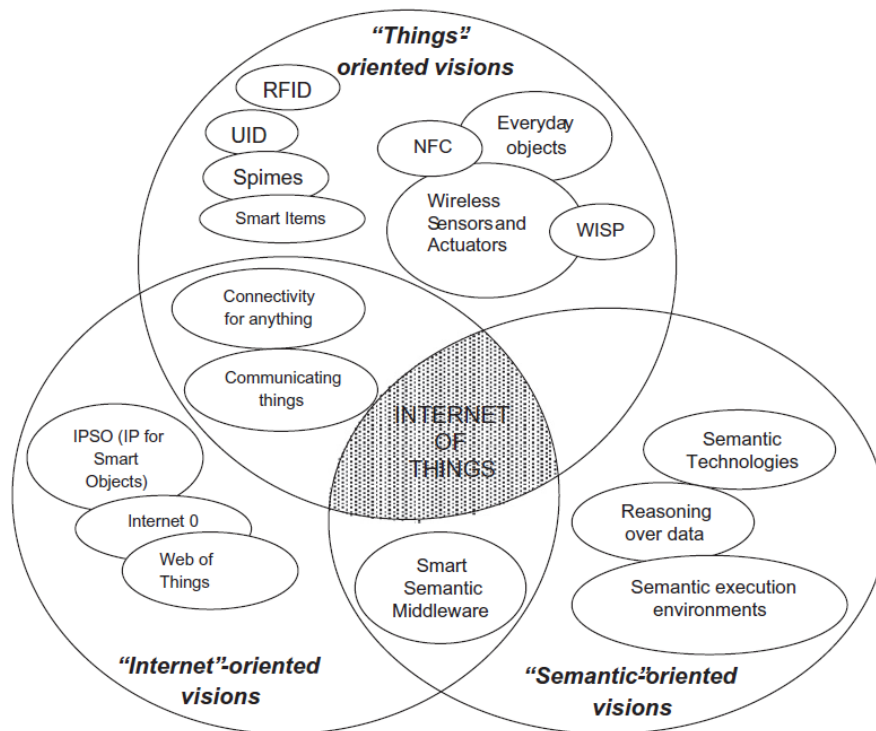


Figure 2.3 – “Internet of Things” paradigm as a result of the convergence of different visions (Atzori et al., 2010, p. 2789)

The first vision, **things oriented (sensors)**, respects the physical devices that tie the physical environment with digital one. When IoT concept started to disrupt, things were only associated to RFID tags which are still distinguished as the foremost technology due to its low price and maturity degree. However, the concept seized a wider perspective defining things or objects as collection of technologies not only capable of identifying the object such as RFID and uID (Ubiquitous Identifier), but also capable of tracing and addressing objects, as NFC (Near Field Communications) and WSAAN (Wireless Sensors And Actuators Network) (Abdmeziem & Tandjaoui, 2014) (Table 2.4).

Table 2.4 – Objects of IoT

Object	Concept
<b>RFID</b>	<p>Radio-Frequency Identification tags are used identify items, to which they are attached, through radio waves. These tags transmit their ID and receive signal for RIFD readers nearby.</p> <ul style="list-style-type: none"> <li>▪ Passive RFID tags are powered through the radio signal received from RFID readers nearby.</li> <li>▪ Semi-passive RFID tags include a battery that is powered through the radio signal received from RFID readers nearby.</li> <li>▪ Active RFID tags include a battery that power their ID transmission (Atzori et al., 2010).</li> </ul>
<b>uID</b>	<p>Ubiquitous Identification is an architecture focus on identifying and tracing objects by assigning them ucode – Ubiquitous Identifiers (Sakamura, 2006).</p>
<b>Spimes</b>	<p>Neologisms coined by Bruce Sterling (2005) that are defined as “manufactured objects whose informational support is so overwhelmingly extensive and rich that they are regarded as material instantiations (...) They are fabricated by digital means, and precisely tracked through space and time throughout their earthly sojourn.” (Sterling, 2005, p. 13), hence its denomination results on the union of the words “space” and “time”.</p>
<b>Smart Items</b>	<p>Smart Items are variety of sensors that not only are capable to process and communicate data but also entail other capabilities such as decision making as they act autonomously by being responsive to the environment (Atzori et al., 2010).</p>
<b>NFC</b>	<p>Near Field Communications technology regards a “set of protocols for low range and bidirectional communications”(Atzori et al., 2010, p. 2798).</p>
<b>WSAN</b>	<p>Wireless sensors are small units capable of sense, process and communicate data in short distances. The value of this elements relies in their performance combined working as sensor network (Akyildiz et al., 2002).</p>
<b>WISP</b>	<p>Wireless Identification and Sensing Platform is a wireless, battery-free programable RFID sensor that is read by standard UHF RFID sensors (Yeager et al., 2017).</p>

The second vision, **Internet oriented (the middleware)**, focuses on the infrastructures available that allow the connection between both environments, hence this vision regards IoT’s connectivity. IPSO stands for IP for Smart Objects and it is a result of an alliance of companies that endorse the adaptation of Internet Protocols (IPs) architecture for connecting “things” worldwide (Atzori et al., 2010). Likewise, Internet 0 approach presented by Raffi Krikorian (2004) in his master thesis supports IP simplification in order any device

can be connected without an intermediary but by taking advantage of a mature networking standard.

Finally, the third vision, **semantic oriented (the knowledge)**, emphasizes the growing number of networked devices and consequently the data collected. In order to make sense of the enormous amount of data and to face challenges ahead, IoT is supported by semantic technologies in order to organize and add context to the different types of data collected to extract useful knowledge (Atzori et al., 2010; Singh et al., 2014).

Hence, to appropriate each field needs, there are various types of sensors in the market to react to different types of signals or stimuli. These are classified accordingly the actions that need to be measured (Fraden, 2010). Table 2.5 provides a brief classification of sensors and describes each type.

Table 2.5 – Type of Sensors (Holdowsky et al., 2014, p. 7)

Sensor types	Sensor description	Examples
<b>Position</b>	A position sensor measures the position of an object; the position measurement can be either in absolute terms (absolute position sensor) or in relative terms (displacement sensor). Position sensors can be linear, angular, or multi-axis.	Potentiometer, inclinometer, proximity sensor
<b>Occupancy and motion</b>	Occupancy sensors detect the presence of people and animals in a surveillance area, while motion sensors detect movement of people and objects. The difference between the two is that occupancy sensors will generate a signal even when a person is stationary, while a motion sensor will not.	Electric eye, RADAR
<b>Velocity and acceleration</b>	Velocity (speed of motion) sensors may be linear or angular, indicating how fast an object moves along a straight line or how fast it rotates. Acceleration sensors measure changes in velocity.	Accelerometer, gyroscope
<b>Force</b>	Force sensors detect whether a physical force is applied and whether the magnitude of force is beyond a threshold.	Force gauge, viscometer, tactile sensor (touch sensor)
<b>Pressure</b>	Pressure sensors are related to force sensors and measure the force applied by liquids or gases. Pressure is measured in terms of force per unit area.	Barometer, bourdon gauge, piezometer
<b>Flow</b>	Flow sensors detect the rate of fluid flow. They measure the volume (mass flow) or rate (flow	Anemometer, mass flow sensor, water

	velocity) of fluid that has passed through a system in a given period of time.	meter
<b>Acoustic</b>	Acoustic sensors measure sound levels and convert that information into digital or analog data signals.	Microphone, geophone, hydrophone
<b>Humidity</b>	Humidity sensors detect humidity (amount of water vapor) in the air or a mass. Humidity levels can be measured in various ways: absolute humidity, relative humidity, mass ratio, and so on.	Hygrometer, humistor, soil moisture sensor
<b>Light</b>	Light sensors detect the presence of light (visible or invisible).	Infrared sensor, photodetector, flame detector
<b>Radiation</b>	Radiation sensors detect radiations in the environment. Radiation can be sensed by scintillating or ionization detection.	Geiger–Müller counter, scintillator, neutron
<b>Temperature</b>	Temperature sensors measure the amount of heat or cold that is present in a system. They can be broadly of two types: contact and non-contact. Contact temperature sensors need to be in physical contact with the object being sensed. Non-contact sensors do not need physical contact, as they measure temperature through convection and radiation.	Thermometer, calorimeter, temperature gauge
<b>Chemical</b>	Chemical sensors measure the concentration of chemicals in a system. When subjected to a mix of chemicals, chemical sensors are typically selective for a target type of chemical (for example, a CO <sub>2</sub> sensor senses only carbon dioxide).	Breathalyzer, olfactometer, smoke detector
<b>Biosensors</b>	Biosensors detect various biological elements such as organisms, tissues, cells, enzymes, antibodies, and nucleic acids.	Blood glucose biosensor, pulse oximetry, electrocardiograph.

Alongside IoT acceptance, considerable literature regarding its integration in business models has appeared (Chan, 2015; Dijkman et al., 2015; Glova et al., 2014; Haller & Magerkurth, 2011; Ju et al., 2016; Liu & Jia, 2010). Haller, Karnouskos & Schroth (2009) stated that the implementation of smart items results on a more stable and better performance business activity, that consequently can generate new profit inflows. Through

the incorporation of these devices into business strategies, edge processing, i.e., the processing and decision-making functions embed in smart items, triggered the decentralization of the decision-making process.

The usage of IoT-enabled products allowed to further enhance the range of possibilities both for customer and enterprises. Even though the data generated by IoT-components increased significantly, concerns emerged regarding the **privacy** of the users. Privacy is a key restrictive element in IoT dissemination, its regulations vary according to different cultures from one country to another. Moreover, IoT differs significantly in the way it collects data, since it is not dependent from active use, and the user whose data is being recorded should decide if he allows it. This is hard to achieve because if an individual enters a place equipped with sensors, he cannot control what data is being collected (Ten Bok, 2016). Also, security fails may also risk private information since “out of date IoT products are vulnerable to critical security or privacy threats, putting the consumers’ sensitive data at risk.” Also, security fails may also risk the privacy of the information since “out of date IoT products are vulnerable to critical security or privacy threats, putting the consumers’ sensitive data at risk.” (Khan et al., 2018, p. 1) .

Furthermore, questions rise regarding the **reaction of the customers** themselves upon the usage of these types of equipment. Ten Bok (2016) refers that privacy and security breaches might lead to lack of trust in the devices, while Roy (2018) findings express the necessity to offer superior functionalities compared to previous technology used, that is simultaneously user-friendly. Upon the equation of implementing IoT-enabled equipment the customer variable is held with high regard from the retailer’s perspective. The major factors taken into consideration by retailers mostly rely in expected revenue. Since the customer perspective cannot be directly measured, this factor is “implicitly assumed to be positive” (Inman & Nikolova, 2017, p. 7). Nevertheless, recent data breaches pose a difficult threat towards attaining the desired reaction. For example, the 2013 data breach in Target resulted in a leakage of over 40 million households credit card information. In the same year Home Depot (56 million credit card accounts) and Nieman Marcus (1 million credit card accounts) suffered similar breaches. Situations like these lead to a loss of trust from the customers and consequently to lower activity.

**Employee’s reaction** and acceptance is another factor that should be considered as their lack of cooperation may cause retailers to lose the upper hand that IoT is supposed to deliver. Some types of worker might be less necessary with IoT introduction, hence is important that employees learn about the technology in order to trust it, without feeling replaced (Roy et al., 2018; Ten Bok, 2016).

Other concerns like **data processing and storage** can be a hassle for unprepared retailers. “The average retailer is not ready yet to deal with all this data” (Ten Bok, 2016, p. 9), and only a few would provide enough data storage due to the massive data generated by IoT (Lee & Lee, 2015).

The growing development of technology associated with the cost decrease of sensors allowed the proliferation of IoT solutions in different sectors of society. Multiple segments improved their performance by implementing of IoT, such as: automotive, logistic, healthcare, among others. Smart technologies brought a new dynamics to the customer experience which retailers need to explore to acquire new clients and improve retention (Foroudi et al., 2018).

One of the many direct usages of IoT was performed by Ralph Lauren. In order to further enhance their product capabilities, sensors were introduced to the PoloTech Shirt in 2014. These generated data regarding the user's movement, heart and breathing statistics. The data generated is then transmitted to the app available on iTunes. Basically "the shirt itself is effectively one big sensor gathering real-time data" (Marr, 2016, p. 197). Even though at the time the concept was generated it was on early stages of development, it allowed to understand public interest towards these new areas. Since then, many wearables got into the market, like smart watches that allow to monitor physical activity, vitals, and even make contactless payments, smart shoes to track running session or even smart glasses. Many brands took a chance on these devices like Samsung, Huawei, Xiaomi, Apple, Google among others. Glass by Google are smart glasses that are being used by many companies to make their operations more efficient. This device displays instructions and critical information, while the worker is hands-free and therefore, able to keep performing other tasks. DB Schenker and DHL use Glass to deliver instructions to the employees regarding the order they are picking, therefore making the process much faster (Google, n.d.).

Following the same line of action, **automotive** sector further focuses on data-centric approaches to extract the highest amount of data available. In specific sectors, such as automotive racing, time is an essential factor. In order to extract the maximum potential from vehicles, Lotus implemented nearly 200 sensors which range from tyre pressure and temperatures to g-forces obtained and engine related metrics. The data collected throughout the different sessions in a racing weekend is analysed and given to models to predict car behaviour and consequently define different strategies (Marr, 2016). In Italy, Trenitalia, a train service operator, implemented IoT into the business to take full advantage of the longevity of trains' components. To achieve this, the company installed sensors in its trains to gather real-time data on the components condition, that data is sent to a cloud to perform almost real-time analytics. This implementation allowed Trenitalia to perform reactive maintenance and, therefore, reduce the number of maintenance events without risking security (Gartner, 2017).

**Agriculture** is solid sector in every country, providing the basis of development for people. The usage and development of sensors allowed to introduce IoT into this sector, to further enhance results. John Deere decided to take one step further into providing a solid experience to their customers. By placing sensors into the machinery sold to farmers and

providing a platform to use for analysis, the company generated the possibility for their customers to understand how different situations can affect production. This methodology generated intense shockwaves, since it allowed to generate a community in which data and information are shared, so that all farmers can obtain the best possible results (Marr, 2016).

IoT delivered many benefits in **healthcare** as well from controlling patients' medical conditions in real time, tracking newborns in a hospital to monitoring blood blanks and medication routes (Sultana, 2018). Gergely Vértés at the University of California, Berkeley, led a project called SeizelT. This device monitors brain activity for people with epilepsy and allows to detect seizures, in order patients can receive the right treatment in time (IMEC.ICON, n.d.). Proteu Digital Health created a pill with a digestible sensor that, alongside a skin patch sensor, allows to track if patients are taking their meds (Minteer, 2017). In addition, IoT also helps in fighting fraud by tracking drugs with RFID tags in the pharmaceutical industry (Sultana, 2018).

Regarding people's daily life, IoT entered their houses to deliver **connected houses** through appliances (e.g. robot vacuum cleaners), lighting systems, climate control systems, entertainment devices, house security devices, and other IoT-base products that allow user to connect with these items through apps or voice assistant devices, and provide automation and interactions in new ways (Figure 2.4) (Gregory, 2015).

As described in this section, IoT has been implemented under different domains to monitor different metrics and optimized businesses.

Table 2.6 summarizes this section by presenting several settings where IoT is being implemented and generating value according to the McKinsey Institute report.

Regarding the main topic of this research, Internet of Things as also made its way into **retail** businesses from customers' houses to their local stores where smart devices can be found right around the aisle. From RFID tags to track products to smart fitting rooms that create a more interactive customer experience. Amazon, as previously mentioned, has implemented successfully IoT into their stores, under the chain Amazon Go and Amazon Go Groceries using sensors and computer vision to deliver convenience as the user can collect its necessities and walk out the store without any pay stop. Mango also decided to implement IoT in their physical stores to dynamize customer experience. Smart fitting rooms can be used in the flagship store in Lisbon that allows the customer to connect with store employees to ask for help (Beth Osborne, 2018). There are many other examples IoT application inside brick-and-mortar stores, Figure 2.5 present some of them. Furthermore, the dissemination of IoT through retail supported the concept of IoT-commerce as it allowed customers to shop from their connected smart appliances for example, as it is explained in the sections 2.1 and 2.1.1.

IoT revolutionized many sectors by providing real-time data, consequently allowing real-time analytics, and therefore assisting the decision-making process in real time.

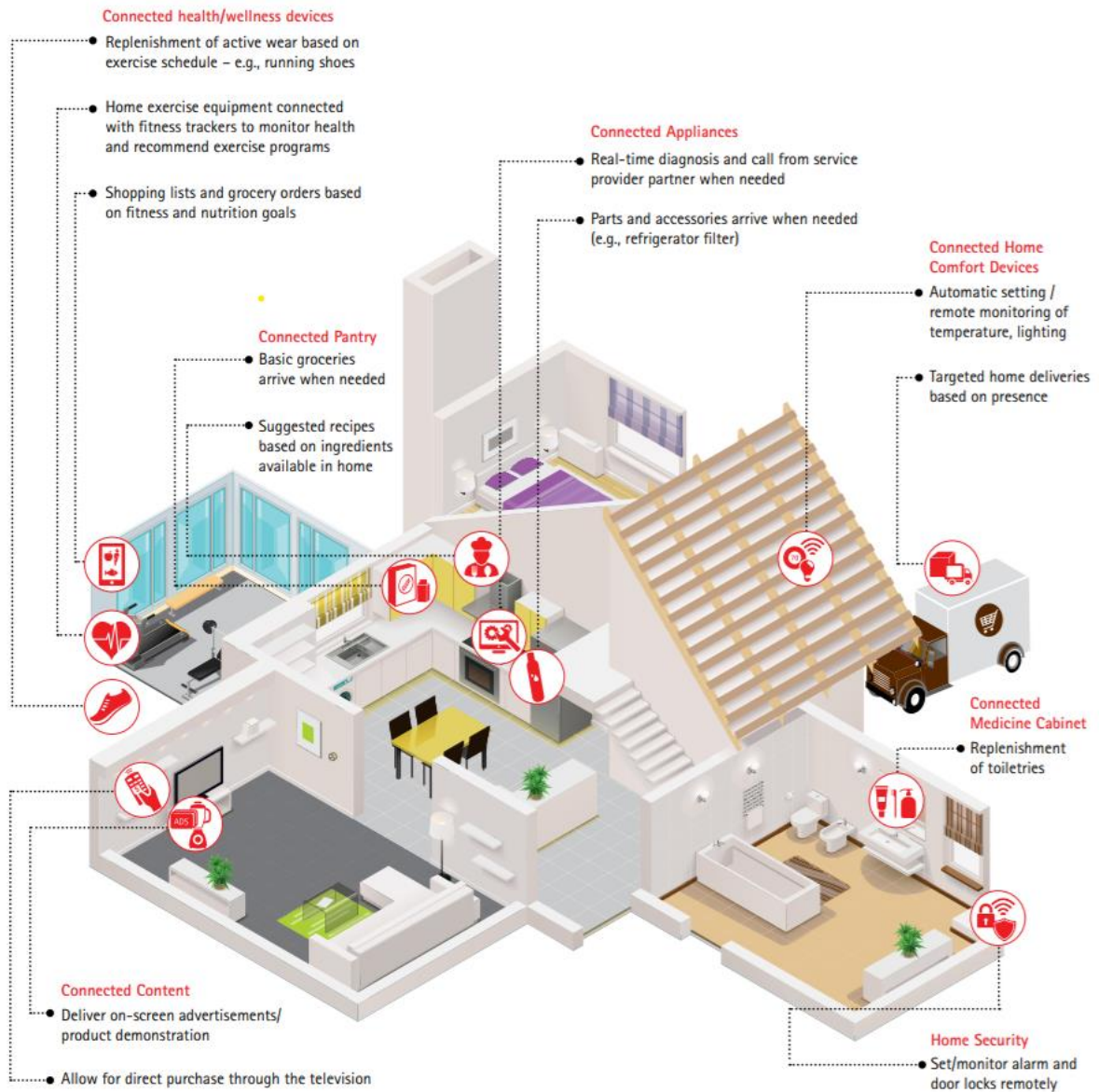


Figure 2.4 – The connected house (Gregory, 2015, p. 5)

Table 2.6 – Examples of settings where IoT creates value (McKinsey Global Institute, 2015, p. 3)

<b>Setting</b>	<b>Description</b>	<b>Examples</b>
<b>Human</b>	Devices attached to or inside the human body	Devices (wearables and ingestibles) to monitor and maintain human health and wellness; disease management, increased fitness, higher productivity
<b>Home</b>	Buildings where people live	Home controllers and security systems
<b>Retail Environments</b>	Spaces where consumers engage in commerce	Stores, banks, restaurants, arenas—anywhere consumers consider and buy; self-checkout, in-store offers, inventory optimization
<b>Offices</b>	Spaces where knowledge workers work	Energy management and security in office buildings; improved productivity, including for mobile employees
<b>Factories</b>	Standardized production environments	Places with repetitive work routines, including hospitals and farms; operating efficiencies, optimizing equipment use and inventory
<b>Worksites</b>	Custom production environments	Mining, oil and gas, construction; operating efficiencies, predictive maintenance, health and safety
<b>Vehicles</b>	Systems inside moving vehicles	Vehicles including cars, trucks, ships, aircraft, and trains; condition- based maintenance, usage-based design, pre-sales analytics
<b>Cities</b>	Urban environments	Public spaces and infrastructure in urban settings; adaptive traffic control, smart meters, environmental monitoring, resource management
<b>Outside</b>	Between urban environments (and outside other settings)	Outside uses include railroad tracks, autonomous vehicles (outside urban locations), and flight navigation; real-time routing, connected navigation, shipment tracking

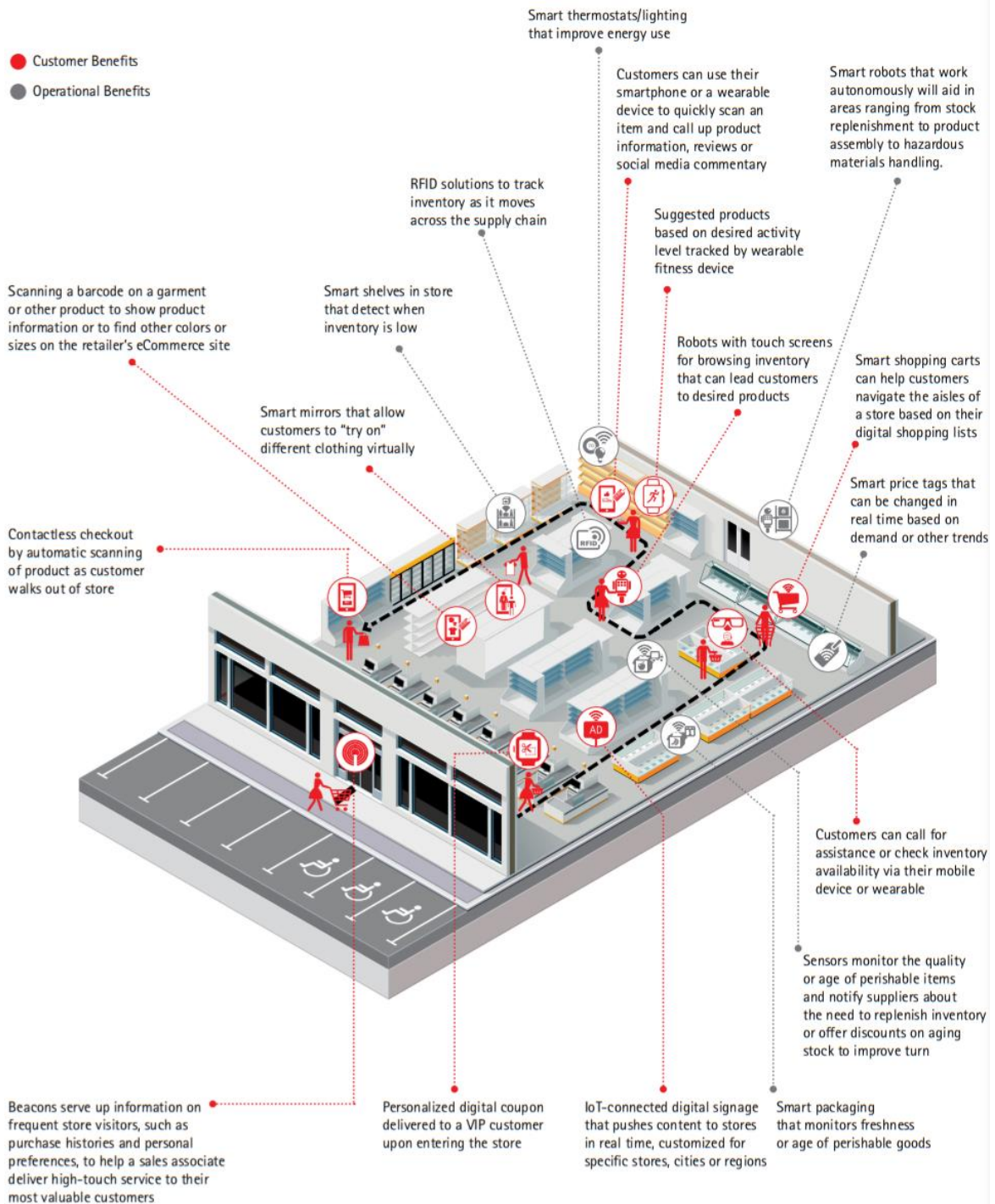


Figure 2.5 – The in-store experience of tomorrow (Gregory, 2015, p. 3)

### 2.3. ANALYTICS

Making use of data to make well-informed decisions is not something new, but the concept of business analytics appeared in the mid-1950s with new techniques that surpassed human capacity alone to gather data, uncover patterns and extract useful information. Business analytics is not more than “how a business arrives at an optimal or realistic decision based on existing data” (Attaran & Attaran, 2018, p. 19). Dursun Delen (2019) gives a more detailed definition of analytics as “the variety of methods, technologies, and associated tools used for creation of new knowledge/insight to solve complex problems and to make better and faster decisions”. Nevertheless, it was evolved over the years, as the volume of data was increasing, and its velocity of generation was getting quicker. Internet, social media, mobile devices, sensors, etc. all contributed to this massive change. Davenport identified three different eras in analytics evolution (Attaran & Attaran, 2018; Davenport, 2013a). Table 2.7 summarizes and compares the three milestones in this evolution.

From 1950s to mid-2000s took place the first analytics era, **Analytics 1.0**, the era of Business Intelligence. The focus during this time was to extract a deep understanding of distinct business occurrences the company had faced in the past. It was the first step to support with real facts the decision-making process made until then based on intuition only. The development of computing capabilities was an underlying circumstance to this era evolution, from data warehouses for collecting data to business intelligence tools for querying and reporting information like OLAP cubes. The data was structured and datasets at this time were small and generated at a relative low pace by internal companies’ systems. Analysis would take months and most of the time was spent in data preparation. The application of descriptive analytics and reporting practices to make sense of historical data was the main concern and predictive analytics were out of the picture (Davenport, 2013a).

**Analytics 2.0** was kicked by the concept of Big Data. In general terms, Big Data refers to a high volume of data which surpasses the capability of traditional tools to collect, store and analyse data. However, Big Data is more than its volume, according to Russom (2011), velocity and variety are also important features of Big Data, since there are different types of data created and its generation speed its faster than traditional tools processing ability. These attributes are known as the 3 Vs of Big Data (Figure 2.6).

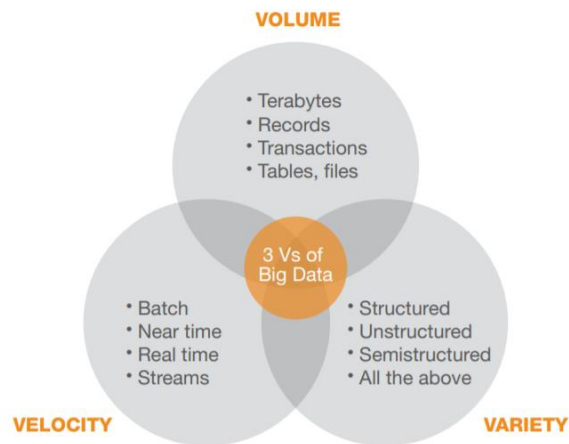


Figure 2.6 – The 3 Vs of Big Data (Russom, 2011, p. 6)

Big Data analytics became the sole focus of analytics 2.0 to exploit its full potential. This new data was not strictly generated from internal sources anymore but was also extracted from the Internet and various sensors. The main goal of this period was not using data to exclusively assist internal decisions, but to serve customers directly. Online companies started to introduce data-based products like search and recommendation engines, for example, Google with AdSense, Maps and Scholar, Facebook with People You May Know, or LinkedIn with Jobs You May be Interest In. The idea of sharing data freely started to become a reality with public data projects like the human genome project. Big Data was hard to grasp, hence many new technologies were created in the attempt to process it. Hadoop became popular on this matter for being an open-source software that uses distributed computing for batch processing, since particular features of Big Data would not allow these data to be processed on a single server. Furthermore, to collect the unstructured data generate, NoSQL databases became popular due to their flexibility since they are free of relational databases rules. Machine learning techniques were also used to generate models and follow along the fast pace of data creation (Davenport, 2013a, 2013b).

The third and last era, **Analytics 3.0**, is marked by the entrance of other traditional companies in the creation products and services using data. The data economy is open virtually to every industry. This period is all about the blending of Analytics 1.0 and Analytics 2.0, small data and Big Data are combined to get better insight and there is a steady boost of speed of analytics. Regarding the technology used, the goal is an integration of what those companies were already utilizing with Big Data analytics tools. Analytics are being integrated into customer-oriented products but also into operational systems to automate decision-making process using scoring models and analytics-based rules. At this point, all types of analytics are being used, descriptive, predictive, and prescriptive, being the last one under the spotlight. UPS is one of the companies that is applying this by integrating the ORION (On-Road Integrated Optimization and Navigation) system, that uses optimization algorithms alongside telematic devices and online map data to change delivery routes when needed and, therefore, optimize their itineraries (Davenport, 2013a, 2013b).

Table 2.7 – Evolution of Analytics (Davenport, 2013a, 2013b)

	<b>Analytics 1.0</b> <b>(1950s to mid-2000s)</b>	<b>Analytics 2.0</b> <b>(mid-2000s to 2015)</b>	<b>Analytics 3.0</b> <b>(2015-Today)</b>
<b>Analytics type</b>	5% predictive, prescriptive 95% reporting, descriptive	5% predictive, prescriptive 95% reporting, descriptive (visual)	90%+ predictive, prescriptive Reporting automated commodity
<b>Data sources</b>	Small and structured from internal systems	Complex, large and unstructured from internal and external systems	Seamless combination between small data and Big Data
<b>Cycle time</b>	Months	An insight a week	Millions of insights per second
<b>Context</b>	Companies want to gain deep understanding of important business phenomena. They are focus on the past.	The main concern is to deal with Big Data through new analytical and computational capabilities to harness more insight and deliver data-based product to customers.	The era of data economy where analytics is a core capability employed by every industry.
<b>Technology</b>	Data warehouse and data mart Standalone spreadsheets OLAP cubes On-premise servers ETL tools	NoSQL databases Data-based products Hadoop Machine Learning In-memory analytics In-database	Hybrid technology Environments Hadoop on commodity server clusters Cloud technologies Data warehouses

### 2.3.1. Customer Analytics

In the retail sector, as customer centricity became a reality, capturing customer-related knowledge turned out to be a vital step so that retailers could create long lasting relationships with their clients. Earlier in time, this was achieved through surveys targeting clients. Later on, customer analytics also became the focus of many studies (Davenport, 2006; Erevelles et al., 2016; Germann et al., 2014; Yerpude & Singhal, 2019). Understanding customers, predict their needs and deliver a desired experience can turn out be a major competitive advantage for retailers and brands. Each interaction with the organization

weights on customer experience evaluation and can be decisive for future engagement. Data-driven companies have been leveraging technological innovation to extract customer behaviour data and generate insight and consequently customer engagement. Retailers can adapt and redefine their price strategy, different client profiles, stores design and personalize promotions as well as products design (Yerpude & Singhal, 2019).

According to Hossain (2020, p. 3), customer analytics is the “advanced technology embedded process that assists in extracting insight about customer behaviour from both online/mobile and offline channels to predict offerings and enhance the adaptive capacity to formulate marketing strategies”. Alternatively, Jessica Ekholm and Melissa Davis (2021) define it as “the enabling data and analytics technology used to segment customers for acquisition, growth and retention, and to develop targeted marketing, sales and service interactions to improve the customer experience”. For the purpose of this dissertation and to line up the variety of definitions, **customer analytics** shall be defined as the process to extract insight from customer-related data to develop a detailed perception of a customer in order to add value across the customer life cycle and to improve customer experience (Figure 2.7).

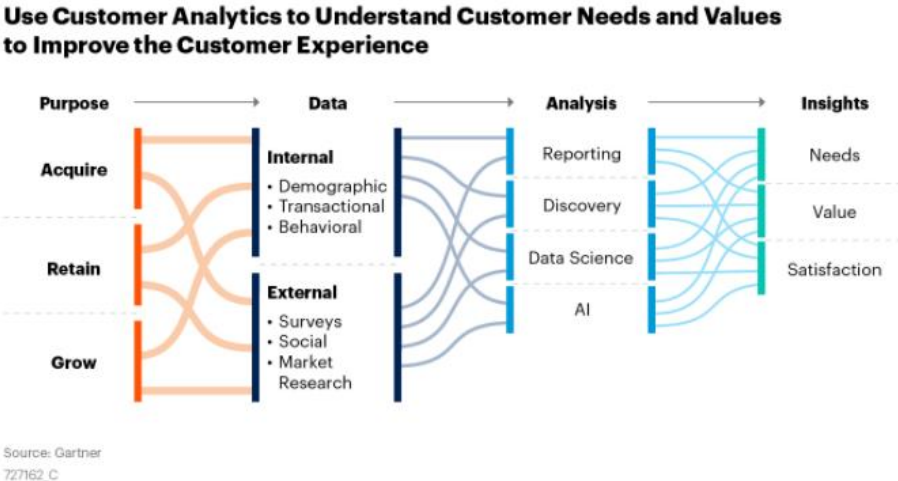


Figure 2.7 – Customer analytics (Ekholm & Davis, 2021)

Commonly analytics techniques are classified in three major categories as previously mentioned: descriptive, predictive, and prescriptive; and these can also be applied to customer analytics according to the business goals. Table 2.8 presents their differences and examples of outcomes regarding customer behaviour. Inside each category, there is an array of methods to tackle every business decision related to customer behaviour.

Sridharan (2014), also defends that to leverage customer analytics at its full potential it is important to understand their dependencies, how they boost each other, for example customer lifecycle value can be used in segmentation, and how they can develop truthfulness if used together. Table 2.9 presents some examples of customers analytics as

well as their description and category and Figure 2.8 portrays how they are interrelated within customer lifecycle.

Table 2.8 – Major three types of analytics (Adi et al., 2020; Nikoletta Bika, 2020)

	<b>Descriptive Analytics</b>	<b>Predictive Analytics</b>	<b>Prescriptive Analytics</b>
<b>Goal</b>	Extract insight from historical data.	Discover patterns through historical data in order to predict future outcomes.	Understand prediction and generate insight on possible outcomes providing suggestions on how to act.
<b>Question</b>	What customers have been doing	What is likely customer will be doing	How to react to the expected customer behaviour
<b>Customer analytics outcome example</b>	30 percent of customers returned product X within a month of purchase	In the fall of 2020, purchases of product X are expected to decline	Social media campaigns and online ads can increase sales of product X by 25 percent
<b>Analytical techniques</b>	Data modelling Reporting Visualization Dashboards	Data mining Predictive modelling Neural Network Analysis	Machine learning Heuristics Optimization Simulation

Table 2.9 – Examples of customer analytics (Sridharan, 2014)

Analytical Method	Commonly used metrics or techniques	Description	Type of Analytics	Customer Lifecycle stage
<b>Behavioural customer segmentation</b>	<ul style="list-style-type: none"> <li>▪ Cluster analysis</li> <li>▪ Factor analysis</li> </ul>	It uses customer behaviour data to create smaller, homogeneous groups of customers.	Descriptive	Acquisition
<b>Customer look-alike targeting</b>	–	It identifies potential clients identical to the profitable existing customers with the intent to target the ones most likely to convert.	Descriptive	Acquisition
<b>Customer lifetime value analysis</b>	Metric	It intends to define customers monetary value to a company during their relationship.	Descriptive	Acquisition
<b>Customer propensity models</b>	Logistic regression	It determines the likelihood of a customer behaving in a certain way, like buying something or answering a campaign.	Predictive	Retention
<b>Churn and attrition models</b>	<ul style="list-style-type: none"> <li>▪ Logistic regression</li> <li>▪ Survival analysis</li> <li>▪ Hazard analysis</li> </ul>	It helps to pinpoint clients most likely to leave and when that is most likely happen.	Predictive	Retention
<b>Social network analysis</b>	Statistical graph analysis	It applies to networks of customers in order to discover complex connection patterns of affinity and influence. It focusses on group behaviour instead of individual customer behaviour.	Descriptive	Retention
<b>Sentiment analysis</b>	<ul style="list-style-type: none"> <li>▪ Text analytics</li> <li>▪ Natural language processing</li> </ul>	It intends to uncover customers feelings about a brand, a service or specific product from unstructured data of different sources	Descriptive	Retention

		like social media comments (social listening), surveys, call centre transcripts, etc.		
<b>Customer location analysis</b>	Visual mapping	It pinpoints customer location through GPS, beacons inside the stores, etc. It is useful to trace customer movements and define which are the better places to deliver certain experiences, for example location-based marketing.	Descriptive	Retention
<b>Customer device usage analysis</b>	–	It focusses on data generated from devices used by customers, like wearables and smartphones. It aims to uncover how customers use them.	Descriptive	Retention
<b>Customer satisfaction analysis</b>	Perception-based metrics	It is nothing more than a comparison between customer expectations and opinions regarding specific experiences. This analysis uses all types of voice of customer data.	Descriptive	Retention
<b>Customer engagement analysis</b>	<p>Metrics:</p> <ul style="list-style-type: none"> <li>▪ Website engagement</li> <li>▪ Service interactions</li> <li>▪ Content consumption</li> <li>▪ Registrations</li> </ul>	It uncovers which type and level of engagement customers are having and the drivers that led to it.	Descriptive	Retention
<b>Customer journey and path analysis</b>	<ul style="list-style-type: none"> <li>▪ Sequence mining</li> <li>▪ Time-series analysis</li> <li>▪ Path to conversion</li> </ul>	It aims to discover patterns in the customer journey. It can be helpful to discover the preferred path and trigger real-time actions when the customer deviates from it.	Descriptive	Retention

<b>Cross-sell/up-sell models</b>	Market-basket analysis	It describes the connection between products to assess which combinations can be more profitable. Usually used to push a portfolio of product, to create new bundles and to increase wallet share.	Descriptive	Growth
<b>Recommendation analysis</b>	<ul style="list-style-type: none"> <li>▪ Collaborative filtering</li> <li>▪ Content-based filtering</li> </ul>	It aims to suggest products based on customers' preferences.	Predictive	Growth
<b>Next-best-action models</b>	–	This model predicts what situation or product deal will trigger a successive preferred action.	Prescriptive	Growth

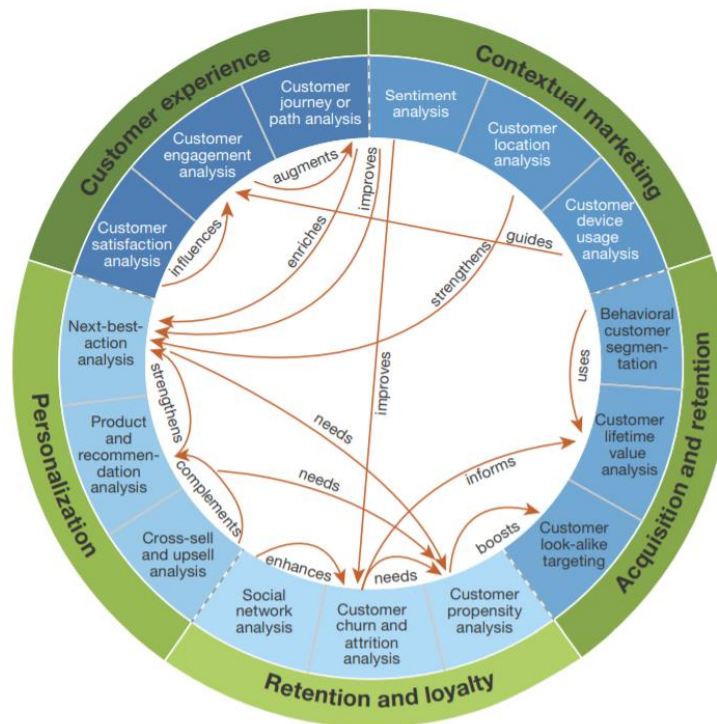


Figure 2.8 – Customer analytics aligned with customer lifecycle and their dependencies (Sridharan, 2014)

### 2.3.2. IoT and Customer Analytics

Prior to IoT introduction, the data collected on customer behaviour in a physical environment was limited to purchase history. The huge technological growth in terms of data collection, storage and the expansion of data structures add complexity but also a new opportunity to take advantage. With the rise of the digital world, a new data source to track and understand the online customer behaviour was introduced (Bijmolt et al., 2010).

Later, new data was brought to the table in the attempt of unifying digital and physical worlds. IoT provoked a fast-growing flow of data being generated through different touch points. In what regards retail, for example, data is collected from loyalty cards, transactions, mobile apps, traffic counters, web activity, RFID tags, computer vision, etc. This would cause an expansion of Big Data boundaries: increasing volume, velocity, and variety. The explosion of structure and unstructured customer data create the opportunity and inevitably the necessity of exploiting this through analytics, the data-driven decision-making process. IoT expanded data availability and consequently the analytical capabilities, as massive amount of sensory data is being mined with advanced machine intelligence techniques (Adi et al., 2020; Yerpude & Singhal, 2019). It became possible to sense customers in physical stores, to know their journey inside the store, the time spent in each sector, face and body expressions, etc. Still, to achieve and to extract insights from IoT data, new infrastructures had to be adopted.

Adi et al. (2020) identify three types of infrastructure to deploy IoT analytics: cloud computing, edge computing and fog computing (Figure 2.9). Cloud computing allows a centralized data processing with servers spread in different facilities that connect to the Internet to collect, store, control, and process data. However, moving the massive data generated by IoT devices to the cloud would be costly and would need a high communication bandwidth. Therefore, edge computing defies this by allowing data processing near or embedded in IoT devices, i. e., at the edge of the network. This structure is better suited for low latency and real-time data processing needs. It has solutioned the bandwidth problem by pre-processing data prior sending it to the cloud. Finally, fog computing is very similar to edge computing, however it uses a LAN (Local Area Network) to enable processing near IoT devices while edge computing interfaces the IoT devices directly through embedded computing.

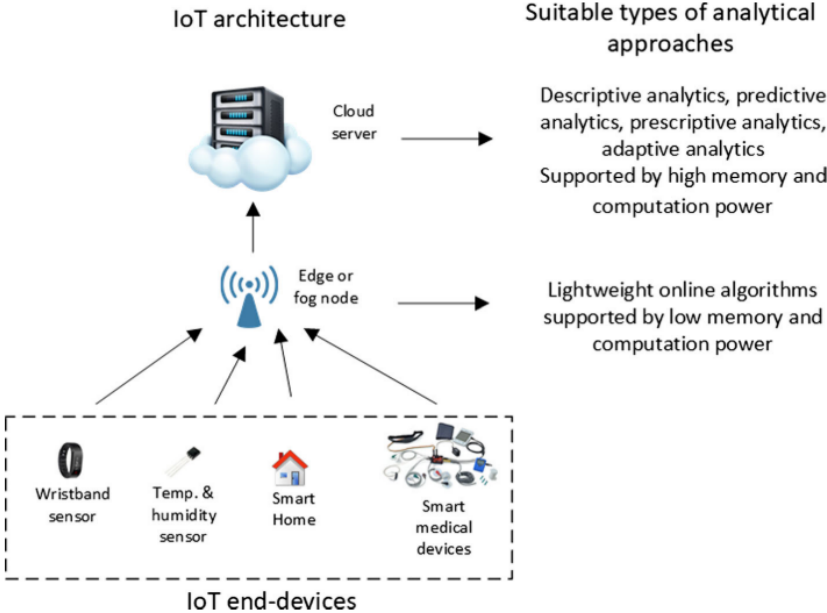


Figure 2.9 – IoT architecture and analytics (Adi et al., 2020)

In Malaysia, 10 Sephora stores are already leveraging this through strategically positioned axis cameras working along with video analytics provided by AllGoVision to gain better insight on traffic pattern and boost marketing operations (Kirkpatrick, 2020).

As it has been a constant reminder throughout this literature review, companies need to get the upper hand when it comes to technology to be ready and able to answer customers’ needs and expectations and consequently keep thriving. IoT not only brought a new dynamism to the customer experience with its novelties, but when combined with analytics the value added to the retail businesses increases greatly.

### 3. METHODOLOGY

This section aims to describe the research method selected that best fit the research questions previously proposed, in order to answer them properly.

The main goal of this research is to understand if and how retail companies are using IoT to its full potential in brick-and-mortar stores to impact customer engagement. More specifically, it aims to discover if retailers are combining IoT data and customer analytics to gain insight to better adjust their activities in order to improve customer engagement.

Considering this premise, the present dissertation was developed through a quantitative research method since it seeks “to identify and explain reality as it exists empirically” (Biddix et al., 2018, p. 298). The process is comprised by two stages to collect primary and secondary data. The first stage entailed the collection of secondary data that was used to set up the literature review in order to gain a better understanding about the main topics and the relationship between them. This data was collected from journals, academic articles, magazines, books, among others, and the databases used were b-on and ScienceDirect. The second stage included a survey research through cross-sectional survey design, since this methodology allows to collect data from a sample extracted from a specific population in a moment in time (Krosnick et al., 2013). Therefore, it allowed to collect information from retail companies at once regarding their IoT applications in their businesses for subsequent exploratory analysis. This survey was created on the online platform Qualtrics and distributed through the social network LinkedIn.

#### 3.1. QUESTIONNAIRE

This questionnaire aims to capture retailers’ perception regarding IoT usefulness, usage purpose within the company, challenges, and its impact on customer engagement. Considering this, the survey comprised 21 questions arranged in three sections: company identification and knowledge assessment of the respondent (1), IoT perception (2) and customer analytics perception (3). All the survey questions were carefully formulated to relate with the research objectives previously defined, Table 3.1 presents which questions associate to each research question and Table 3.2 reveals the questionnaire arrangement.

Group 1 includes some open-ended question to request specific information in order to identify the respondent and the company. Groups 2 and 3 consisted of close-ended questions to keep the results objective and precise. However, multiple choice questions had the option “Other” in case any of the options available would not fit the respondent answer. Likert scale questions were also employed with five levels between 1, “strongly disagree”, and 5, “strongly agree”.

The target population of this questionnaire consists of retail employees in companies operating in Portugal. The sample was gathered through the non-probabilistic convenience

sampling method due to its simplicity and affordability which allowed to gather 20 valid observations for the exploratory analysis.

This survey was available between March 29, 2021, and June 29, 2021.

Table 3.1 – Research question association to survey questions

Research questions	Research objectives	Survey questions
<b>(1)</b> How IoT implementation in brick-and-mortars stores is impacting customer engagement?	To assess how IoT potential is being applied in brick-and-mortar stores in order impact customer engagement.	2.1.
		2.2.
		2.5.
		2.6.
		3.4.
<b>(2)</b> Which sensors do retailers consider more effective to collect customer data inside stores?	To identify the most effective sensors for collecting relevant customer data inside a store.	2.3.
		2.4.
<b>(3)</b> Which type of customer analytics are being carried with the data collected?	To determine which type of analytics are being preferred to gather valuable information about customers.	3.1.
		3.2.
<b>(4)</b> How are insights gather being used to improve customer engagement?	To establish how the information collected is turning into actions to improve customer engagement.	3.3.

Table 3.2 – Questionnaire arrangement

Section	#	Question	References
1	1.1.	What is your company's name?	–
	1.2.	What is your title at your company?	–
	1.3.	How long has your company been in business (in years)?	–
	1.4.	Classify your retail business according to its main economic activity (based on CAE-Rev. 3).	(Instituto Nacional de Estadística, 2007)
	1.5.	In how many countries does your company operate?	–

	<b>1.6.</b>	What is your company's main location?	–
	<b>1.7.</b>	How many employees has your company (in units)?	–
	<b>1.8.</b>	What was your company's estimated annual revenue regarding the last fiscal year, in thousands of euros?	–
	<b>1.9.</b>	How many brick-and-mortar stores does your company own?	–
	<b>1.10.</b>	Please rate your level of expertise regarding IoT. <ul style="list-style-type: none"> <li>▪ (1) Not knowledgeable at all</li> <li>▪ (2) Slightly knowledgeable</li> <li>▪ (3) Moderately knowledgeable</li> <li>▪ (4) Very knowledgeable</li> <li>▪ (5) Extremely knowledgeable</li> </ul>	–
	<b>2.1.</b>	Is your company taking advantage of IoT or is taking steps towards it? <ul style="list-style-type: none"> <li>▪ (1) Yes</li> <li>▪ (2) No</li> <li>▪ (3) I do not know</li> </ul>	–
<b>2</b>	<b>2.2.</b>	How do you think your company's business can benefit from IoT implementation? <ul style="list-style-type: none"> <li>▪ (1) Labour saving</li> <li>▪ (2) Customer loyalty and retention</li> <li>▪ (3) Customer convenience</li> <li>▪ (4) Dynamic customer experience</li> <li>▪ (5) Secure better insight about customers inside brick-and-mortar stores</li> <li>▪ (6) Improve stock management</li> <li>▪ (7) Optimize staff schedule</li> <li>▪ (8) Other(s)</li> </ul>	(Goode, 2021; Inman & Nikolova, 2017; Pantano & Vannucci, 2019; Polacco & Backes, 2018; Roggeveen & Sethuraman, 2020)
	<b>2.3.</b>	Which IoT technologies have your company implemented so far inside physical stores? <ul style="list-style-type: none"> <li>▪ (1) Contactless Payment</li> <li>▪ (2) RFID tags</li> <li>▪ (3) Scan and Go (contactless checkout)</li> <li>▪ (4) Just Walk Out Shopping (contactless checkout)</li> <li>▪ (5) Interactive mirrors supported by RFID solutions</li> <li>▪ (6) Virtual trial room / showroom (with AR technology)</li> </ul>	(Goode, 2021; Inman & Nikolova, 2017; Pantano & Vannucci, 2019; Polacco & Backes, 2018; Roggeveen & Sethuraman, 2020)

- 
- (7) Robotic shopping assistant
  - (8) Smart cart
  - (9) Smart shelves
  - (10) In-store cameras and video analytics
  - (11) Geofencing
  - (12) Other(s)
- 

In your perception, which sensors can be more effective to gather customer behaviour data inside a store?

- 2.4.**
- (1) Position (potentiometer, inclinometer, proximity sensor)
  - (2) Occupancy and motion (electric eye, RADAR)
  - (3) Force / Pressure (piezoelectric sensor, touch sensor, weight sensors)
  - (4) Flow (anemometer, mass flow sensor, water meter)
  - (5) Acoustic (microphone, geophone, pickup) (Holdowsky et al., 2014)
  - (6) Humidity (hygrometer, soil moisture sensor)
  - (7) Light / Optical / Machine vision (infrared sensor, photodetector, flame detector)
  - (8) Radiation (Geiger–Müller counter, scintillator, neutron)
  - (9) Temperature (thermometer, calorimeter, temperature gauge)
  - (10) Chemical (Breathalyzer, olfactometer, smoke detector)
  - (11) Biosensors (blood glucose biosensor, pulse oximetry, electrocardiograph)
- 

The implementation of IoT impacted, or will, positively impact customer engagement in brick-and-mortar stores.

Express your level of agreement or disagreement with this statement.

**2.5.**

- (1) Strongly disagree
  - (2) Disagree
  - (3) Neutral
  - (4) Agree
  - (5) Strongly agree
-

What do you think are, or will be, the biggest challenge(s) of implementing IoT for your company?

- 2.6.**
- (1) Privacy
  - (2) Data storage and processing
  - (3) Internet scalability
  - (4) Data heterogeneity (ability to integrate many types of devices/services/technologies)
  - (5) Customer's attitude towards using IoT technology
  - (5) Employee's (store personal) attitude towards using IoT technology
  - (7) Misbehaving devices (false readings)
  - (8) Other(s)
- (Inman & Nikolova, 2017; Khan et al., 2018)

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Which customer data is being, or will be, extracted inside your company's stores through IoT?

- 3.1.**
- (1) Customer journey inside the store
  - (2) Door traffic (passersby)
  - (3) Foot traffic Number of returning customers
  - (4) Customer waiting time in line
  - (5) Number of times a product is chosen / tried
  - (6) Dwell time per store sector Attributes of products select
  - (7) Customer demographics
  - (8) Other(s)
- (Adi et al., 2020; Inman & Nikolova, 2017)

**3**

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What was, or will be, the main focus of customer analytics, following the IoT implementation in brick-and-mortar stores?

- 3.2.**
- (1) Understand customers behaviour inside stores (customer segmentation, customer journey mapping)
  - (2) Predict customers' future behaviour (demand forecasting, customer revisit prediction, churn prediction)
  - (3) Generate recommendation on how to face the predicted customers behaviour to accomplish the best result possible (optimizations, simulations, automate)
- (Adi et al., 2020)

pricing or assortment recommendations)

---

How is the information gathered being used, or will be used, to improve customer engagement?

- 3.3.**
- (1) Reorganize store layout
  - (2) Improve product placement
  - (3) Automate purchase recommendations
  - (4) Personalized promotions in line with customer needs
  - (5) Redefine up-selling and cross-selling strategies
  - (6) Redefine staff schedules and sector allocation
  - (7) Adjusting inventory levels to answer customer demands
  - (8) Adjust product assortment to customer preferences
  - (9) Adapt pricing strategy
  - (10) Other(s)
- (Inman & Nikolova, 2017; Sridharan, 2014)

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Customer behaviour data collected in store provided or will provide vital insight to boost customer engagement in brick-and-mortar stores.

Express your level of agreement or disagreement with this statement.

- 3.4.**
- (1) Strongly disagree
  - (2) Disagree
  - (3) Neutral
  - (4) Agree
  - (5) Strongly agree
-

## 4. RESULTS AND DISCUSSION

This chapter aims to interpret the results of the questionnaire conducted and their correlation to what was reviewed in the chapter 2.

### 4.1. COMPANY PROFILE

The sample studied was formed by 20 respondents with some knowledge on IoT, which was a restrictive aspect for going forward in the survey. The majority, 55% of the sample (11 respondents), considered themselves moderately knowledgeable on IoT (Figure 4.1).

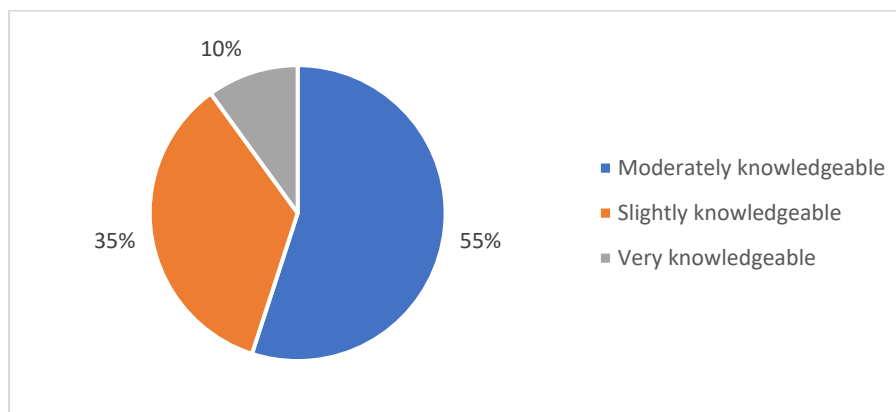


Figure 4.1 – Level of expertise regarding IoT of the respondents

Even though the majority of the companies assessed are based in **Portugal** (35%), the rest of the companies were distributed between other five different countries, namely France, Spain, Germany, USA and United Kingdom (Figure 4.2). In addition to that, their operations are spread across the world, 50% can reach 13 or more countries, yet 5 companies (25%) of the sample only operate in Portugal.

Variables like age, annual revenue, number of stores, number of employees and number of countries where the company operates allow to understand companies' dimension (Table 4.1). It was possible to determine that 50% of the companies have 20,500 employees or less, and that on average, the companies that make this sample have been active for 57 years. Nonetheless, the oldest company in the survey has been in business for 148 years. Regarding annual revenue and stores, the data is very dispersed, however it is feasible to say that 50% of the sample has not made more than 4.450 billion euros and do not own more 890 stores.

Finally, regarding their classification according to their core economic activity, it was possible to identify seven types of retail businesses which have their respective designations expressed in the Table 4.2. **Clothing stores** (35%) are predominant in the sample, followed by **supermarkets and hypermarkets** (25%).

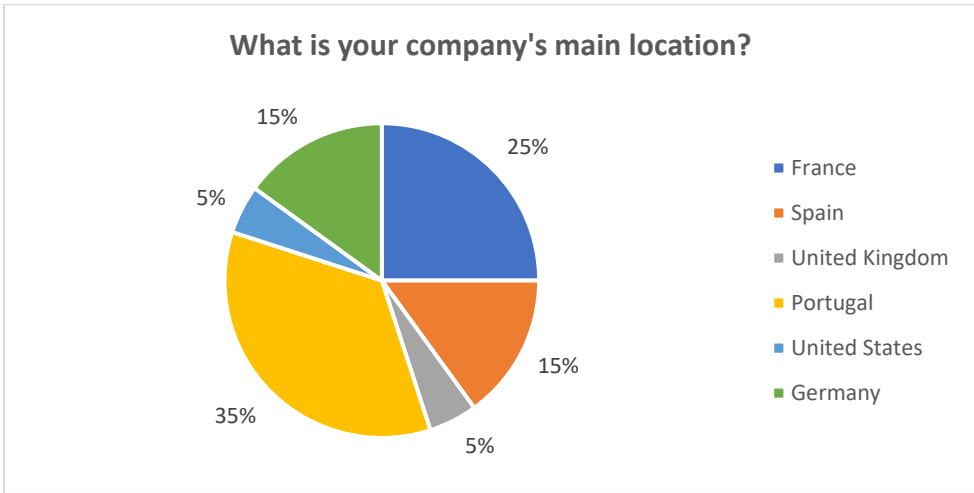


Figure 4.2 - Companies' main location distribution

Table 4.1 – Descriptive Statistics of variables related to the company identification

Variable	Mean	Standard Deviation	Minimum	Median	Maximum
AGE	57.15	34.69	20	46.5	148
ANNUAL_REVENUE	21440135	43727343	700	4450000	183000000
COUNTRIES_COUNT	35.20	44.56	1	12.5	124
EMPLOYEES	54167.80	79696.23	1	20500	315000
STORES	2377.50	4640.22	1	890	18700

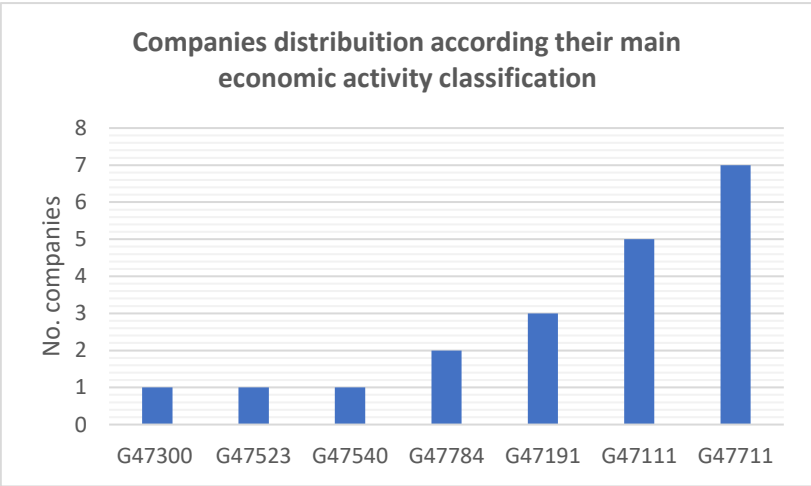


Figure 4.3 – Economy activity classifications of companies’ sample

Table 4.2 – Economic activities classification according to CAE-Rev.3 (Instituto Nacional de Estatística, 2007)

Nomenclature	Description
<b>G47111</b>	Retail trade in supermarkets and hypermarkets
<b>G47191</b>	Non-specialized retail trade, with no predominance of products
<b>G47300</b>	Retail trade of fuel for motor vehicles, in specialized establishments
<b>G47523</b>	Retail trade of DIY equipment, sanitary equipment, tiles, and similar materials in specialized establishments
<b>G47540</b>	Retail trade of home appliances, in specialized establishments
<b>G47711</b>	Retail trade of clothing for adults, in specialized stores
<b>G47784</b>	Retail trade of other new products, in specialized establishments

#### 4.2. IoT PERCEPTION

In the matter of IoT implementation half of the sample (50%) admitted that their companies are or will be leveraging IoT in the future (Figure 4.4). It was noticeable that companies based in Portugal had the highest rate of negative answers, representing 25% of the sample (Figure 4.5). However, the supermarkets and hypermarkets segment in Portugal opposes to this value by representing 40% of the positive answers of this group. Concerning the two main groups identified, clothing stores (G47711) and supermarket and hypermarkets (G47111), 57% (4 companies) and 80% (4 companies) of each group answered “yes” when inquired about this topic.

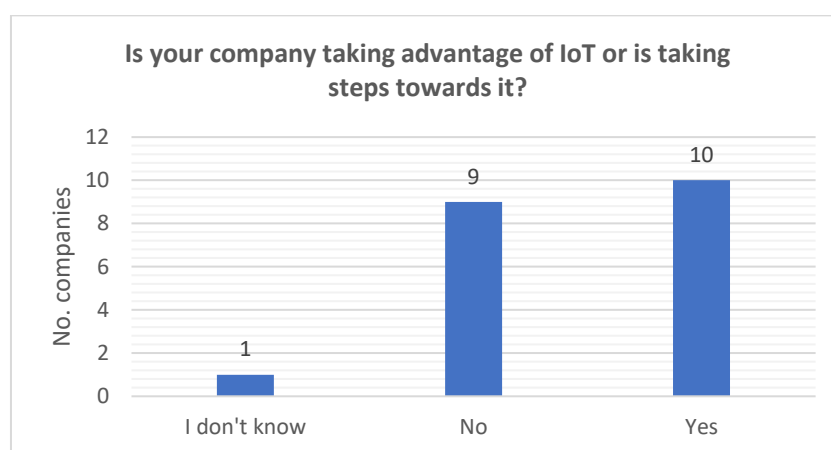


Figure 4.4 – Companies leveraging IoT

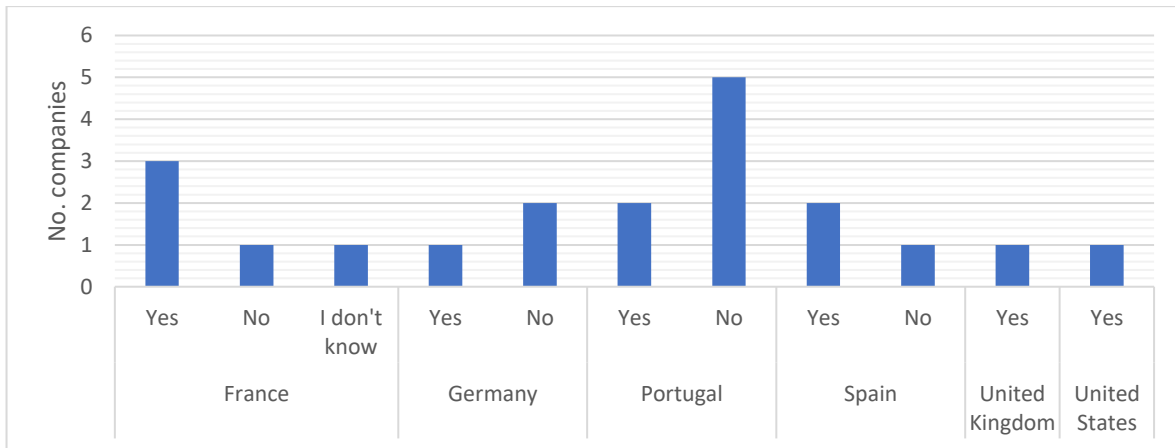


Figure 4.5 – Companies leveraging IoT according to the country they are based

“Secure better insight of customer behavior inside brick-and-mortar stores” was the third most preferred option in terms of IoT implementation benefits with compliance of 40% of the sample. The second was “dynamic customer experience” which entails the direct interaction with customers, and therefore is focused on improve and expand engagement points (Figure 4.6). Even though, the most selected benefit was “**improve stock management**” (80%) which by itself it is directly related to the supply chain department, customer behaviour data is also being seen and taken into account in what is related to IoT implementation as well as customer engagement (Figure 4.6).

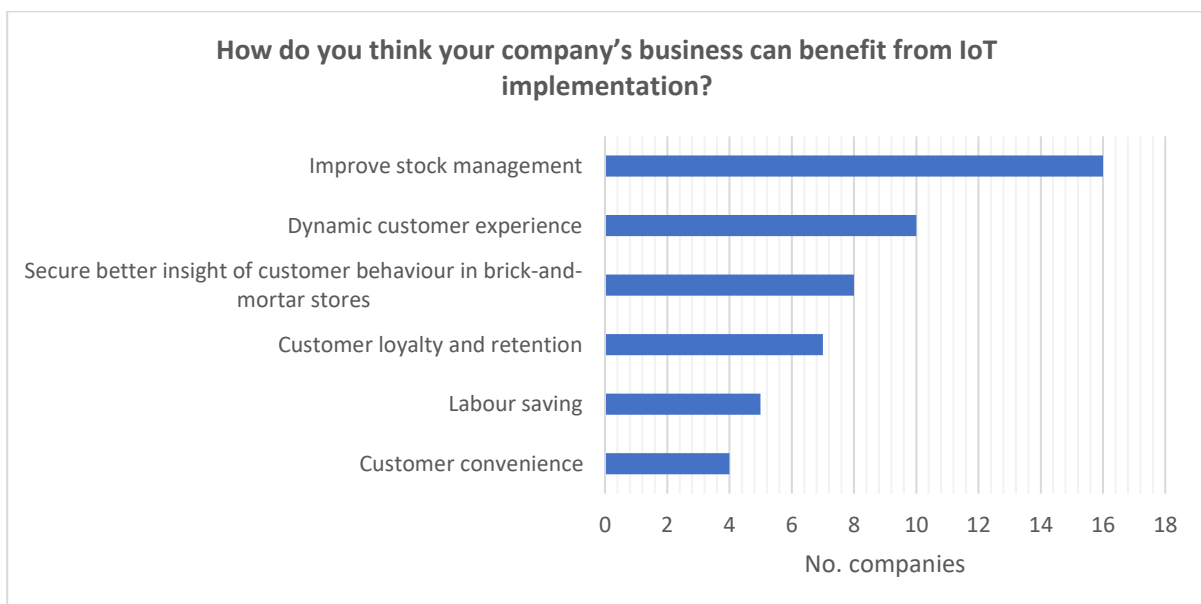


Figure 4.6 – IoT implementation benefits

Further in specifying some IoT-enabler technologies, **contactless payment** clearly stands out compared to the rest since 95% of the companies stated to use this technology (Figure 4.7). **RFID tags** were the second most popular choice with 35% of the sample showing preference for this technology. Moreover, it is also important to notice the implementation of some novelties that portrait a significant change directly in the customer journey and in

his experience in brick-and-mortar stores. In terms of commodity and easiness of the process itself like the Scan and Go (15%) and the Just Walk Out Shopping concept (5%) that reduce the number of interactions needed giving the customer more control over his journey. Also, in a more informative matter to revamp the searching phase, the implementation of interactive mirrors (20%) and robotic shopping assistants (20%) imply a change in the usual interaction with the store staff making it more efficient for both the retailer and the client. These specific novelties noticeably affect the dynamic of customer experience since they promote a human-machine interaction different from what the customers were used to.

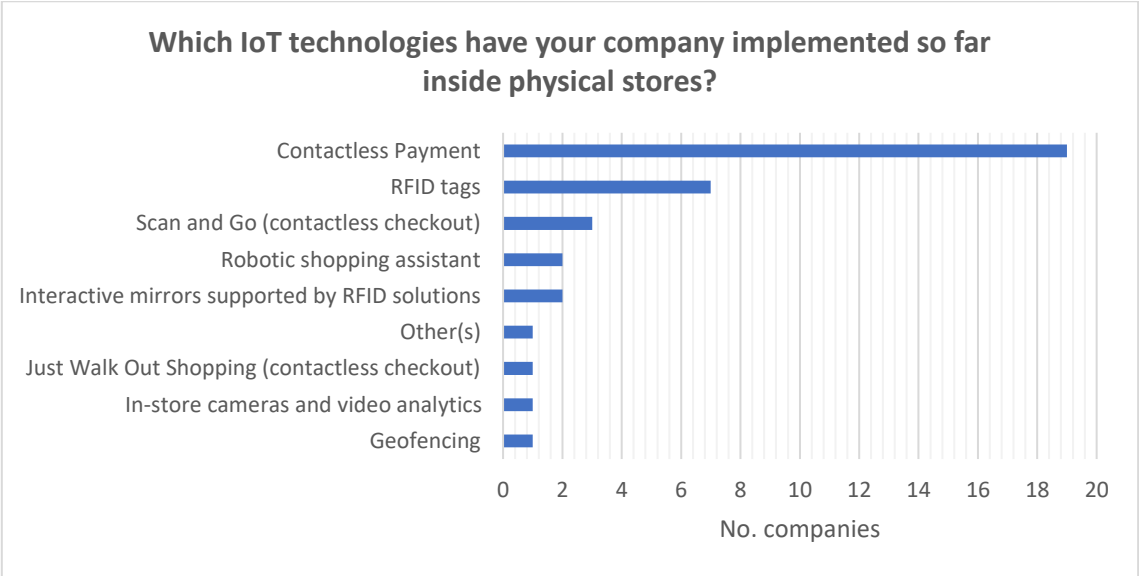


Figure 4.7 – IoT technologies inside physical stores

Subsequently, the respondent was directly inquired about types of IoT sensors, with the intent of understanding which sensors can be more useful to feed customer analytics with customer data. This question also aims to differentiate the use of IoT devices to directly dynamize customer experience from the use of these devices as data generators to support decisions that entail customer behaviour. Therefore, from the list available five different types were selected and most of the answers were clearly inclined towards **position sensors** (80%), followed by occupancy and motion (55%) and light, optical and machine vision (40%) (Figure 4.8). Additionally, about the two main segments previously mentioned, it was possible to identify that position sensors and occupancy and motion ones are considered the more efficient for clothing stores while for supermarkets and hypermarkets the preferred options were light, optical and machine vision, followed by position and force/pressure sensors (Figure 4.9).

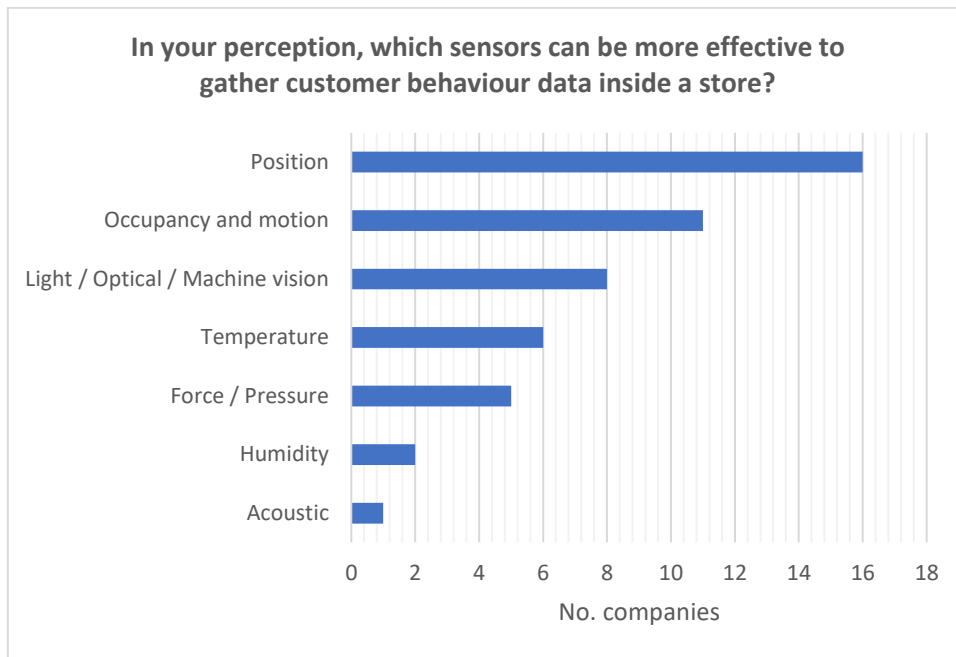


Figure 4.8 – Sensors for data behaviour collection in brick-and-mortar stores

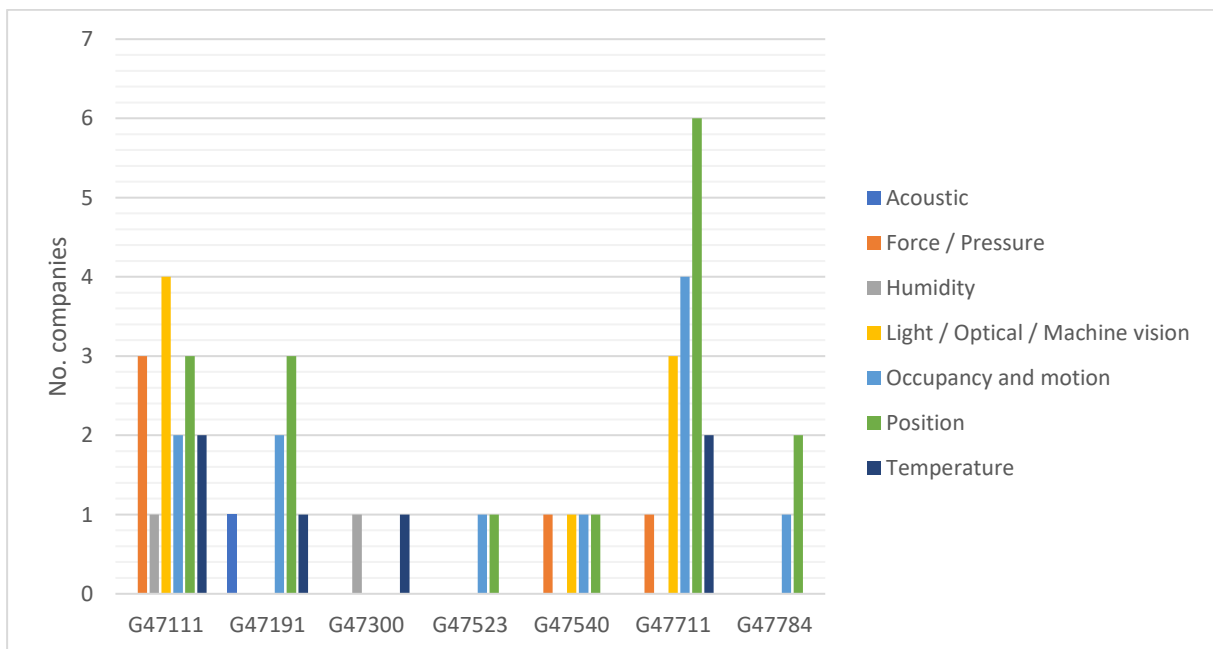


Figure 4.9 - Sensors distribution according to companies' economic activity classification

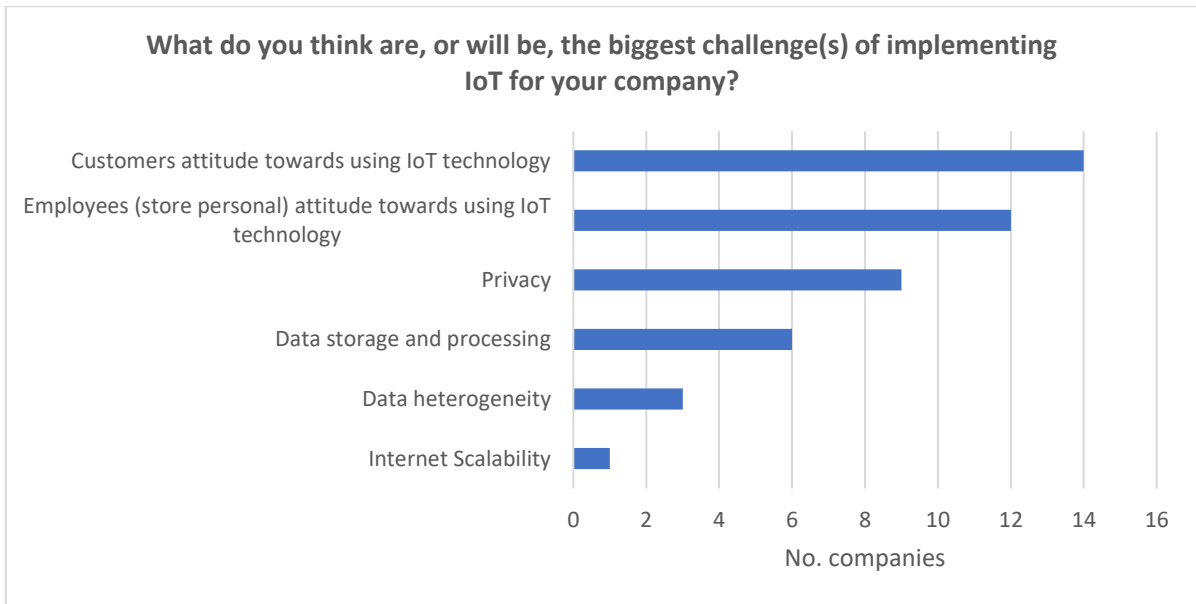


Figure 4.10 – IoT implementation challenges in brick-and-mortar stores

Finally, regarding IoT implementation challenges, the most selected topics where customers’ attitude and employees’ attitude towards using IoT with a rate of preference of 70% and 60% respectively, followed by privacy (45%) (Figure 4.10).

By crossing challenges with the economic activity classification, the clothing stores segment presented privacy as the main concern (71% of the segment) followed by employees and customers’ attitude towards IoT. On the other hand, supermarkets and hypermarkets expressed that customers’ attitude towards IoT were their main concern (60% of the segment) (Figure 4.11). Also, focusing on country, for Portugal companies’ the major issues are perceived to be customers’ attitude and data storage and processing, representing both 57% of the segment (Figure 4.12).

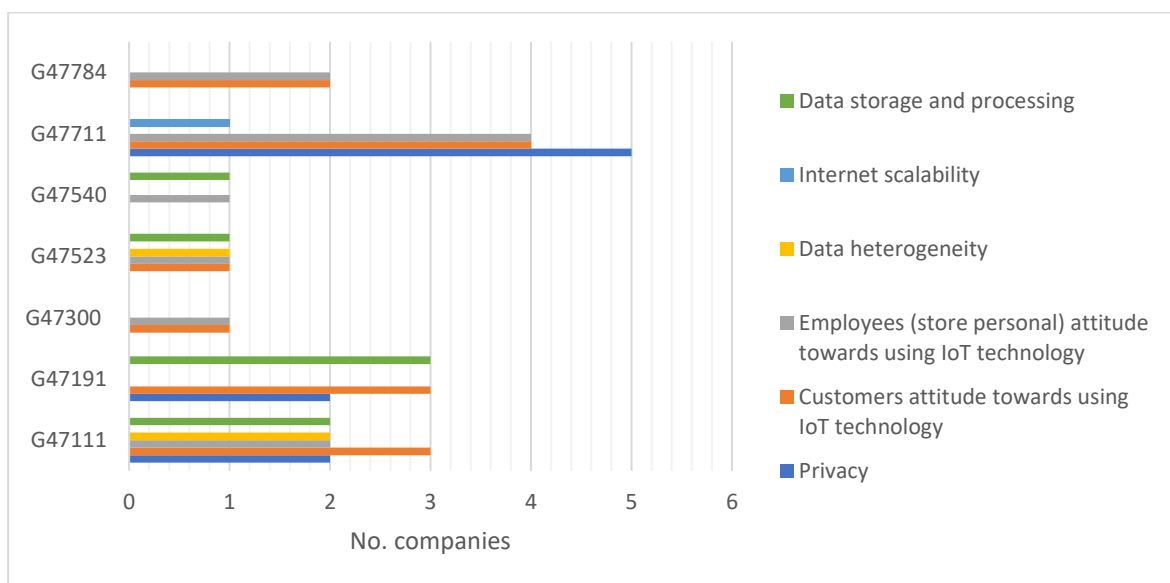


Figure 4.11 – IoT implementation challenges according to companies’ economic activity classification

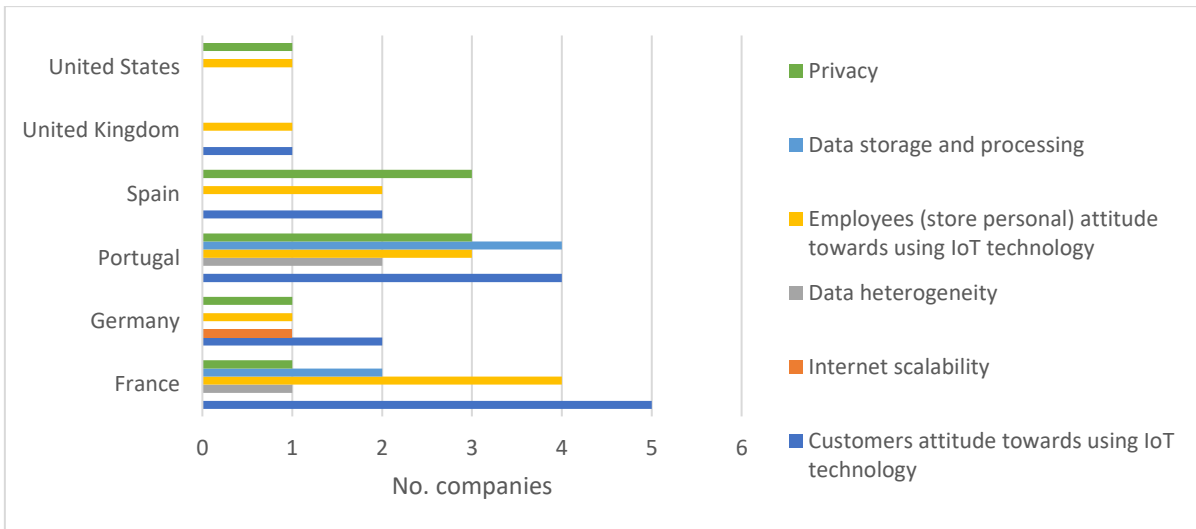


Figure 4.12 – IoT implementation challenges according to the country where companies are based

### 4.3. CUSTOMER ANALYTICS PERCEPTION

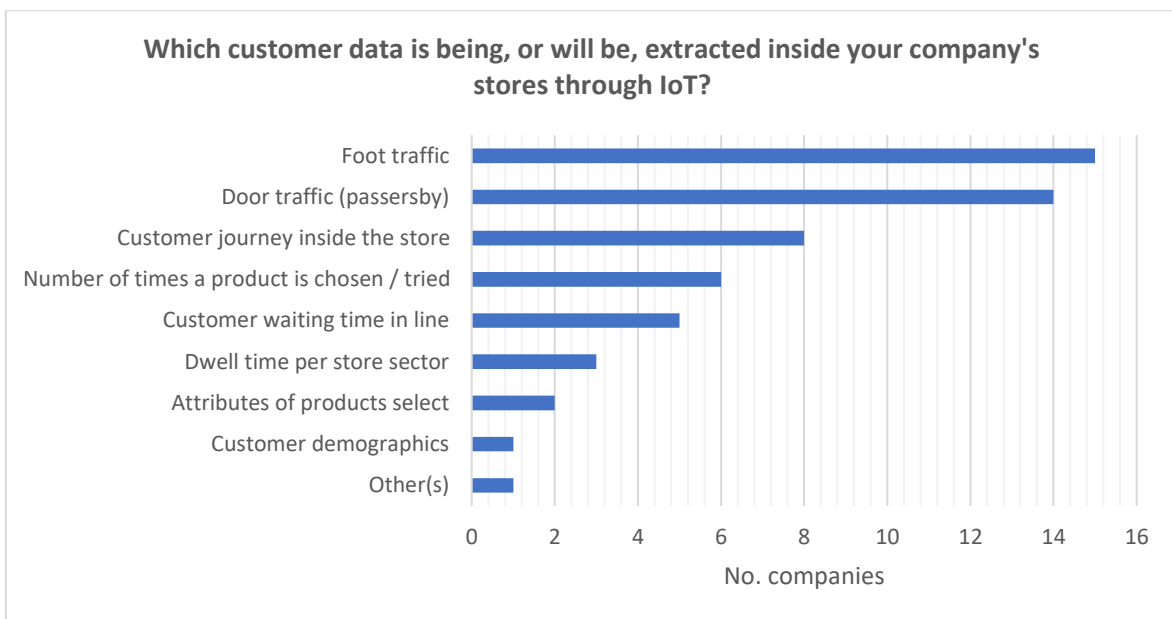


Figure 4.13 – Data extracted through IoT devices in brick-and-mortar stores

Focusing on customer analytics, the focal point was on understanding which type of data was being gathered in brick-and-mortar stores through IoT devices. The results show that **foot traffic data** (75%), **door traffic** (70%), and **customer journey** (40%) inside the store were the main concerns of the companies under investigation, when it comes to data collection in physical stores (Figure 4.13).

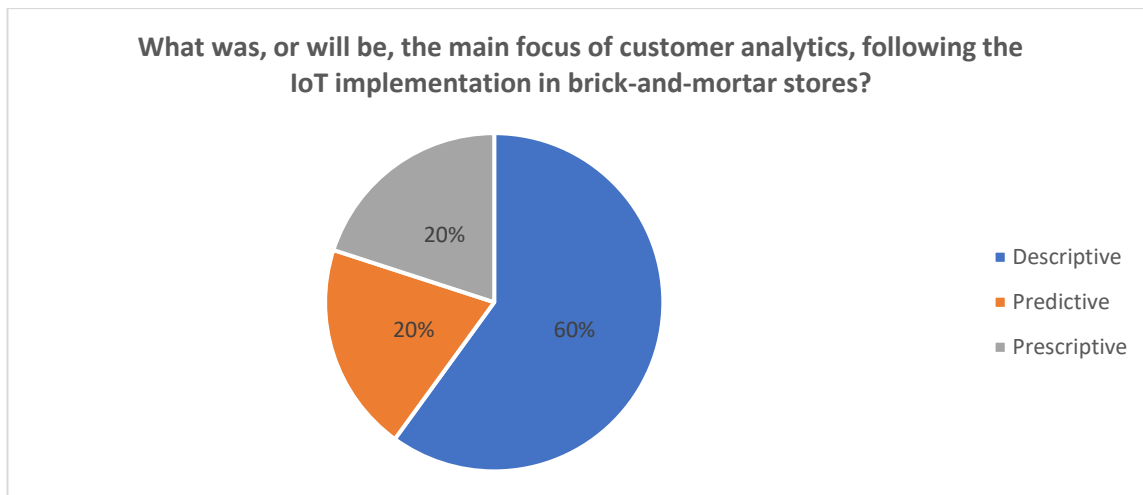


Figure 4.14 – Companies’ analytical focus related to IoT implementation

The following point of interest was to understand the analytical focus of companies regarding the use of that data, which was in its majority descriptive (Figure 4.14). Most of the companies are focused on understanding how customers behave inside brick-and-mortar stores, more than in predicting their behaviour.

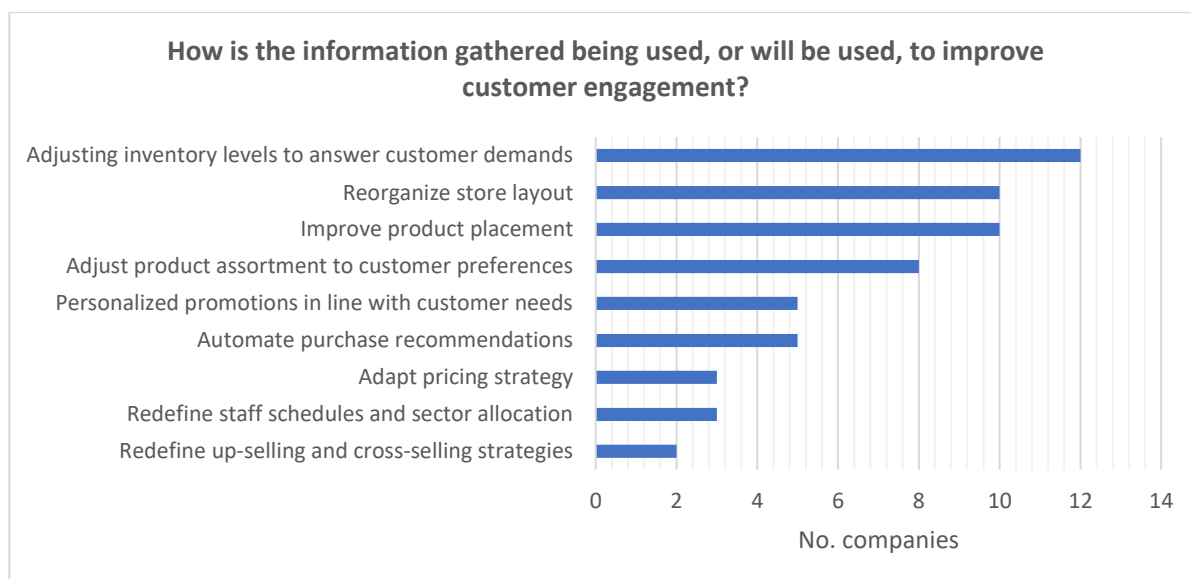


Figure 4.15 - Actions companies are taken from insight gather from IoT

Consequently, the last step was to access how the data was being applied inside the stores. **“Adjusting inventory level to answer customer demand”** was the pick of 60% of the inquiries (Figure 4.15) which reaffirms the choice of what companies expects to benefit or are benefiting from IoT: **“Improve stock management”** (Figure 4.6). In second place, the two options with same rate of selection were **“improve product placement”** and **“reorganize store layout”** selected by 50% of the sample. It is possible to perceive that IoT data is being used or is expected to be used to address spatial issues regarding the store organization

whether it concerns the restructuration of the store sections in a more suitable way considering the customer journey or the repositioning of products within each section.

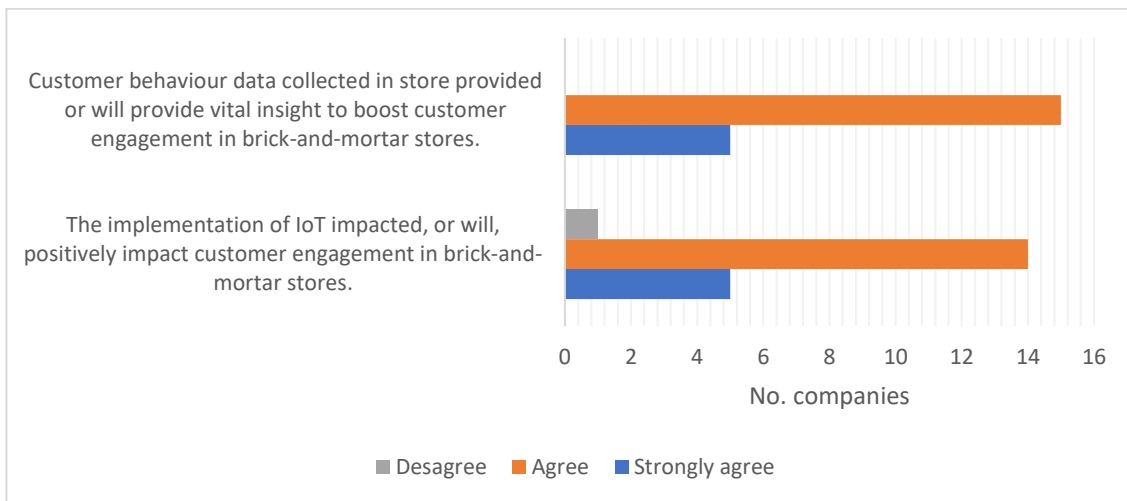


Figure 4.16 – Evaluation of the impact perceived from IoT and customer analytics in brick-and-mortar stores

Finally, to evaluate a general perception of the respondents regarding IoT implementation and customer analytics value to promote customer engagement in brick-and-mortar stores, it was measured the level of agreement with two statements. In what relates to customer analytics, 15 respondents (75%) agree that the extract of insight from customer behaviour data inside brick-and-mortar stores can be beneficial to improve customer engagement.

Regarding the IoT implementation itself, whether it was from the data the devices can collect or from the new type of interactions these novelties have to offer, 14 of the respondents (70%) agree that this technology impact or will positively impact customer engagement in brick-and-mortar stores.

#### 4.4. DISCUSSION

Even though innovation is recognized as a key factor for companies' development to deliver customers' expectations and therefore to gain competitive advantage by many authors (Adapa et al., 2020; Alexander, 2019; Pantano & Vannucci, 2019; Rigby, 2011), discoveries reveal some resistance regarding IoT implementation. According to Ten Bok (2016, p. 9), "retailers are mainly adaptors of innovation rather than innovators themselves". In his study he concludes retailers are not technology experts and that innovation is not treated as fundamental for businesses. According to the results, the entrance of IoT into retail businesses has been divided, since 50% of the sample admitted that **the company is not leveraging IoT** or proceeding to do so (Figure 4.4).

With the purpose of understanding, what was negatively weighting on that decision, the **challenges that could condition IoT implementation** were examined in this research, and the top three bottlenecks selected were customers' attitude towards using IoT technology (70%), employees' attitude towards using IoT technology (60%) and privacy (45%) (Figure 4.10).

The customers' attitude towards using IoT technology was the main challenge identified by this study and it was also confirmed by different authors as an important constrain. Roy (2018) stated that customers' negative attitude regarding IoT and their resistance to SRT might be related with some missing features: the absence of help to make the shopping process more efficient, the inability to provide a personalized service or the lack of additional and advanced functionalities compared with the existing technologies, i.e. there are not major benefits perceived to value their introduction. His findings revealed that positive attitude from customers, may well appear if these elements are applied. Moreover, Ten Bok (2016) identified this issue as the top concern limiting IoT implementation, however he relates this concern with privacy and security which consequently influence customers trust on the technology itself.

In light of that, Privacy is also one of the challenges that IoT implementation faces according to the survey results (40% of the sample). It was also acknowledged as a major concern by Ten Bok (2016), since the collection of personal data through IoT devices is hard to control that consequently creates an obstacle, since customers need to trust the devices in order to accept them and express a positive attitude towards this technology.

Employees' attitude towards using IoT technology is also in the top choices. It is referred that the introduction of IoT technology requires that employees learn how to operate with these novelties without feeling replaced which can be a huge barrier to cooperation and therefore to the success of the implementation (Ten Bok, 2016). The apprehensions in taking advantage of IoT may possibly be the result of these claims that suggest the lack of maturity of IoT integration in retail.

To perceive ease of use and usefulness regarding IoT, Roy (2018) mentioned that is required to stimulate a positive attitude from customers. According to the author, retailers should look for simpler SRTs that promote efficiency in the shopping experience. However, in the assessment of **technologies that are being implemented** inside physical stores, only contactless payment stands out, being chosen by 95% of the sample. Other technologies that offer those benefits to customers like Scan and Go and Just Walk Out Shopping that promote contactless checkout, have a much lower rate of implementation (Figure 4.6).

While promoting innovation to fulfil customers desires and provide the right experience has been a staple condition according to many authors to leverage IoT implementation (Ferracuti et al., 2019; Foroudi et al., 2018; Piotrowicz & Cuthbertson, 2014; Rigby, 2011), in terms of **benefits perceived from IoT implementation**, the sample focus deviates from the customer to logistics, by showing preference on improving stock management (80% of the sample) (Figure 4.6). This shows similarities with Ten Bock (2016) findings, since he states that retailers adapt rather than innovate, focusing mostly on reduce process costs by reinventing logistics rather than the services provided to clients. Nevertheless, the need for a more dynamic customer experience that could be delivered by IoT was also selected by 50% of the respondents. Which reinforces Foroudi (2018) position that retailers should take advantage and benefit a better dynamic from SRTs in order to enhance customer experience and stimulate customer engagement.

About **analytical capabilities and the data extracted**, Ten Bok (2016) emphasizes the IoT innovation that is expected to have the greatest impact on retail is customer tracking, which is also corroborated by this study. Among the different types of data that IoT innovations allow to collect, companies' interest concentrates on tracking customers traffic (foot traffic – 75% – and door traffic – 70%) and customer journey inside brick-and-mortars (40%) (Figure 4.13). To gather data, the **sensors considered more effective** were positions sensor (80%) and occupancy sensors (55%) useful to track both foot traffic and door traffic, followed by light, optical and machine vision (40%) that can offer a deeper knowledge of the customer journey inside brick-and-mortar stores (Figure 4.8). Little literature was found concerning sensors and particularly regarding their effectiveness to gather specific data.

Studies reveal the absence of infrastructures and staff trained to address this need technological update, there is a lack of capabilities which restrains the improvement of customer experience (Lee & Lee, 2015; Ten Bok, 2016). Companies under investigation are mostly concentrating their efforts on **descriptive analytics** and are not leveraging prediction (Figure 4.14), this suggests a low level of maturity of IoT implementation which is consistent with the lack of IoT and analytics capabilities emphasized by the studies previously mentioned.

The benefits chosen by the sample were in line with Ten Bok's study, given that **insights gathered** are being used to optimize back-end processes related to logistics and supply chain to adjust inventory levels and therefore answer customer demand (60%). It was also possible to uncover that IoT data is being used or is expected to be used to address spatial design issues. This concern was noticed due to focus on improving product placement (50%) and reorganizing stores layout (50%).

Even though IoT implementation is far from being mature in retail, most of the inquires agree that both customer analytics and IoT can have a positive impact in brick-and-mortar stores and improve customer engagement.

Together, these findings confirm that “IoT is able to satisfy the customer demand for innovativeness, as it provides several tools that enhance the overall shopping experience by making it more easy, fun, interactive and personal” (Ten Bok, 2016, p. 10).

## 5. CONCLUSIONS

This chapter offers an overview of the research conducted throughout this dissertation and ultimately delivers a succinct answer to the research questions previously presented in the first chapter.

The retail sector has evolved over the years around the customer and its needs. As the technological world evolved, innovations were integrated into retail businesses to offer customers what they expected from it or in the best case what they would be expecting from it in the future. It is vital to leverage the right technologies to succeed and in the right way.

With the digital era new channels were created to provide more purchase options, eventually retailers pursued these channels integration to deliver a seamless experience and answer customers' expectations. With the Internet, e-commerce came to live and was promptly supported by Web Analytics that allow to track customers journey and provide an overview about the different points of engagement. However, the seamless experience concept was yet a critical problem to overcome. In light of that, IoT introduction in retail was the inherent answer to this issue as it would provide the same perspective regarding customer behaviour that until then was only delivered in a digital setting. IoT entered retail to allow an effective integration between physical and digital worlds and consequently to keep brick-and-mortar stores updated and as valuable assets to the future of the business.

As in every innovation addition, companies need to readjust their operations to implement IoT and to fully leverage the advantages it has to offer. It is important to emphasize that the implementation of these devices exposed two different outcomes. They could change the dynamic of the customer experience, directly by promoting machine-human interaction like the interactive trial rooms or by changing the purchase process like the Scan and Go technology, or indirectly by using data analytics to support business decisions. Both outcomes will ultimately reflect on customer engagement.

Hence, this was the foundation of this dissertation main objective: to understand how IoT implementation in brick-and-mortar stores is impacting customer engagement. To achieve this and build a proper line of thought, the following secondary research questions needed to be answered first.

1. *Which sensors do retailers consider more effective to collect customer data inside stores?*

According to results of the questionnaire conducted, the preference of retailers is firstly directed to position sensors, followed by occupancy and motion sensors and light and optical sensors. Position sensors allow to determine objects' positions and occupancy and motion sensors focus on detecting human presence and their movements (Holdowsky et al., 2014)

which might support retailers intention of tracking the customer movements inside brick and mortar stores. However, it was not found relevant literature about their effectiveness.

## *2. Which type of customer analytics are being carried with the data collected?*

Under three main analytics categories, retailers show preference for descriptive analytics with the intent to understand the customer journey inside brick-mortar stores rather than predict customer behaviour, this might be due to IoT low maturity state of implementation. Companies might not be ready to evolve their use of analytics. The data being collected to achieve this, according to the survey, is related to foot traffic, door traffic and the customer journey inside stores, as this last was considered the innovation that will impact the most brick-and-mortar stores, according to Ten Bok (2016).

## *3. How are insights gather being used to improve customer engagement?*

Regarding the use of the data collected, retailers move toward issues more related to the supply chain rather than focus directly on customer engagement as the most selected option was “adjusting inventory level to answer customer demand”, this support Ten Bok (2016) findings as retailers are identified as adaptors to innovation rather than innovators, focusing therefore in back-end processes and logistics to reduce costs, rather than in service innovation. It was also highlighted retailers’ interest in spatial design through the desire to improve product placement and reorganize store layout. These might suggest the focus on spatial issues possibly to offer the customer what he expects and desires in his journey inside the store and promote customer engagement trough different engagement points through the store.

Finally, it is possible to answer to focal question of this research: *how IoT implementation in brick-and-mortars stores is impacting customer engagement?*

Both the use of IoT and customer analytics can have a positive impact on customer engagement in brick-and-mortar stores. Nevertheless, only half of the sample admits being leveraging IoT which implies a slow dissemination within retail businesses. Among the benefits, improving stock management was the preferred option which does not focus directly on customer engagement, however the intent to create dynamic customer experience was also a popular option which suggests an intent to promote a better understanding of customer journey and consequently of the customer engagement points.

Retailers are slowly adopting this new paradigm by leveraging customer analytics through IoT-collected data. Nevertheless, this implementation is providing a new way for retailers to understand the customer journey with descriptive analytics and apply this knowledge to improve stores designs and product placement in order to offer the customer what he expects. Additionally, retailers are entertaining customers by using IoT to create new points of engagement inside physical stores and to offer convenience in every visit with technologies like Scan and Go and Just Walk Out. Nonetheless, there are some issues that

still concern these companies like customers and employees' attitudes towards IoT that might be delaying the exploration of its full potential.

This work main contribution for the academia was the complete empirical study elaborated regarding the IoT implementation in brick-and-mortar stores which was missing in the literature available. Additionally, for practice, this work provided retailers a full overview of the IoT devices available and customer analytics methods that can be implemented in brick-and-mortar stores to enhance customer experience and consequently customer engagement.

## 6. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE WORKS

Like any other study, this work research also had a couple of constraints. These were found within the primary data collection and for that reason the findings should be cautiously interpreted before being considered. The major bottleneck faced during the investigation was the reduced number of survey’s entries and, consequently, the impossibility to attain a representative sample to ensure truthfulness of the results submitted. Moreover, the questionnaire is based on respondents’ perception, being therefore subjective and possibly different results could be attained if answered by different employees from the same company. Taking this into account, the results may be biased.

For future research, a new in-depth questionnaire could be prepared to grasp a better understanding regarding costumer analytics usage and the data collection time should be increased in order to attain a more feasible sample. Also, it might be prudent to use a stratified random sampling method to gather information about the IoT implementation in each specific retail segment to be able to compare the different impacts since their business’ operations differ considerably. Likewise, the resort to a new research method like interviews could be beneficial to reach a clear view about the topic in order to understand the full spectrum of IoT applications, which insights are being extracted by employing analytics and the different ways that they are being used. The extent of devices available that allow a multitude of dynamic interactions with customers as well as the collection of different types of data and a variety of applications for the insight gathered cannot always be captured with objective questionnaires. Nonetheless this study still holds value since it displays information from real applications of IoT in retail businesses, giving a perspective of what is being done.

For future research, new variables could be introduced to understand their effect on IoT and analytics usage in brick-and-mortar stores. Table 6.1 introduces some examples of topics to pursue further research.

Table 6.1 - Future work recommendation

<b>Key aspects</b>	<b>Future research topic</b>
Customer perception	Customer’s feelings and attitudes towards smart technology in brick-and-mortar stores
Employee’s perception	Store employees’ feelings and attitudes towards smart technology in brick-and-mortar stores
Covid-19	How brick-and-mortar stores are coping with covid-19 by leveraging IoT and costumer analytics

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