THE IMPACT OF IOT TECHNOLOGY ON PHARMACEUTICAL GREEN SUPPLY CHAIN MANAGEMENT

Research dissertation presented in partial fulfilment of the requirements for the degree of MSc in International Procurement and Supply Management

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I certify that the dissertation entitled:

The Impact of IoT Technology on Pharmaceutical Green Supply Chain Management submitted for the degree of MSc in International Procurement and Supply Management is the result of my own work and that where reference is made to the work of others, due acknowledgment is given.

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ABSTRACT

THE IMPACT OF IoT TECHNOLOGY ON
PHARMACEUTICAL GREEN SUPPLY CHAIN MANAGEMENT

Rabia Celik

This research aims to explore the current state and role of Internet of Things (IoT) technology in Green Supply Chain Management (GSCM) practices through examination of the pharmaceutical industry.
Internet of Things technology, Green Supply Chain Management practices and the pharmaceutical industry were the main topics investigated from existing works, in order to identify possible correlations, existing technology solutions and challenges.
The research approach was exploratory in nature, the data was collected through interviews with three pharmaceutical companies and one public health care distributor centre. The interviews produced qualitative and quantitative data, which were analysed with a pragmatic philosophy. The dual nature of findings created a detailed and comprehensive view of IoT benefits and challenges when the technology is implemented within the organisation, and when is used to support GSCM practices. In details, the findings were analysed to summarize major drivers for IoT adoption, challenges and future possibilities. On the other side, this research investigated how IoT enables and supports GSCM practices.
The combination of primary and secondary data served to uncover the positive relationship between IoT solutions, sustainability and business value, with significant benefits discussed throughout the findings. This research confirmed that IoT technology allow business growth and indirectly enables sustainable practices. The overall positive impact of IoT in pharmaceutical GSCM practices discovered in this research, confirmed that exists a strong relationship between sustainability and business value, when using IoT.

Acknowledgement

I would like to thank my supervisor Turlough Kieran for his advice, direction and valuable time in assisting me with completion of my dissertation. I would also like to thank Justin F. Keogan for his imparting his knowledge throughout the course of the master's programme. Finally, I would like to thank the participants who agreed to participate in the interviews.

Dedication

This dissertation is dedicated to my partner Danilo Panettieri and my mother who always believed in me. Thank you for your constant support and encouragement throughout the many challenges presented during my master's degree. Without your support I would not have been in a position to dedicate the time to achieving this goal.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

List of Abbreviations

IoT	Internet of Things
GSCM	Green Supply Chain Management
ICT	Information Communication and Technology
ERP	Enterprise Resource Planning
SCM	Supply Chain Management
NPL	National Physical Laboratory
TCP/IP	Transmission Control Protocol and Internet Protocol
DNS	Domain Name System
RFID	Radio Frequency Identification
WSN	Wireless Sensor Network
EPCIS	Electronic Product Code Information Services
SDGs	Sustainable Development Goals
R&D	Research and Development
GHG	Greenhouse Gas
EMA	European Medicine Agency
FDA	Food and Drugs Administration
EC	European Commission
WMS	Warehouse Management System
RBV	Resourced Based View
AI	Artificial Intelligent
AWS	Amazon Web Services
KPI	Key Performance Indicator
SKUs	Stock Keeping Units
E2E	End to End

CHAPTER ONE: INTRODUCTION

1.1 OVERVIEW

This research will investigate how the adoption of Internet of Things (IoT) technology improves green supply chain management practices in the pharmaceutical companies and what are the potential difficulties through an exploratory method. The following section includes research purpose, significance of study, research objective and structure of study.

1.2 RESEARCH PURPOSE

The purpose of the research is to understand how IoT adoption improves green supply chain management practices within pharmaceuticals.

Over the last two decades we experimented a fast development and integration of new technologies in organizations, with the purpose to improve the performance and increase the value of the company. Information Communication and Technology (ICT) has demonstrated to be an effective instrument for the productivity, flexibility, and competitiveness of the organization. Furthermore, ICT develops an effective inter organizational networks, it is enough to think about sharing information between suppliers, producers and buyers. In particular, IoT is gaining relevance along the market and scholars, due to the ability to connect stand-alone object (e.g. devices, vehicles, machines, containers) through the internet, that when integrated with software has the potential to collect, analyse and control data over the internet (Gubbi et al., 2013).

IoT technology is a progression of the classical ICT Information communication technology (e.g., email, phone, bar code, ERP). It differs from ICT applications for ubiquity, intelligence and autonomy (Kahlert et al., 2017), adding the potentiality to capture information, exchange it in real-time and automatically processed (Ferreira et al., 2010). On the other side, recently a large number of consumers and businesses are always more interested to sustainable and environmentally friendly products when making a purchase decision. Furthermore, global consciousness on the importance of an economic, environmental and social sustainable market, leads governments and legislations to require compliance by manufacturers, retailers, brand managers, traders, and distributors.

The application of environmental management principles to the entire set of activities across the whole customer order cycle, including design, procurement, manufacturing and assembly, packaging, logistics, and distribution (Handfield et al., 1997; Islam et al., 2017) are having strong impact and giving an important value to pharmaceutical companies.

A strong interest along researchers and businesses is having the implementation of IoT technology along the supply chain, in order to obtain performance improvement and a sustainable business advantage (Cui, 2018; Rocha et al., 2017).

The research gives insight into IoT technology implementation and challenges in pharmaceutical GSCM and sustainability, focusing on the long-term profit.

1.3 SIGNIFICANCE OF THE STUDY

The implementation of a green supply chain is becoming always more crucial and unavoidable for organizations, due to government regulations, environmental concerns, and market thrust (customer decision).

A better insight of a specific technology, in this case IoT is a key factor for the development of a successful supply chain. This research can help pharmaceutical organizations to evaluate and decide if proceed in a certain direction. Furthermore, study the impact of IoT challenges in the GSCM, it is helpful to determine where an organization should put more effort, in order to obtain the maximal beneficial effect from the use of IoT in the GSCM.

GSCM and IoT are still young research fields. The interaction of these two different topics in pharmaceutical industry, may enable innovation. support future researches and real applications.

1.4 RESEARCH OBJECTIVE

To fully understand IoT's potentiality and the possible role into the pharmaceutical GSCM, a literature review of IoT capability, GSCM practices and pharmaceutical industry is necessary. Once those arguments are analysed, a deeper understanding of IoT integration in SCM and pharmaceutical GSCM was possible.

As previously mentioned, the research aims to understand how IoT adoption enables and improves pharmaceutical green supply chain management practices through a survey base and interview research method. The following hypothesis will be verified:

Hypothesis: H1: IoT capability has a positive effect on supplier, customer and internal integration.

H2: IoT capability has a positive impact on GSCM in the Pharmaceutical industry

H3: Adoption of IoT in GSCM generates disadvantages.

1.5 STRUCTURE OF STUDY

This dissertation separated into 6 chapters. Each chapter contributes to the research objective and the process for exploring the proposition.

The first chapter represents to introduce the purpose of the research, the significance of the study, the research objective and how the research will be structured.

The second chapter provides a complete literature of IoT technology, Green supply chain management practices and pharmaceutical industry. The literature review is the key to fully understand and identify possible correlations, existing technology solutions and IoT challenges. The literature is broken down into the key areas of this research and also contains the conceptual framework that will guide the research.

The third chapter describes the methodology and research approach. This chapter aims to clarify the methodology and strategy that was used to collect the primary data, which is both qualitative and quantitative. For the purpose of this research, a pragmatic approach was taken through the survey and interviews.

Chapters four and five present the findings from the collection of the primary data. It also contains a discussion section which contrasts and compares the findings with the conducted literature review. The findings and discussion chapter are designed to explore the results of the research.

The final chapter highlights implications, limitations and recommendations for future research. It also includes both conclusions and reflections. The following chapter is a literature review that was explored for understanding the research objective further.

CHAPTER TWO: LITERATURE REVIEW

2.1 OVERVIEW

To fully understand the impact of IoT on the GSCM in the Pharmaceutical Industry the literature review critically explores the three main topics involved in this research. First of all, IoT technology has been presented from a technical point of view, in order to fully appreciate the potential and the advantages that could bring to the SCM and GSCM. An investigation of IoT technology disadvantages has been also undertaken, to understand which problems can arise from the implementation of this technology. Is important to highlight that the research aim is also to empirically verify the truthful and grade of the disadvantages.

A deeper investigation has been done on the integration of customer, supplier and internal information, using IoT enabled supply chain, due to the fact that the supply chain integration is a key factor for a successful GSCM (De Vass et al., 2018; Yu et al., 2017). Subsequently, GSCM practices have been analysed to create an effective survey for the research.

Finally, the literature review critically explores the pharmaceutical industry and the impact that it has on the environmental, the challenges in implementing a sustainable and green supply chain, and how IoT technology can be implemented to support GSCM in the pharmaceutical industry.

2.2 INTERNET OF THINGS

2.2.1 THE ORIGIN OF INTERNET

The technological evolution began with early research on ARPANET and packet switching which is a commercial network that developed by National Physical Laboratory (NPL) a way of avoiding congestion in busy networks by cutting up data at one end and putting back together at the other (Leiner et al., 2009).

The internet today is widespread information infrastructure, there is no a single founder of the internet. There are many researches and scientists behind the evolution of the internet.

Leiner et al. described the internet briefly:

"The internet is at once a world-wide broadcasting capability, a mechanism for information dissemination, and a medium for collaboration and interaction between individuals and their computers without regard for geographic location" (Leiner et al., 2009).

According to ARPANET, that one of the founders of the first network, in the 1960's first network experiment aim was not communication, the aim was optimizing process usage, or time sharing, in particular sharing the power of the computer at once.

CYCLADES is a packet-switching network that was invented in early 1970's as an alternative to ARPANET. It contributes direct connection between computers and gateway computers.

By the end of 1969 there were few computers connected to the ARPANET and kept grow in 1970's and there was no single global internet, then Transmission Control Protocol and Internet Protocol (TCP/IP) developed by Robert Kahn and Vinton Cerf. TCP/IP is a communication model that set standards for how data could be transmitted between multiple networks and adopted by ARPANET. In early 1980s Domain Name System (DNS) was invented by Paul Mockapetris, the DNS permitted a scalable distributed mechanism for resolving hierarchical host names (e.g. www.acm.org) into an Internet address (Leiner et al., 2009). The online world then took on a more recognizable form in 1990, when computer scientist Tim Berners-Lee invented the World Wide Web.

2.2.2 WHAT IS INTERNET OF THINGS

The Internet of things (IoT) is defined by Gubbi et all as *'Interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications. This is achieved by seamless ubiquitous sensing, data analytics and information representation with Cloud computing as the unifying framework'* (Gubbi et al., 2013). In other word IoT is modern wireless technologies (e.g. Radio-Frequency Identification, tags, sensors, actuators, mobile phones, etc.) that are able to interact with each other and cooperate for the common goal (Atzori et al., 2010).

IoT technology enables real time collection and analysis of huge amounts of data making it available through the Internet. The monitored data can be analysed in real time with a proper network and server infrastructure. An appropriate set of real-time alarms can be configured to advise potential safety threats in a timely manner. Not only proper alarm can be configured, but also effective action can be taken automatically from the IoT device, if an actuator is used. This is the real advantage of IoT technology, it differ from Information and Communication Technology (ICT) applications for ubiquity, intelligence and autonomy (Patel et al., 2016). In general sense of IoT applications is extended internet services and devices that provides business and society better information process beyond computers or smart phones.

The impact of IoT technology enhanced every-day life users both working and domestic fields over the past decade. For instance, consumer connected devices include smart TV, smart speaker, toys and smart wearable technology such as smart watches, glasses etc.

An idiomatic example is in the cold supply chain. A temperature-sensing IoT device will ensure that highly perishable product remains within safe temperature ranges (Chandra and Lee, 2014), so to protect the consumer. If the temperature is out of the ranges a temperature control can be applied from the IoT device in autonomous way.

The Internet of Things consists of four main technologies summarized as follow:

1. **Radio Frequency Identification (RFID)** (Lee and Lee, 2015) allows data gathering via radio waves, a reader and a tag. The tag is used to store data and the reader to capture it, the interaction is all wireless and automatic. RFID can be passive or active.

2. **Passive RFID** are not battery powered, and they are commonly used in the retail and supply chain management (Gubbi et al., 2013).
3. **Active RFID** instead rely on their own battery and can engage communication with the reader. General applications are monitor temperature, pressure, chemicals, and other conditions, they are mainly used in manufacturing, hospital laboratories, and remote sensing (Lee and Lee, 2015)
4. **Wireless Sensor Network (WSN)** consists in a distributed autonomous network of sensor devices used in remote sensing applications; they differ from RFID due to the capability to share the sensor data to a centralized system for analytics. RFID have a limited processing capability and storage when compared to WSN (Gubbi et al., 2013).
5. **Cloud computing** is a concept for access a wide pool of resources (servers, sensor, applications) over the internet. IoT devices generate an enormous amount of data directly available via internet, this can enable the creation of a virtual Infrastructure as a Service IaaS or a Software as a Service SaaS (Lee and Lee, 2015)
6. **IoT applications** enable interaction between human and technology through a customization of the software to tailor any business needs (Lee and Lee, 2015). IoT application allows efficient exploiting of data gather by IoT devices and it can be used to integrate and elaborate various data along the supply chain.

2.2.3 IOT ADOPTION IN SUPPLY CHAIN

IoT technology if properly implemented allows the full virtualization and integration of the supply chain management; this is the main advantage of assuming such technology in the company. All the actors involved in the supply chain (suppliers, customers and internal) are now able to monitor, control, plan and optimize business processes (Ferreira, et al., 2010) remotely and in real-time through the Internet, based on virtual objects instead of observation on-site (Verdouw, et al., 2013). Furthermore, virtualization permits artificial intelligence to be exploited in the processes.

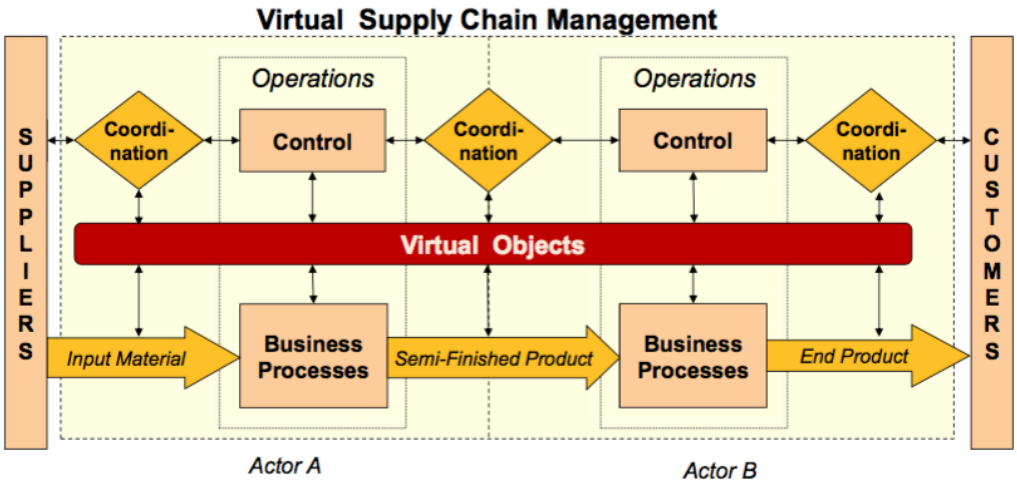

Figure 1: Virtualization of the supply chain from IoT perspective

(Verdouw, et al., 2013)

One of the strongest in sight industry by governments and customers, due to the necessary of high-quality product has always been the pharmaceutical sector. Not authenticity or damage of pharmacies causes high losses to the government and companies but also seriously healthy issue to the customer life. Internet of things makes possible improvement in monitoring for drug supply chain, and also update drugs information in real time (Yan and Huang, 2009). The pharmaceutical factory can use IoT in several phases: manufacturing, warehousing and cold chain distribution.

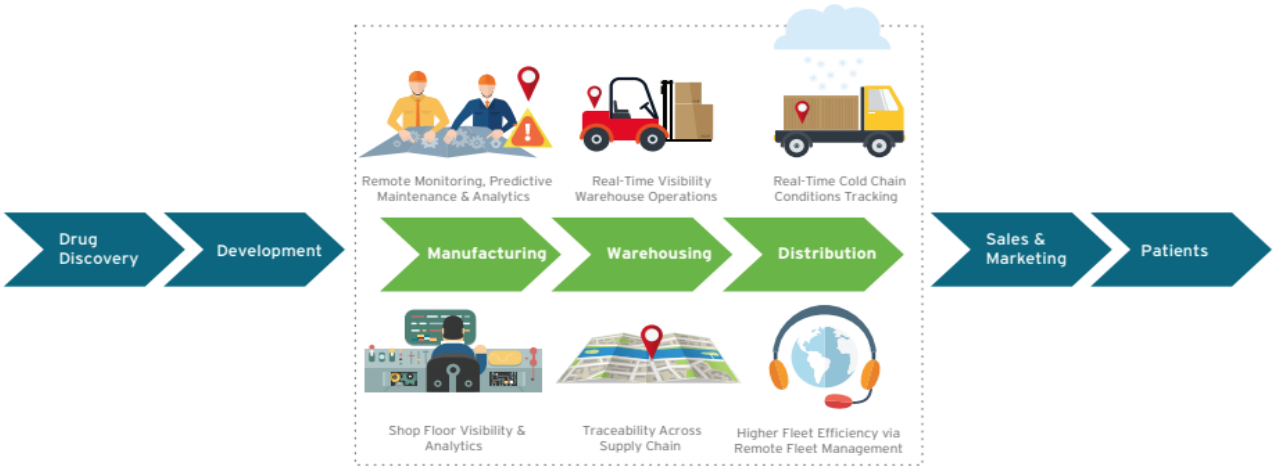

Figure 2: IoT applied to pharmaceutical supply chain

(Saboo et al., 2017)

Equipment needs to be continually maintained and calibrated to assure the safety and efficacy of drug products, sensor network is the best solution to monitor in real time the performance of the manufacturing process and target manufacturing error.

Real-time tracking and 3-D view of warehouse operations with detailed, contextually relevant data at their fingertips allows to:

- Monitor and track sensitive and expensive medicines in controlled zones.
- Optimize the warehouse space.
- Track and reduce inventory of finished goods.
- Keep track of the situation and aware issues that require human intervention.

Finally, the distribution monitoring and remote control in this sector is becoming vital, pharmaceuticals manufacturers are commencing always more biologic products, which are highly sensitive to storage conditions. IoT devices can be positioned with the drugs during the shipment, the temperature sensor continually records temperatures and environmental condition, which can be recorded and checked by the control centre.

IoT devices can be also used to implement environmentally friendly procedures and controls, for example optimizing the warehouse space and track and reduce inventory will results in a reduce of waste for the company.

Nowadays, case studies and publications of IoT in Supply chain management, focus only on specific sensors and network to be implemented in particular case. To obtain the best result IoT needs to be properly embedded into the supply chain, for this reason, it becomes essential define and develop an information system architecture (Verdouw et al., 2016) that considers the full chain from suppliers to consumer.

Another sector where the IoT integration results vital is the food industry; high quality standard imposed by the government and customers can be monitored from the farm to the table.

The information in the food supply chain follows a distributed architecture. For example, Electronic Product Code Information Services (EPCIS) is the used standard to realize distributed traceability systems between several suppliers in the food industry.

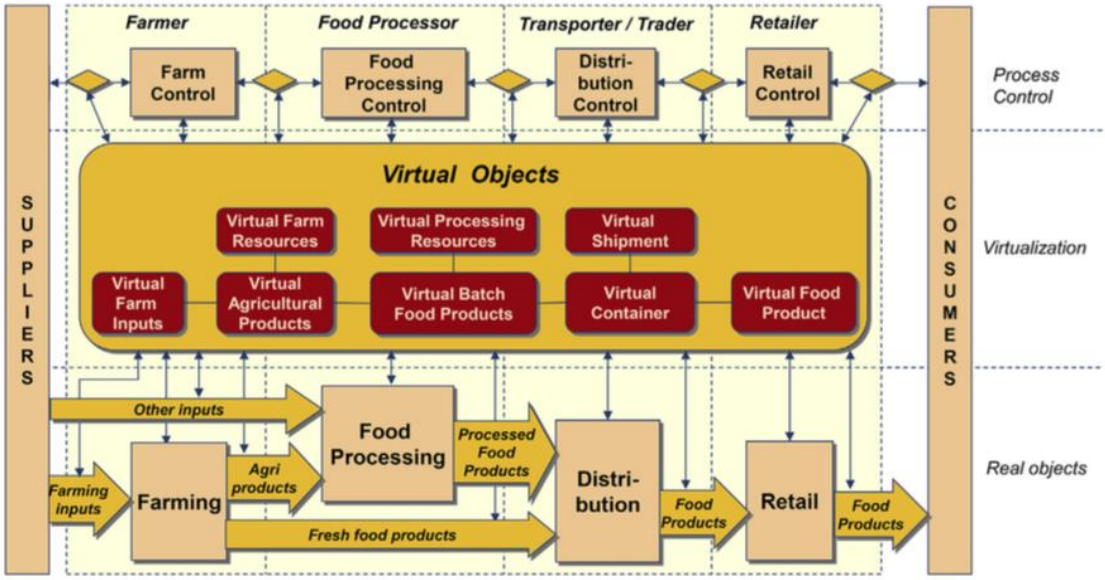

Figure 3Virtualization in the food supply chain management

(Verdouw, et al., 2013)

2.2.4 SUPPLY CHAIN INTEGRATION

Supply chain integration is a collaborative management strategy between suppliers, customers and intra-organization. An intra & inter organizational cooperation create effective and efficient flows of products, information and provide the maximum value to the end customer at the lowest cost and the greatest speed (De Vass, et al., 2018) .

Supplier and customer integration refers to strategic common management, information sharing and in general collaboration between suppliers and customers (Wu, 2013; Yu et al., 2017). Instead internal integration refers to the breakdown cross-function barriers within the organization speed (De Vass, et al., 2018). In order to obtain successful supply chain integration a system that joins all the information retrieved along every step of the supply chain is necessary. Supply chain integration is the last step of a successful IoT implementation.

One software useful for this purpose is FIspace (Verdouw, et al., 2014), it is a cloud-based platform for business collaboration, which is based on a common set of Internet technology. The following Figure (4) shows all the step of the food supply chain and the correspondent virtual layers created via IoT devices. These virtual layers are joined with FIspace, that become an intermediary platform between them and allow handling information, problem notification and decision-making.

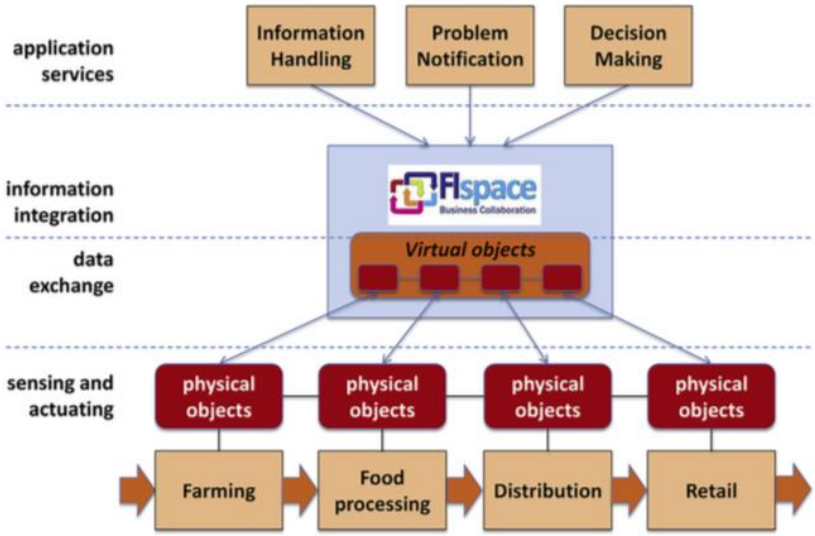

Figure 4: Information systems architecture for the food supply chain
(Verdouw, et al., 2014)

2.2.5 CHALLANENGES OF IOT ADOPTION

The advantages of IoT are undeniable, and widely documented, but almost no research focus on the negative impact that IoT can have on the SCM. We can assume that IoT adoption brings the same disadvantage for SCM.

Privacy issue and **security** concerns are the main disadvantage of IoT applied to the SCM (Weber, 2010), (Weber, 2015).

Some of the data that are collected appear to be not important but they revel indirectly production process and company policies, these data are highly valuable and requires an adequate protection, for this reason know the security issues affecting those technology (U.Farooq et al., 2015) is a must for the success of the SCM.

Skill gap in control and management to make profitable this new technology is another major issue,

As reported by Shah, (2017) “Almost a third of executives at large global enterprises believe that the IoT faces a major skills gap, and that this is preventing businesses from being able to exploit new capabilities”.

Management of huge amount of data gathered by IoT devices is another aspect that if underestimated, can lead to an inefficient use of IoT technology. For this reason, the use of management software to integrate the supply chain information and actions is of primary importance.

Furthermore, integration of IoT technology in an existing infrastructure can create additional challenges, such as compatibility issue.

Malfunctions is another issue; the intrinsic autonomy of this technology make possible automatic action such as place an order for goods or discard materials. When the decision-making process is automatic, a malicious malfunction could cause huge problems, and difficult to identify.

2.3 GREEN SUPPLY CHAIN MANAGEMENT

2.3.1 THE CONCEPT

The GSCM researches and practices have been increasing over the last decades due to customer requirements, environmental legislations and regulation. In addition, Sustainable Development Goals (SDGs) have a significant impact on the adoption of green practices. SDGs are a number of goals that take into consideration economic, environmental, social issues and set by United Nations (Bebbington and Unerman, 2017).

Srivastava (2007) as cited by Micheli et al. (2012) the concept of GSCM is *"integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life"*.

The purpose of GSCM is to satisfy customers demand for green products and services produced by green processes. Such as eliminating hazardous chemical and solid waste, reducing energy consumption and CO2 emission from entire supply chain (Green et al., 2012). Moreover, different GSCM studies show that successful practices and initiatives can be done in various are such as reverse logistics, product recovery and reuse of used products, green design, green procurement, and collaboration with suppliers and customers (Islam et al., 2017).

2.3.2 GREEN SUPPLY CHAIN MANAGEMENT PRACTICES

Reverse Logistic

The reverse logistic a useful practice for green supply chain management and it aims to reduce negative environmental impact of organizations, maximize the value of unused items, conserve resources and minimize cost (Skinner, et al., 2010). Reverse logistic is defined as monitoring the physical of products, components and materials flowing from users/owners to re-users (Glenn Richey et al., 2005). The goods are moving back from customers to manufactures or distributors rather than traditional logistic. GSCM focuses on both environmental issues and economic concerns. Therefore, reverse logistic can play an important role in the GSCM.

Green Design

According to Tseng et al., (2013) most studies have broadly considered "green design" idea for end-of-life product to recover valuable components. Nevertheless, a green design is an approach to building goods and services with environmental awareness (Tseng et al., 2013).

For instance, reducing carbon footprint, resource conservation, cleaner production, waste management, pollution prevention etc. (Zhu and He, 2017)

Green Procurement

Green procurement is a process of acquiring goods and services that take into consideration environmental, social and economic impact (Trivedi and Singh, 2016). Green procurement practices have a significant impact on green supply chain management.

Collaboration with Suppliers and Customers (Supply chain integration)

Building environmental collaboration between organization and customers, organization and supplier reduce cost and negative environmental impact of supply chain (Pagell and Wu, 2009). Therefore, it has an incontrovertible role in GSCM.

Green Manufacturing

'Green manufacturing considers environmental impacts throughout the product lifecycle including the sale of used, unsold, or returned products in secondary markets'(Islam et al., 2017). Green manufacturing process involves reducing use of sources, using green energy, and reusing wastes etc. Green manufacturing can lead to lower raw material cost for organizations.

2.4 PHARMACEUTICAL INDUSTRY

2.4.1 OVERVIEW

The pharmaceutical industry has a vital role in modern economy, developing medications and vaccines to reduce the spreading of disease, to cure diseases and improve the people's life (Nead, 2017). Pharmaceutical Industry first objective is to meet complex and always increasing healthcare demands of populations. In order to do so, companies in this industry are responsible of researching, developing manufacturing and distributing drugs for human or veterinary needs (ITA, 2016). The research and creation of innovative drugs have a clear and massive impact on global health, economic grow and prosperity of population, by improving life and eliminating deadly disease. Pharmaceutical industry is complex and wide, drugs are produced in various form such as pills, tablets, capsules, vials, ointments, powders, solutions and suspensions. Furthermore, there are several pharmaceutical product sectors; drugs can be innovative or generic products, chemically derived or biologically derived products, prescription-based or over-the-counter products. Although pharma industry presents a wide range of products across several sectors, the core remains the same across: R&D, manufacturing, distribution are always the essential steps along the Supply Chain.

The origin of pharmaceutical industry lies back to the middle age when pharmacies were providing traditional remedies based on centuries of folk knowledge (Walsh, 2010). This is far from our understanding of the industry today, pharmacology science developed during the 19th century with Oswald Schmiedeberg generally recognised as the founder of modern pharmacology (Hester and Harrison, 2015) and two main companies Merck, Eli Lily and Roche that had developed and supplied natural products such as morphine in large-scale production of drugs for the first time.

Meanwhile, new companies as ICI, Pfizer and Bayer started to establish research labs and develop new medical products and applications. During the beginning of the 20th century and second war world several inventions were made as penicillin, insulin, aspirin which allowed the pharmaceutical industry to develop and flourish. Finally, the implementation of the healthcare system in several countries and the intervention of the government created a stable market. Between the 1950 and 1990 an endless stream of improved products have released, making this period the golden age of the pharmaceutical industry. Since then the industry has faced a series of new challenges and problems, ranging from sustainability to expiring licence.

Nowadays pharmaceutical market is one of the most competitive and complex, due to a large number of laws and regulations for patenting, testing, safety, sustainability that affect the growth rates of the market. Furthermore, high development costs for creating new medicines can be a barrier for small companies (The Business Research Company, 2018). However, the Pharmaceutical global market is expected to grow at an annual rate of 4.9% to $1.3 trillion by 2020 (ITA, 2016).

2.4.2 ENVIRONMENTAL IMPACT

Till the late 1990s pharmaceutical industry was not considered to have massive negative environmental impact (Daughton, 2016), environmental awareness and company responsibility is a relative new topic and the only environmental concern was related to manufacturing facilities. This view has changed since pharmaceutical residues has been found in surface waters in 1994, pharmaceuticals can enter the environment in three ways from the wrong disposal of expired drugs, via excretion from patients and from manufacturing sites (Hester and Harrison, 2015). Drugs once used by human can follow several paths, from dispersion in open water to the land field affecting animals with clear consequences for humans and the environment. Pharmaceutical compounds enter the environment at every stage of the supply chain, but major pollution is during the manufacturing phase. Releasing antibiotics in the environment can promote the development of antibiotic-resistant pathogens (Nawrat, 2019).

Pharmaceuticals in the environment is not the only challenge in this sector, big and global companies like Merck, Pfizer, Abbvie, Sanofi, Amgen, J&J and Roche, Eli Lilly, P&G, Abbott, GSK, Teva, Novartis and Astrazeneca are responsible to emit massive quotative of GHG emission. Pharmaceutical sector is far from being a green sector. In fact, the sector's emission intensity in 2015 was 48.55 Mt-CO2e/$M, which is about 55% higher than that of the Automotive sector of 31.4 Mt-CO2e/$M for that same year (Belkhir and Elmeligi, 2019; Jackson and Belkhir, 2018).

The study showed also that the whole sector would need to reduce emissions by 58.6%, from 2015 levels, by 2025 in order to comply with emission targets established in the Paris Agreement.
Following figures shows carbon emission intensity of pharmaceutical and automotive industries.

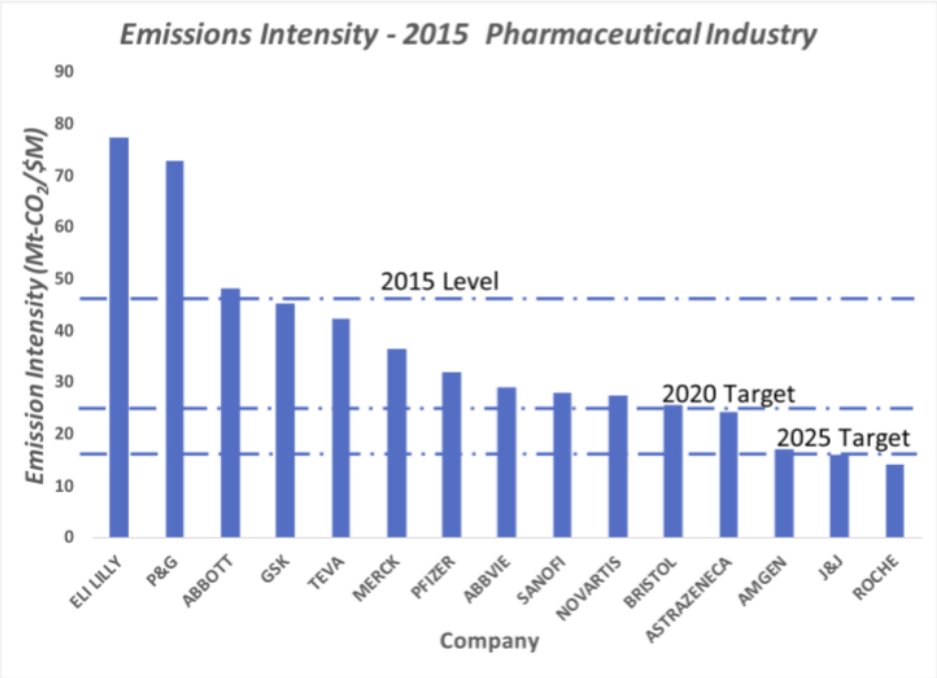

Figure 5: Emission intensities for 15 pharmaceutical companies in 2015, shown with the emission intensity of the pharmaceutical sector in 2015, along with projected levels in 2020 and 2025
(Belkhir and Elmeligi, 2019)

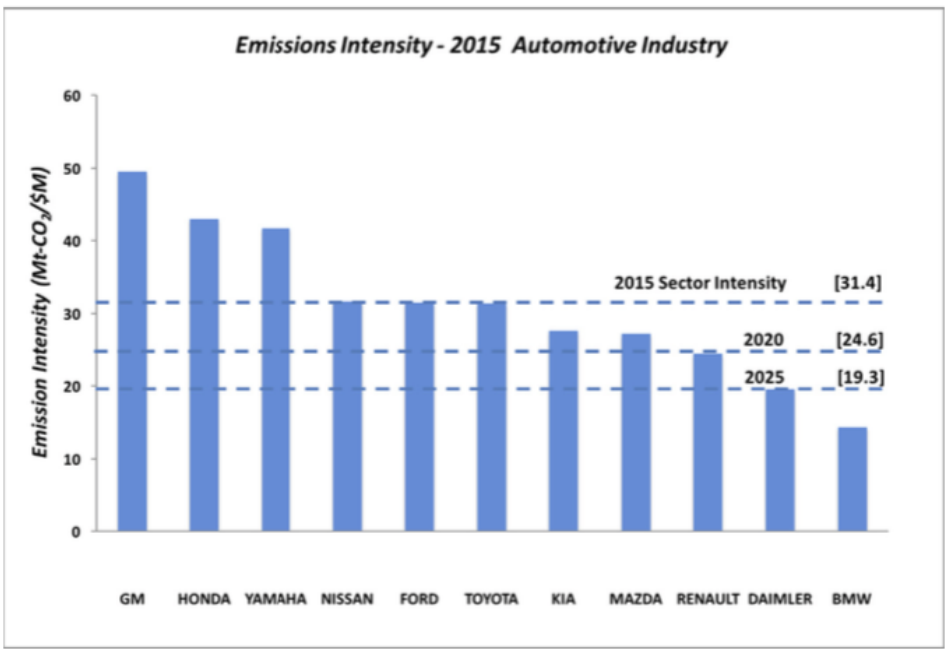

Figure 6: Emission intensities for 10 auto makers in 2015, shown with the emission intensity of the automotive sector in 2015, along with the projected levels in 2020 and 2025

(Jackson and Belkhir, 2018)

From a general point of view, the environmental impacts can be classified as direct (those on which the company can actually operate) and indirect (which relay on consumers).

Irresponsible disposal of unused medicines and release of pharmaceuticals in the environment by 3rd party waste companies and users have indirect negative impacts on the environment and pharma companies have little influence on those issues.

Instead, companies have a huge responsibility on direct impacts like pollution and carbon emission when transporting medicines, or energy and material consumption when producing medicines.

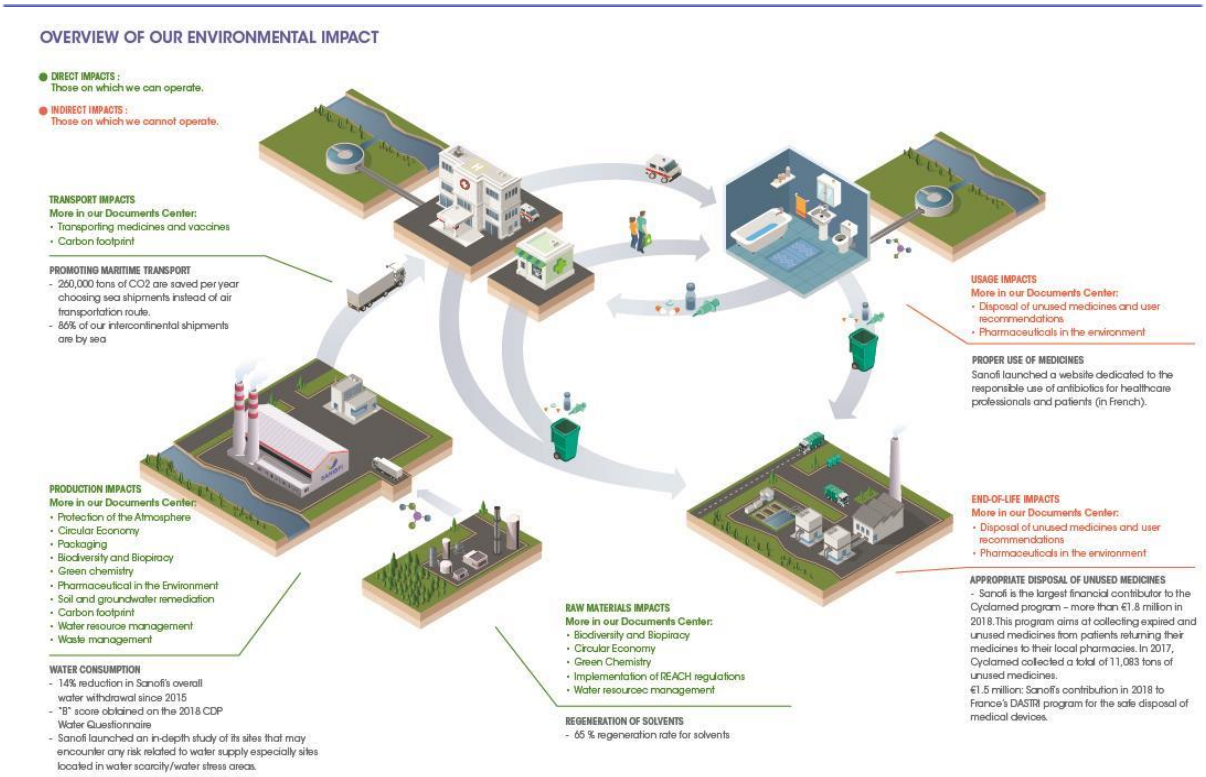

Figure 7: Environmental impact of pharmaceuticals

(Sanofi, 2018)

All those concerns demonstrate that need of higher attention to the supply chain in order to mitigate every negative impact of the pharmaceutical industry on the environment. The Figure (7) above illustrates environmental impact of pharmaceutical industry.

2.4.3 GREEN SUPPLY CHAIN IN PHARMACEUTICALS

GSCM practices aim the integration of environmental management thinking in the whole supply chain process including source of raw materials, product design, manufacturing, delivery of the product and end of life product (Khan, 2018).The concept of GSCM is becoming a popular trend in the Pharma Industry due to pressure of government's regulations, pollution and environmental concerns of the consumers.

The pharmaceutical product leftovers carry an environmental risk to join manufacturing process. Researchers found some pharmaceutical leftovers like painkillers, antidepressants, antimicrobials etc. in drinking waters, ground waters and some animal tissue.

The regulator agencies like EMA (European Medicine Agency) and FDA (Food and Drugs Administration) are requiring more complex business process and stricter reporting methods. The European Commission (EC) have issued a set of goals across Europe to achieve green and more sustainable business by 2030. Some multinationals leading pharmaceutical companies like Pfizer etc. have already shifted their traditional business strategy to sustainable business model (Bravo and Carvalho, 2013).

The traditional pharmaceutical supply chain management has been very profitable in the market. Study cases show that adopting environmental thinking in the business operations has several positive impacts on the businesses, including better quality management, increased margin profit, competitive advantage, reputation and positive image, greater customer satisfaction (Porter and Kramer, 2019).

The pharmaceutical supply chain involves primary manufacturers, secondary manufacturers, logistics service providers/wholesalers, healthcare providers and retail outlets (Ding, 2018).

Green Network Design and Warehouse

The pharmaceutical industry relies on air transportation other than sea and rail transportation for its speed, reliability and efficiency in delivering high-value, time-sensitive, temperature-controlled cargo. However, green warehouse and supply chain network design practices has crucial impact in order to improve more sustainable, green and environmentally friendly supply chain management activities (Dukkanci et al., 2019). Many pharma companies are redesigning their network and warehouse due to protect environment and increase efficiency supply chain model. Practices include relocation of chemistry plants and pharmaceutical plants, encouraging sea transportation rather than air transportation, developing railway transportation in the supply chain network, decreasing number of trucks on the road and using renewable energy vehicles in terms of green network design. For instance, Sanofi has started a new project in Paris using only Natural Gas Vehicles and in Saõ Paulo launched anti-flu campaign using only electric vehicles due to improve quality of green supply chain management. In other words, everything starts with energy in the supply chain process, like every business pharmaceutical companies reduce energy consumption along the supply chain including source of raw material, manufacturing, warehouse and distribution to address the best green practice.

Green Manufacturing

Pharmaceutical manufacturing may comprise environmentally dangerous chemicals and toxics (European Comission, 2017). The green manufacturing practice is referred to practicing environmentally friendly processing and production flow. Pharma manufacturing process can be divided into series of units depending on the goods produced. Green practices in production improve efficiency of processes.

Green production process involves responsible and sustainable raw material sources, fermentation, shifting indigents, dry mixing, blending, coating, packaging, resource recovery and recycling, warehouse monitoring etc.

Energy efficiency has a significant role in the green pharmaceutical manufacturing in order to achieve sustainable manufacturing process. Due to "green manufacturing" term using cleaner energy and decreasing energy consumption are significant way to address this goal. Renewable energy resources are main way to achieve energy efficiency during the manufacturing process. For instance, big companies like Roche, Merck, Sanofi, Bayer, Pfizer and Eli Lily etc. publishes every year annual reports. The reports include their sustainability practices and environmental impacts including energy consumption, carbon emission, water usage. In order to achieve green energy practices in manufacturing process companies reduce their usage of fossil fuels, cut energy consumption, and increase the proportion of sustainable energy like solar energy, wind powers, hydropower etc. According to Roche's annual report, they include the implementation of innovative technologies and continuous upgrading of infrastructure to improve energy efficiency, usage of sustainable energy increased since 2015 by 6.3% and decreased total un-sustainable energy consumption by 7.7% meanwhile sales grew 7% (Roche, 2018). Another effective green manufacturing practice is reducing greenhouse carbon emission along manufacturing process.

The Paris Agreement is an agreement that aims to tackle climate change and greenhouse gas emission, countries that signed, accepted and approved to decrease their greenhouse carbon emission 20% and increase 20% renewable energy in energy efficiency by 2025 (United Nations, 2015). For instance, Sanofi divides into three scopes greenhouse carbon emission by end 2025. Scope 1 & 2 determines industrial, R&D and tertiary sites, including the medical rep fleet. Scope 3 is GHG emissions are the other indirect emissions associated with other functions of the value chain including transportation, purchased goods and services, waste generation, etc. (Sanofi, 2019). According to company report carbon emission decreased by 22% since 2010 and 9% by 2018 using Planet Mobilization Program, Maalox case study and renewable energy sources.

Waste Management

Waste management takes important part in the green supply chain management, waste management practices improves quality and profit of GSCM (Darnall et al., 2008).

Health waste divided into two category as communal waste and biomedical waste. Communal waste are solid wastes that are non-chemical (Jaseem et al., 2017) e.g. boxes, paper, food waste, plastic and glass bottles. Biomedical wastes are special waste that can be extremely hazardous for the environment e.g. cultures, tissues, needles, scalpels, knives, blades, expired or no longer needed medicines or pharmaceuticals, genotoxic waste, chemical waste, radioactive waste etc. (Pratyusha et al., 2012).
However, pharmaceutical companies practice green waste management along with resource recovery, recycle and energy recovery.
Furthermore, "ISO 14001 certification helps organizations to improve their existing environmental standard and waste reduction" (Faisal, 2015). As an illustration, Sanofi decreased hazardous waste by 12% and non-hazardous waste by 9% compared to 2017 with "implementation of the new wastewater treatment plant enabling the increase of on-site treatment" (Sanofi, 2019), Pfizer reduced disposing waste by 15% compared to 2012 (Pfizer, 2018), GlaxoSmithKline decreased the waste by 7% that they produce since 2016 (GSK, 2018).
"Pharmaceutical companies are using the Global Reporting Initiative as a way to implement and measure their level of sustainability" (Bravo and Carvalho, 2013).
The findings of the report include transparency and environmental performance. The adoption of GSCM practices like generation of waste, increasing efficiency of materials and energy, innovating by new and environmentally friendly products and services improves pharmaceutical industry and increase businesses competitive edge amongst rivals. Linton et al. effectively explains that this type of approach leads to the increase business performance and profitability, sustaining their activities longer.

2.4.4 IOT IN GREEN SUPPLY CHAIN PHARMACEUTICALS

Only a few previous researches have investigated IoT practices in pharmaceutical green supply chain management. There are several common kind practices of IoT like RFID and WSN and cloud computing etc. that have been discussed earlier in literature. However, since pharmaceutical regulatory agencies persuade high pressure on industry in terms of concerning environment and sustainability practices companies improving the use of technology to address government regulations.
According to Marathe and Awwad (2018) study, IoT brings solutions to GSCM challenges faced by pharmaceutical companies, these challenges categorised as: real time visibility, collaboration issues, temperature control, warehouse management, regulatory compliance and data handling.

Real time visibility

In pharmaceutical GSCM practices visibility and traceability is very crucial. IoT technologies enable traceability in terms of GSCM practices, including waste reduction, energy consumption, greenhouse gas emission, transportation and reverse logistic. For instance, some drug shortages like oncological medicines pose a significant public health concern (Nonzee and Luu, 2019), *" theft and the counterfeit of drugs during the transit period is one of the major concerns for every pharma company"* (Marathe and Awwad, 2018) and thus cause popularity of shortage drugs in the parallel market.

The following figure illustrates real time 3-D view of IoT in the pharmaceutical supply chain integration within Enterprise Resource Planning (ERP) and Warehouse Management System (WMS).

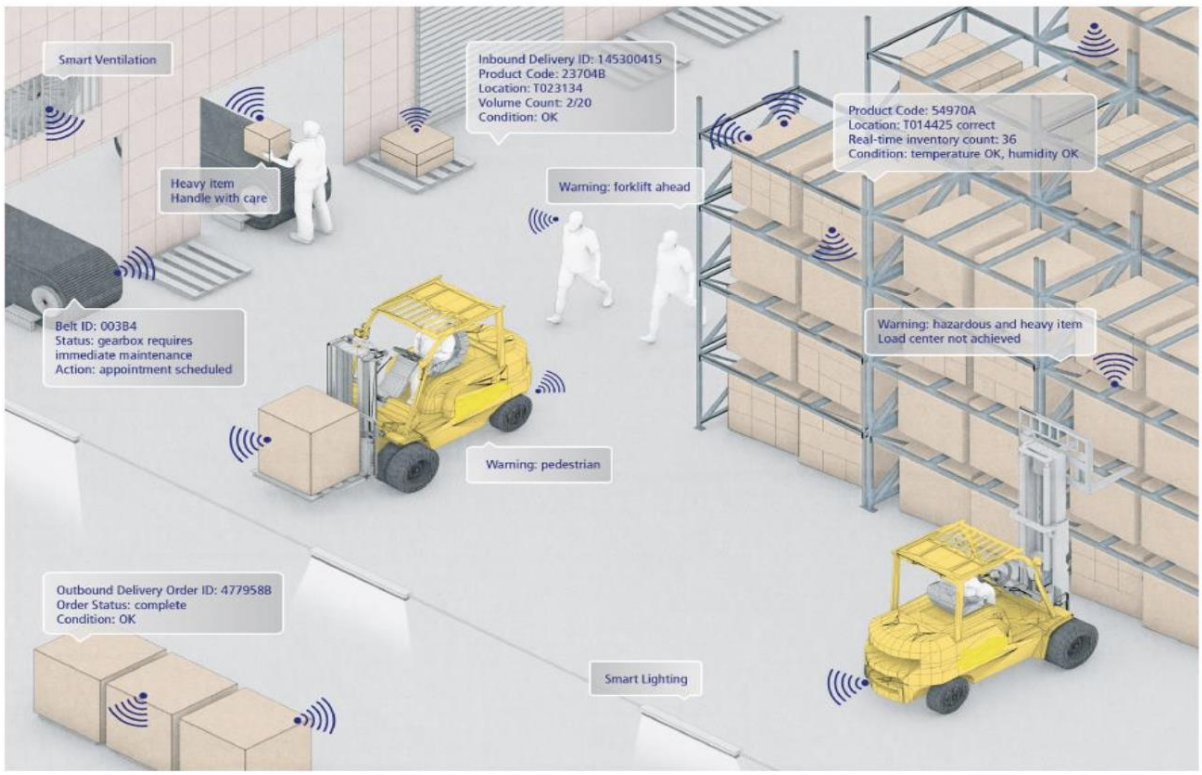

Figure 8: IoT in warehouse

(Marathe and Awwad, 2018)

Collaboration

The importance of transparency and reporting in pharmaceutical GSCM initiatives, data sharing with suppliers and vendors might be big challenge for pharmaceutical companies. Furthermore, complex data flow can cause delays and trust problem with the partner organisations. Pharma businesses can take advantage of IoT to improve data management. For example, IBM 'Smarter Supply Chain of Future' study case enforces IoT technologies to improvement and smooth data flow with suppliers, vendors, third parties and business partners.

Temperature control

The cold chain has significant value in procurement and supply chain, due to temperature sensitive health care products like vaccines etc. IoT apply in cold chain through wireless sensors and batteries. According to (Saboo et al., 2017) 20% of temperature sensitive biologic pharmaceutical goods are wasted during transit. IoT helps to maintaining desired storage conditions of temperature and humidity sensitive. Regarding to (Archa et al., 2018) study, IoT implementation can reduce pharmaceutical product wastes and helps to ensure compliance with regional and international target market norms and environment regulations (Marathe and Awwad, 2018).

2.5 CONCEPTUAL FRAMEWORK

The initial phase of the conceptual framework was derived from the literature review in the previous section (Section 2).

Based on the researcher's understanding of this topic from the literature review, the author proposed a conceptual framework as illustrated in Figure (9) for an adoption of IoT technology in the Pharmaceutical Supply Chain Management practices, most of all in green supply chain practices.

The conceptual framework based on a resource-based view (RBV) theory, RBV suggests that a competitive advantage comes from possessing valuable and rare resources that competitors cannot easily acquire or reproduce, in this case IoT solutions.

Therefore, the study proposes that IoT adoption has a positive effect on the supply chain integration, which is the main aspect to obtain a successful GSCM within pharmaceutical industry. Supply chain integration is not the only positive impact included in the conceptual framework; the positive impact of the remaining green practices is under study. There are no consistent literatures (secondary resources) on IoT impact on these GSCM practices implementations, opportunities and challenges. Furthermore, disadvantages of IoT technology are reported as a general topic, this study aims to gather a complete and comprehensive view of IoT adoption in the Pharmaceutical green supply chain.

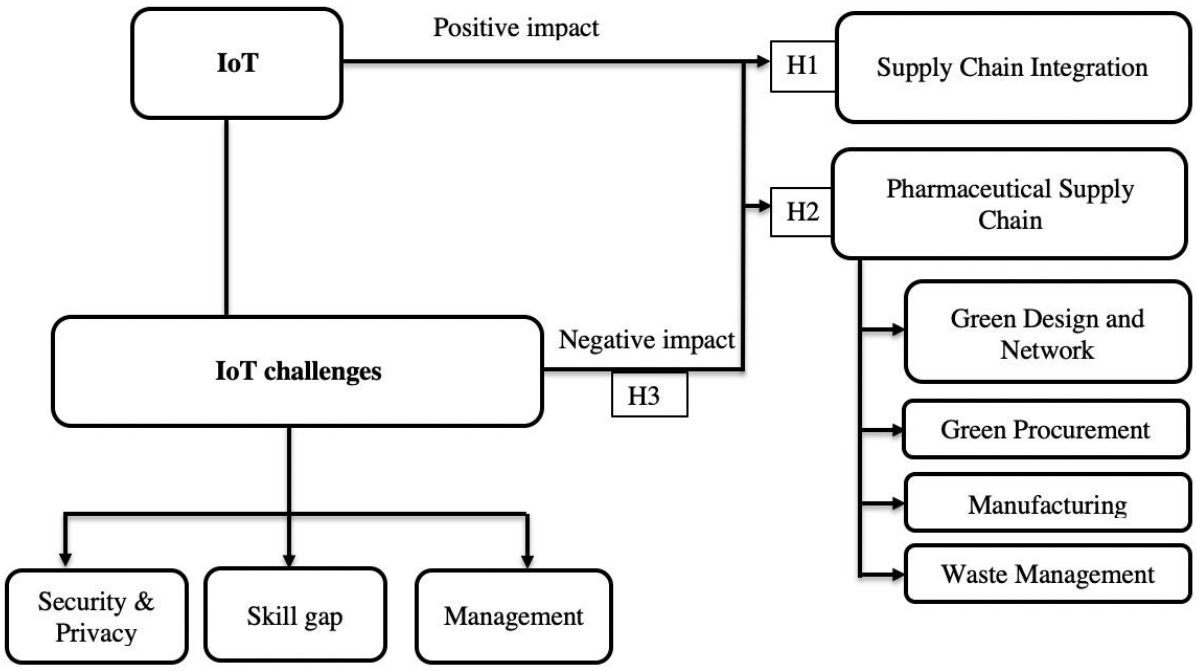

Figure 9: Conceptual Framework of the Study

The dependent variables of the study listed as following: (1) the integration of IoT technology on supply chain, (2) the implementation and the impact of IoT on pharmaceutical supply chain, additionally (a) green design and network, (b) green procurement, (c) manufacturing, (d) waste management.

The independent variable of the study determined as the implementation of IoT technology within the company. Primary data collected from the literature review has shown that an academic study on IoT impact on the GSCM is poor and not focused on pharmaceutical industry, furthermore no case study has been found on this specific topic.
The case study analysed and reported in the literature review were mainly theoretical, hypothetical or based on the general supply chain management, rather than focalize on the green supply chain management. Moreover, no study has been found that analyses the environmental impact of IoT use in the pharmaceutical industry.
As a consequence, the conceptual framework of this study aims to link IoT technology and pharmaceutical green supply chain management with the help of primary data gathered from a range of Pharmaceutical companies and public healthcare centres.

Hypothesis: H1: IoT capability has a positive effect on supplier, customer and internal integration.
H2: IoT capability has a positive impact on GSCM in the Pharmaceutical industry
H3: Adoption of IoT in GSCM generates disadvantages.

Once defined the hypothesis to verify within this study, a research methodology has been selected to obtain the most clear and comprehensive data result.
Due to the many independent variables and the many way IoT Technology can be implemented within the Pharmaceutical company under review, in deep interview has been adopted as a method to gather data. Finally, a deductive approach has been followed to extrapolate meaningful findings to grade the impact and the challenges of the IoT technology in the GSCM. The findings are subsequently compared with the literature-based framework to highlight the general findings of the research.

CHAPTER THREE: METHODOLOGY AND RESEARCH DESIGN

3.1 OVERVIEW

This chapter outlines the research philosophy, research strategy, data collection and analysis methodology to carry out the research, define findings and reach the conclusions.

The objective of this research is to discover how IoT technology impacts pharmaceutical supply chain management in terms of green practices.

Saunders et al. (2009) clearly defined research methodology '…techniques and procedures used to obtain and analyse data. This, therefore, includes questionnaires, observation and interviews as well as both quantitative (statistical) and qualitative (non- statistical) analysis techniques…' and he used 'The Research Onion' to illustrate different levels of the research methodology process. The principal research levels are as follow:

- Research philosophy
- Research approach
- Research strategy
- Research choices (i.e. single, mixed or multiple methods)
- Time horizons (i.e. cross-sectional or longitudinal)
- Techniques and procedures (i.e. data collection methods and data analysis).
  (Saunders et al., 2009)

3.2 RESEARCH PHILOSOPHY AND APPROACH

This chapter explains the main philosophical framework that will guide this research. The research in subject involves two main topics: IoT technologic management, and the effect of IoT adoption in the pharmaceutical GSCM, those two topics will be evaluated using a pragmatic philosophy.

A pragmatic philosophy gives the freedom to use any of the methods or techniques associated with qualitative or quantitative, in order to mitigate the limitations that every method can introduce (Saunders et al., 2009). On the other side, this freedom grade, introduces increased difficulty in the integration of data. The pragmatic philosophy assumption is the result of two different aspects of the research.

First of all, the positive or negative impact of IoT adoption could be perceived in a different manner, depending by the organization and interviewed person, for this reason there is space for subjective interpretation (interpretivism). It is important to notice that a sample can be influenced by subjective interpretation, and the data can be subject of value bias. In order to decrease the effect of the bias a mixed method approach will be used.

From another point of view, the impact of IoT adoption is something that can be quantified, using quantitative data (Linkert scale survey) (Boone, Jr. and Boone, 2012). Moreover, the research aims to verify pre-defined hypothesis (deductive approach) using a positive philosophy.

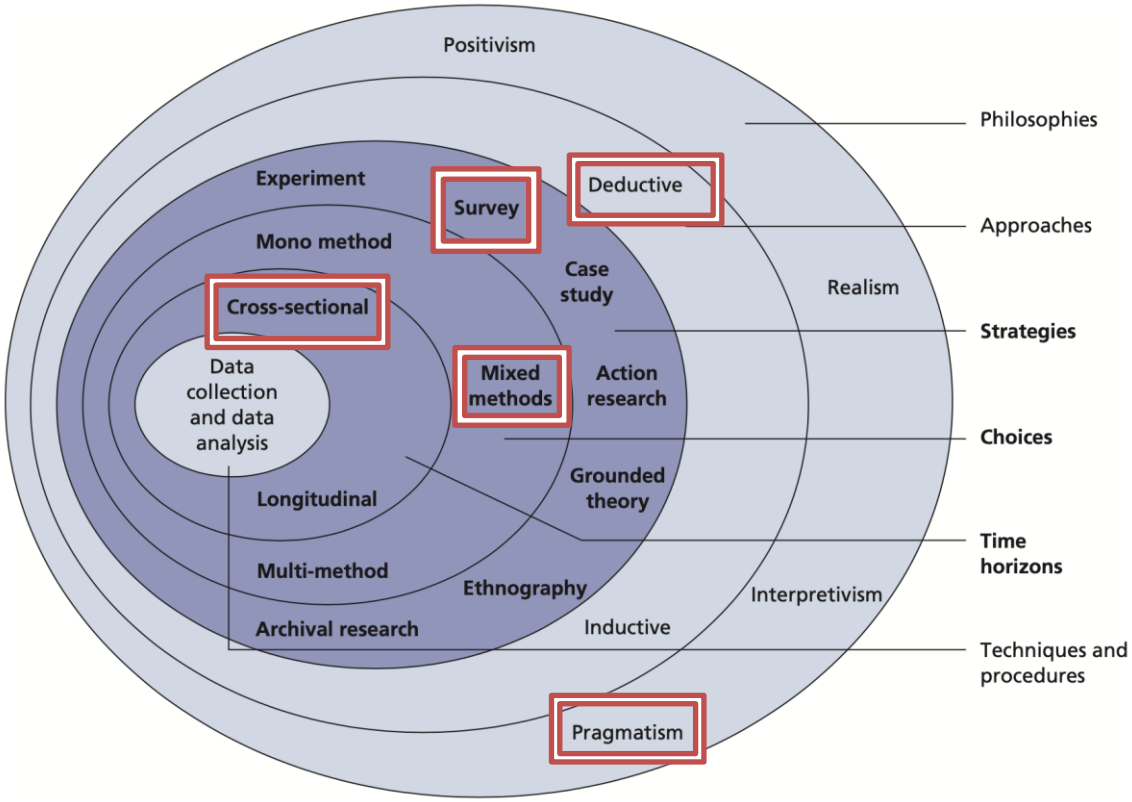

Figure 10: The research onion

(Saunders et al., 2009)

Positivism relies on quantifiable observations in our case a survey with closed-ended questions. Furthermore, the results of this survey are based on human senses and objective situation. Moreover, in positivism studies "the researcher is independent from the study and there are no provisions for human interests within the study" (Crowther and Lancaster, 2012).

A positivism philosophy usually adopts a deductive approach. A deductive approach is when hypothesis are developed, and the analysis of the data will support or not the hypothesis.

In this research three hypotheses have been developed studying what others have done and what are the existing theories. Analysing the research data, we will discover if they support or not that hypothesis. This is a clear deductive approach.

For all those reasons, a pragmatic philosophy is the most suitable for the intrinsic dual nature.

Using a positivism philosophy, descriptive and quantitative data will be collected and analysed; instead, interpretivism philosophy will be used for qualitative in deep results. In this research, the quantitative data will be improved with a qualitative approach, in order to verify the hypothesis (deductive approach). The quantitative data will be collected via a closed ended survey (Likert scale), then a had doc interview will be performed based on the result of the survey and other secondary data, in order to fully interpret the reply and gain further qualitative insights.

3.3 RESEARCH STRATEGY

The strategy used to collect the data was dedicated to verifying and confirm three hypotheses. Those three hypotheses define the impact that IoT technology can have on the GSCM more specific in pharmaceutical. The research has been designed as follow, not only to confirm if IoT technology has a positive impact on GSCM practices for organisations, but also to explore issues and problematics that can be introduced when using IoT within pharmaceutical supply chain.

A mixed methods research involves collection, analysis and integration of qualitative and quantitative data. The study uses a simple mixed methodology, joining a quantitative survey with a qualitative post hoc interview, those qualitative questions have been created after analyse survey data, because their purpose it to clarify some reply and gain further qualitative insights. The interview is also required for investigate on disadvantage and negative impact of IoT technology within the organization.

The survey is a Likert scale questionnaire, for nature is defined as positivism and quantitative research. The survey's scope is not only verifying the hypothesis, but also gain information on the actual IoT technology implemented in the firm's GSCM.

A cross sectional time horizon is considered; the interviews will gather data from multiple samples, as many as the researcher will be able to gather, at one point in time, this will provide a statistical snapshot of a specific point in time.

A mix of descriptive and exploratory is proposed as the most suitable approach for this research. It is explorative because there is no exhaustive research done previously in the field under study. Moreover, there is no existing study that explores and verifies the third hypothesis.

It is in part descriptive, because the survey-based analysis will gather information on the use of IoT technology in the GSCM.

3.4 COLLECTION PRIMARY DATA

This section outlines the sources of the primary data collected, access and ethical issues related to the collection of data.

3.4.1 SOURCE OF DATA

As explained in previous section, this research exploits a mixed methods research as source of data, in the specific a Likert survey model and a post-created ad doc interview.

Due to the nature of the data, the research is mainly based on primary data collection as survey, interview and observations.

A survey method is about asking to the subject of the research specific and clear questions, in order to obtain an effective data. Survey method can be used in both, quantitative, as well as, qualitative studies. Moreover, if survey well-constructed, primary data are relatively easy to analyse, the survey method is faster compared to other methods of primary data collection, such as observation and experiments.

A survey can be conducted via mail, telephone or personal interview. In this research, the data collections were performed via mail or telephone due to the low numbers of questions.

The Likert survey is spitted in a list of Green supply chain practices previously analysed (i.e. reverse logistics, supplier collaboration) as showed below. Following tables show the Likert survey of the research.

Two main questions were asked to the subject:

1) Is IoT technology implemented for thus GSCM practice?

2) How positive would you define the IoT impact on this practice?

Question number 1 can be answered using the following five-point Likert-type scale:
(1 = not considering it, 2 = planning to consider it, 3 considering it currently, 4 = carrying out to some degree, 5 carrying it out fully)
Question number 2 can be answered using the following five-point Likert-type scale:
1 = not at all, 2 = a little bit, 3 = to some degree, 4 = relatively significant, 5 =significant

	Is IoT technology implemented for this GSCM practice?				
	Not considering it	Planning to consider it	Considering it currently	Carrying out to some degree	Carrying it out fully
1. Green Design	1	2	3	4	5
2. Green Procurement	1	2	3	4	5
3. Green Manufacturing	1	2	3	4	5
4. S/C Collaboration	1	2	3	4	5
5. Reverse Logistic	1	2	3	4	5

Table 1: The level of IoT implementation in GSCM practice

	How positive would you define the IoT impact on this practice?				
	Not at all	A little bit	To some degree	Relatively significant	Significant
1. Green Design	1	2	3	4	5
2. Green Procurement	1	2	3	4	5
3. Green Manufacturing	1	2	3	4	5
4. S/C Collaboration	1	2	3	4	5
5. Reverse Logistic	1	2	3	4	5

Table 2: IoT impact on GSCM practices

In order to gather a comprehensive data of the IoT impact in GSCM, a second list follows, reporting disadvantages and issues. The following question was asked, to gain a quantitative grade of negative impact of IoT adoption:

3) Has IoT created the following issue within the company?

	Has IoT created the following issue within the company?				
	Not at all	A little bit	To some degree	Relatively significant	Significant
1. Security	1	2	3	4	5
2. Privacy	1	2	3	4	5
3. Skill gap	1	2	3	4	5
4. Management	1	2	3	4	5

Table 3: IoT issues within the company

The author conducted semi-structured interviews although all questions were prepared in advance to ensure the interview flowed like a conversation.

The following interview questions were prepared to cover and gain insight of all the research aspects:

PHARMACEUTICAL COMPANY

IoT implementation

i. When did the company start using IoT technology?

ii. What was the major driver for the adoption of this technology along the supply chain?

iii. How much budget / effort has been dedicated to the implementation of IoT technology?

iv. How IoT adoption impacted the business?

v. Does the company plan to implement this technology to improve any other aspect?

vi. Have you experienced any problems using IoT technology?

IoT in GSCM Practices

vii. How IoT improved Green Design?

viii. How IoT improved Green procurement?

ix. How IoT improved Green manufacturing?

x. How IoT improved supplier and customer integration?

xi. How IoT improved Reverse Logistics?

xii. Why do you think IoT has an overall positive/negative impact to improve GSCM practices?

xiii. Have you experienced any problems in adopting IoT in the GSCM?

xiv. How the company faced and resolved these challenges?

xv. Do you think the company will intensify the use of IoT to improve GSCM practices and sustainability?

PUBLIC HEALTHCARE (DISTRIBUTOR CENTER)

i. Are you directly expose to IoT technology implemented by pharmaceutical companies?
ii. When did you start to see a massive implementation of IoT technology?
iii. How IoT technology has been implemented by pharmaceutical companies?
iv. How wide is the use of IoT technology for reverse logistic?
v. How wide is the use of IoT Technology for waste management?
vi. Do you think IoT technology has a positive impact? If yes, why?
vii. Have you experienced any problems using IoT technology?
viii. Do you think Pharmaceutical companies could do more to improve sustainability?

3.4.2 ACCESS AND ETHICAL ISSUES

The significant success of the research relies on accessing valid data sources. There are distinctive strategies that can help to research proper data (Saunders et al., 2009). This research proposal focuses on survey and interview methods, following a specific data collection strategy.

There are several ways to achieve successful survey data results. It is important to have a clear and narrow definition of survey objectives; it can help to gain right data results. Identification of right audience is as important as survey objective; it can hugely impact survey results. Furthermore, adequacy of question is necessary to achieve significant results in research. Although, testing survey may not see necessarily before the real practices, it is important to test on different platforms due to lack of technology.

There are several key issues to gain access to data, such as organisation may not wish to allocate sources due to sensitivity of the data. In terms of ethical issues, all the participants of the survey and relative firm have the right to remain anonymous (Saunders et al., 2009). Therefore, the author is responsible to ensure the keeping safe all personal and confidential data in order to avoid breach of data protection.

3.5 DATA ANALAYSIS

The survey has been set out to discover which IoT solutions are used in pharmaceutical GSCM. To be able to determine the positive impact on every GSCM practices. In regard of quantitative data, mean scores is computed from the responses given by all the respondents on the Likert Scale. The factors scoring higher mean value, for each objective, were assumed to be the ones with the most significant effect.

An integration of quantitative and qualitative data is performed to understand the negative impact of IoT adoption; a general quantitative impact factor is gathered by the 3rd question, then further qualitative date (ad doc interview) is used to understand the effect of the negative impact on the Green supply chain and where along the supply chain has caused damage.

Further qualitative data through the interview, is necessary to understand why the interviewee has expressed “significant” or “not at all” impact on specific GSCM practice.

CHAPTER FOUR: FINDINGS AND DISCUSSION

4.1 FINDINGS

This chapter will explore the interview findings, which are the result of the previously explored conceptual framework. Every finding corresponds to one or more questions answered by each pharmaceutical company involved in the study. The author created two different sets of questions, one set is suitable for company operating in the pharmaceutical sector, the other set is to gather useful information from public healthcare. The author decided to involve public healthcare in the research because it is an essential point in the pharmaceutical supply chain. Distribution centres as public healthcare link directly all pharmaceutical companies to the customers.

The first step was to create the following tables with the data collected, in order to review the validity and provide an overview of information that the interview provided. When the interview did not provide sufficient data, the company was discarded from the study, it is important to note that many positions within the organization have not sufficient background or knowledge of IoT technology and the full supply chain. Furthermore, in order to comply with data privacy requirements was given to the interviewee the possibility to remain anonymous. Disclosure of sensitive data is of particular concern in the pharmaceutical industry.

It is important to note that not all questions were addressed during the interview, due to several reasons: privacy concerns, inapplicability reasons and inadequate knowledge on the topic. The following tables report the addressed questions for each company.

Once the subject of the research was established, to analyse the consistency of the data acquired, a comparative collection of findings was undertaken by the author in order to confirm the hypothesis previously postulated in the research framework.

	Question					
	IoT Implementation					
	1	2	3	4	5	6
Pfizer	X	X	X	X	X	X
Novartis	X	X	X	X	N/A	X
BIEM	X	X	N/A	X	X	X

Table 4: IoT Implementation Questionnaire responses

	Question								
	GSCM and IoT								
	7	8	9	10	11	12	13	14	15
Pfizer	X	X	X	X	X	X	X	X	X
Novartis	X	X	X	X	N/A	X	X	N/A	X
BIEM	X	X	X	X	X	X	X	N/A	X

Table 5: GSCM and IoT Questionnaire responses

Overview of Companies

Pfizer is an American biopharmaceutical company that operates globally, with headquarter in New York city and over 96.599 employees is one of the biggest pharmaceutical company in the market.

The company develops and produces medicines for a wide range of medical disciplines, including immunology, oncology, cardiology, endocrinology, and neurology. Well know products are Lipitor, Lyrica, Viagra, Celebrex, Xerox. Pfizer has major manufacturing facilities in Belgium, China, Germany, India, Ireland, Italy, Japan, Puerto Rico, Singapore, and the US. In all, it operates 63 plants around the world, and IoT is being used on different aspects along the supply chain.

The author's contact in this firm was the Supply Chain Lead Network Solutions for EMEA distribution, he is responsible to deliver Supply chain operations across over 20 countries.

The person for data privacy reasons wished to remain anonymous. For simplicity, the author will refer to the company and not the person. The interview was conducted by means of email correspondence, after detailed research information at current data was shared. The author on all the questions forwarded to the interviewed person obtained detailed data.

Novartis is a Swiss pharmaceutical company operating worldwide, with 129.924 employees and their presence on the market in 155 countries. Novartis aims to improve and extend people's lives, using innovative technology and breakthrough science. This organization develop and produce transformative drugs and innovative treatments in various filed as oncology, respiratory, immunology, neuroscience and cardiovascular. Well-known medicines are Gilenya for multiple sclerosis and Gleevec cancer drug.

The author's contact in this firm was the clinical quality and data specialist in Novartis, he is actively involved in clinical trials, data analysis from manufacturing sites, and identification and resolution of error/ inconsistency to ensure high quality. The person for data privacy reasons wished to remain anonymous. The interview was conducted via phone and a transcript created.

BIEM is a medium sized Turkish pharmaceutical company with headquarters in Ankara, is a privately held pharmaceutical company engaged in manufacturing, distribution and marketing of pharmaceutical and healthcare products. BIEM is conducting its operations in North America, Chile, CEE, Russia, South Africa, ASEAN, MENA and CIS countries, either through distributors or its own affiliates. The company develops and produces wide range of medicines including biologicals, oncology, haematology, ophthalmology, radiology and gynaecology. Well known medicines are Beastin, Biemefrin, Biemoxol, Biemib, Biemparin, Buslera, Calsipar, Caspobiem, Conjiten, Desibem, and Zaridinex.

The author's contact in this firm was the procurement and logistics manager in BIEM pharmaceuticals. The person for data privacy reasons wished to remain anonymous. The interview was conducted via phone and a transcript created.

Public Healthcare

The author's contact in the public healthcare was Mrs. Adriana Panettieri, head of maternity department in a public hospital in Italy, the interviewee is responsible to lead the department, organize stocks and inventory maintenance. The interview was conducted via mail due to unavailability of the interviewee. Maternity department specializes in caring for women during pregnancy and childbirth and provides health care services for infants. The maternity units is composed of 30 employees and registered during 2019 circa 220 birth and was responsible to cure over 150 complicated maternities cases.

1. IoT Technology: Major Drivers and When

This finding was the result of the following two questions:

When did the company start using IoT technology?

What was the major driver for the adoption of this technology along the supply chain?

According to the author's contact in Pfizer, the company is constantly looking at emerging technology and new possibilities to improve the supply chain. In the scope of this journey, IoT technology was adopted to digitize the supply chain several years ago, no precise timeline was provided.

The main reason to implement IoT was to create a highly interconnected supply network, a full end-to-end visibility of the supply chain, from the internal stakeholders to the customers.

The interviewee highlighted that having an interconnected supply chain is critical in an industry where the product saves human life, and it is highly subjected to customer demands.

A highly interconnected network of supply/costumer information has been pointed out to be the key factor to a successfully supply of medicines, which improve and save lives.

At the same time, the company can exploit end-to-end highly orchestrated supply network to improve its processes by focusing the efforts where they are most needed (Pfizer, 2019).

In terms of Novartis the interviewee was unsure on the start date but revealed two open collaborations involving IoT. The first is with Amazon Web Services (AWS) and the second one is implementing Artificial Intelligent (AI) with Microsoft, both of them to strengthen manufacturing and supply chain operations. This suggests that not only the technology was implemented in the past, but also it is the base to enable innovative technology as Artificial Intelligence (Novartis, 2020).
The author's contact justified the use of such technology and in general emerging digital technologies as a powerful tool to help organisations improving drug discovery and development process. This suggests that the key factor leading to innovative technologies was initially focused on productivity and business grow. Furthermore, he cited technologies that became standard for every pharmaceutical company to achieve competitive advantage, such as vision systems, smart package.

According to, author's contact in BIEM, a specific date or year was not indicated in terms of IoT application in the company, but interviewee articulated that the company started the production in 2011, since then adopting new technologies to support an efficient manufacturing, procurement and logistic activities was inevitable (BIEM, 2020).

With regards to public healthcare employee Mrs. Panettieri, basics tags systems were in use far before 2010 and new technology implementation has been in use since 2010 (Panettieri, 2019).

2. IoT Impact on The Business

This finding was the result of the following two questions:
How much budget / effort has been dedicated to the implementation of IoT technology?
How IoT adoption impacted the business?

The Pfizer employee was not able to provide budget info, but he clarified that when new technology is brought into every organization a huge effort from the company and employees is required to resolve incompatibilities with older technologies. Moreover, he highlighted the additional cost required to keep technologies up to date. This was in accordance with Novartis opinion: innovative technologies require great effort, time and expense.
However, IoT technology had a positive impact on the business in many ways, according to author's contact in Pfizer logistics efficiency improved, with systems such as 'pick by voice'; real-time visibility tools also enabled by mobile technology as smartphone or tablet. In particular the whole underlying infrastructure of data capturing, and advanced analytics gave to the business infinitive possibility of improvement. The responder pointed out that this technology enabled incredible monitoring and control capabilities with temperature-sensitive drugs, active cooling and real-time temperature (Pfizer, 2019).

With regards to Novartis, author's contact explained to the author that nowadays is hard to find a business without using these technologies. It is just not pharmaceuticals but also every business uses those technologies to achieve daily business activities. The interviewee clearly stated that all those technologies give an opportunity to strengthen communication and better management system (Novartis, 2020).

In terms of BIEM, the budget was not provided, the interviewee simply clarified that 'implication of such technology cost is significantly high, and the company has not adopted fully IoT technology yet, for this reason it is hard to answer the insight impact- we have general positive results till now in the area where such technology has been used' (BIEM, 2020).

From the public healthcare point of view Mrs Panettieri explained that IoT is in use to tracing medical devices and the drugs this '…helps to manage quickly drugs and instruments, reduce lost and waste' (Panettieri, 2019).

3. IoT Technology Challenges

This finding was the result of the following questions:
Have you experienced any problems using IoT technology?
Have you experienced any problems in adopting IoT in the GSCM?
How the company faced and resolved these challenges?

All of three interviewees agreed that when introducing a new technology in a well consolidate infrastructure, it is inevitable to face challenges and technical issues.
The contact in Pfizer called out as main problem, the number of different systems into play, which made the interconnection of the supply network extremely difficult. This is usually linked to introduction of new technology over time and the need to keep the infrastructure up to date.
Another key barrier that Pfizer is facing when using IoT is guarantee patient's confidentiality, which also explains why it is so difficult for pharma to draw point-of-sale data for demand-sensing purposes. To resolve those challenges, Pfizer decided to put effort into unify the infrastructure towards a unique ERP system, covering financial, commercial and manufacturing sides of the business (Pfizer, 2019). According to the contact in Pfizer the digitization and full end-to-end connectivity of the supply chain was possible only through a huge effort of all the members in the organization, a continued leadership focus and enthusiasm by top management.

In the case of Novartis author's contact made a fair point and example, the interviewee is a data analyst and he personally faced issues using data from sensors in the clinical trial, he clearly stated that the outcomes do not meet the expectation all the time (Novartis, 2020). This clearly means that the expectation is not always achieved when implementing innovative solutions.
The interviewee clarified that the challenges are related to the technology, and not to a sustainable implementation, the author would like to point out that the interviewee did not respond when asked how the company faced those challenges.

In terms of BIEM, the interviewee explained that the company did not experienced major problems using IoT, but proper training was necessary to adopt and efficiently use it. Another important aspect pointed out by the interviewee was that cost and expectation must be well planned by the company before adopting innovative technology (BIEM, 2020).

According to Adriana Panettieri, simple technology implemented by pharmaceutical companies is easy to manage, more complicated once require additional expertise (Panettieri, 2019).

This finding was enriched with quantitative data obtained from the following Likert scale questions:
Has IoT created the following issue within the company?
This question can be answered using the following five-point Likert-type scale:
1 = not at all, 2 = a little bit, 3 = to some degree, 4 = relatively significant, 5 =significant
This question was useful to the author to identify the negative impact of IoT when adopted by the company. The following Chart (1) shows the level of negative impact for each challenge.
It is important to clarify that quantitative data has been analysed by the author only for the three pharmaceutical companies, the public healthcare has not been included.

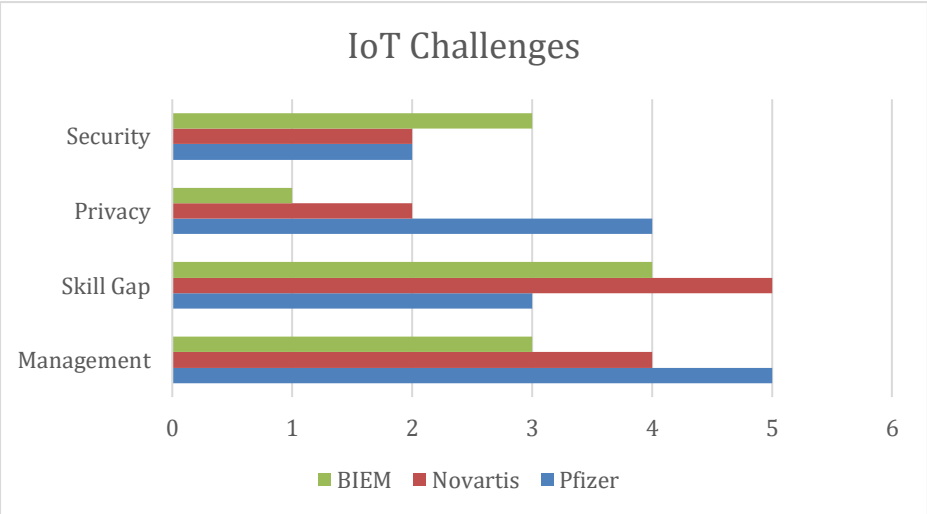

Chart 1: IoT challenges

In order to analyse the results, the author utilized a mean value for each IoT issue:

$$Level\ of\ negative\ impact = \frac{Sum\ of\ all\ likert\ results\ for\ each\ issue}{Number\ of\ companies}$$

"Security" has an overall *Level of negative impact* of about 2.33, "Privacy" has a *Level of negative impact* of about 2.33, "Skill Gap" has an overall *Level of negative impact* of about 4, "Management" has a *Level of negative impact* of about 4.
This quantitative data proves to the author that "Skill Gap" and "Management" are the most relevant concerns for organization when adopting IoT technology. This finding was also confirmed during the interviews.

4. Impact on Green Design

This finding was the result of the following question:
How IoT improved Green Design?

According to the contact in Pfizer, the company is collaborating with IBM to use IoT technology to develop drug and clinical therapies for Parkinson disease, IoT will enable remote measurement of health and quality of life in real time to speed up the clinical trials and new therapeutic decisions.
The interviewee clarified that developing new drugs usually involves a long trial period, which is by nature carbon intensive: trial related travel, team commuting, distributions, energy consumption and coordinating centre premises. Clinical trials contribute substantially to greenhouse gas emissions, some consumption can be reduced using renewable energy sources, but a more effective way to reduce carbon emission is simply reducing trials time (Pfizer, 2019).

The contact in Novartis on the other way, did not provide a specific IoT application that helps developing new drugs in a sustainable manner, but the interviewee expressed that "IoT in conjunction with AI help tracking and analysing carbon emission in real time. Furthermore, thanks to such technology the company is able to understand supplier performance and align them to follow best practices" (Novartis, 2020).

With regards to BIEM, the interviewee explain that the company did not obtain innovative technology in terms of Green Design practices due to high expenses and uncertain results.

5. Impact on Green Procurement

This finding was the result of the following question:

How IoT improved Green Procurement?

According to the author's contact in Pfizer, such technology supported the company to achieve a sustainable procurement evaluating external vendors with real time and remote monitoring, in this way the organization is able to assure correct and sustainable sourcing, at the same time, this saves money, reduce waste and improve competitiveness. As explained by the interviewee external benchmark of research and manufacturing sites are conducted for evaluating sustainability and supply chain management operations, KPI and risk management are main indicators for a sustainable and responsible supplier (Pfizer, 2019)

In term of Novartis, there is high collaboration between the company and suppliers in order to achieve sustainability. Specifically, the interviewee mentioned that 'using smart warehouse makes easier and more efficient to monitoring and tracking our asset achieve sustainability, avoiding shortage or overload' (Novartis, 2020). It is transparent that IoT technology is used for monitoring and tracking purpose and an integration of information between supplier and the company is helping to achieve sustainable procurement.

In sequence, the contact in BIEM explained that IoT widely in use to trace and monitor the entire supply chain such as sensors to control temperature or identify the damage.

The interviewee expressed that "tracing and monitoring our goods give us a competitive advantage on procurement and logistics, reducing costs and waste. This of course makes logistics and procurement operation more environmentally friendly" (BIEM, 2020).

6. Impact on Green Manufacturing

This finding was the result of the following question:

How IoT improved Green manufacturing?

Pfizer interviewee highlighted that IoT helps to support green manufacturing in various way in the company. Moreover, the implications and the benefit of the IoT was explained in detail by the responder "Our organization requires its facilities worldwide to quantify water use, report performance against reduction targets, IoT can enable data collection scope for water metrics to align more closely with those of the Global Reporting Initiative. IoT application helped us to understand water-related risk and opportunities in our operations. Sustainability of the manufacture plants are achieved also reducing energy consumption and carbon emission, intelligent sensor and monitoring has a key role" (Pfizer, 2019).

Regarding Novartis, the interviewee expressed his knowledge “Well, environmental sustainability is a growing concern in many manufacturing companies including pharmaceuticals. Facilities and operations may require great amount of energy and water usage. Unfortunately, this situation cause to increase carbon footprint and waste. We use IoT to improve our conserve resources in the green manufacturing process such as energy and water. We have already made significant progress toward reducing water, energy and waste. Also, thus improved carbon footprint. Another major area of concern for the organization is water quality and preventing pharmaceutical to enter into the environment, technologies as IoT help us monitoring, control and achieve our reduction target” (Novartis, 2020).

With regards to BIEM, the interviewee pointed out that IoT has a contribution in order to achieve sustainability in the manufacturing activities. Those activities addressed by the responder as; energy efficiency, identify quality issues, maintain warehouse inventories and asset management. In addition, she underlined as follows: ‘Let’s say that IoT is intervening massively in our manufacturing plants’ (BIEM, 2020).

7. Impact on Supplier Customer Integration

This finding was the result of the following question:

How IoT improved supplier and customer integration?

This question was responded by the Pfizer interviewee “Our organization is active in more than 175 countries and with a product line of more than 24,000 SKUs, we’re talking about a highly complex supply chain. IoT flexibility and the possibility to interconnect via Internet worldwide sites and different stakeholders is the real added value of this technology” (Pfizer, 2019).

When the author asked this question to the contact in Novartis the respond was not clearly addressed the implications of IoT in supplier and customer integration. However, the interviewee predicted as follows: “I think that IoT sensor as a point of contact to sites worldwide and management software, which is able to join all that information are essential to have a company high view and so integrate the info from supplier to customer. Information is really powerful!” (Novartis, 2020).

The contact in BIEM simply acknowledged this question as follow: “Regarding to, green business and corporate responsibility one of the most important terms is transparency. Using IoT technology gives us fully transparency across the value chain, which is from the source of raw materials, production line, warehouse, transportation to consumers and end of life” (BIEM, 2020).

8. Impact on Reverse Logistics

This finding was the result of the following question:

How IoT improved Reverse Logistics?

According to Pfizer respond IoT technology plays a crucial role due to visibility and monitoring of the drugs in order to carry out reverse logistic activities.

The interviewee mention that the success of a reverse logistics in a globalized world, depends by the connection and integration of the various stakeholders and customers. The end-to-end visibility of the drugs from the vendors to the consumer would tackle down the reverse logistic complexity (Pfizer, 2019).

In terms of Novartis, the interviewee was not sure due to his knowledge and position.

As stated by BIEM, IoT technology is not directly used for reverse logistics. The interviewee pointed out that reverse logistic is a tough approach in pharmaceutical industry in terms of recalling drugs and explained as follow: "…recalling is possible from healthcare institutions and retailers, but not from patients. It is hard to recall from patients; they are not always aware how to safely dispose drugs. IoT can only intervene facilitating the process" (BIEM, 2020).

Finally, Mrs. Panettieri confirmed that such technology is widely used to trace drugs. This capability in conjunction to proprietary management software is improving reverse logistic from the hospital to the pharmaceutical company. Instead, from a waste management point of view, the interviewee explained that 'IoT can intervene in tracing contaminated pharmaceutical products including vaccines and biological products used for therapy' (Panettieri, 2019).

9. Overall impact on GSCM

This finding was the result of the following question:

Why do you think IoT has an overall positive/negative impact to improve GSCM practices?

The contact in Pfizer clearly highlighted that '…I definitely consider IoT impact widely positive' and counited to explain that "monitoring, traceability, and remote control are brought to a brand new level and this has a positive impact to all sustainable practices as could be waste management, energy reduction, drugs manufacturing and sustainable procurement" (Pfizer, 2019).

Regarding to Novartis, the respond was optimistic and the author's pointed out that IoT helps to collect data in order to improve sustainability in the company.

Similarly, regarding to BIEM pharmaceuticals, the author's contact stated that "I believe that IoT has a positive impact when it comes to sustainability, it is a technology that enables several aspects: tracking, monitoring, improving efficiency and overseeing all the supply chain operations" (BIEM, 2020).

According to Panettieri, IoT technology had overall positive impact, traceability and management of drugs has extremely improved the sector. The interviewee clarified that challenges are inevitable when adopting complicated technology, but the overall impact remain extremely positive.

This finding was enriched with quantitative data obtained from the following two Likert scale questions:
1. Is IoT technology implemented for this GSCM practice?
2. How positive would you define the IoT impact on this practice?

Question number 1 can be answered using five-point Likert-type scale:
(1 = not considering it, 2 = planning to consider it, 3 considering it currently, 4 = carrying out to some degree, 5 carrying it out fully)
This question was useful to the author to obtain a high view of IoT utilization within the organizations.
Question number 2 can be answered using the following five-point Likert-type scale:
1 = not at all, 2 = a little bit, 3 = to some degree, 4 = relatively significant, 5 =significant
This question was useful to the author to understand on which practice, IoT had a significant impact.

The following Chart (2) shows the IoT utilization degree, for each GSCM practice considered in this study, it is important to clarify that quantitative data has been analysed by the author only for the three pharmaceutical companies, the public healthcare has not been included.

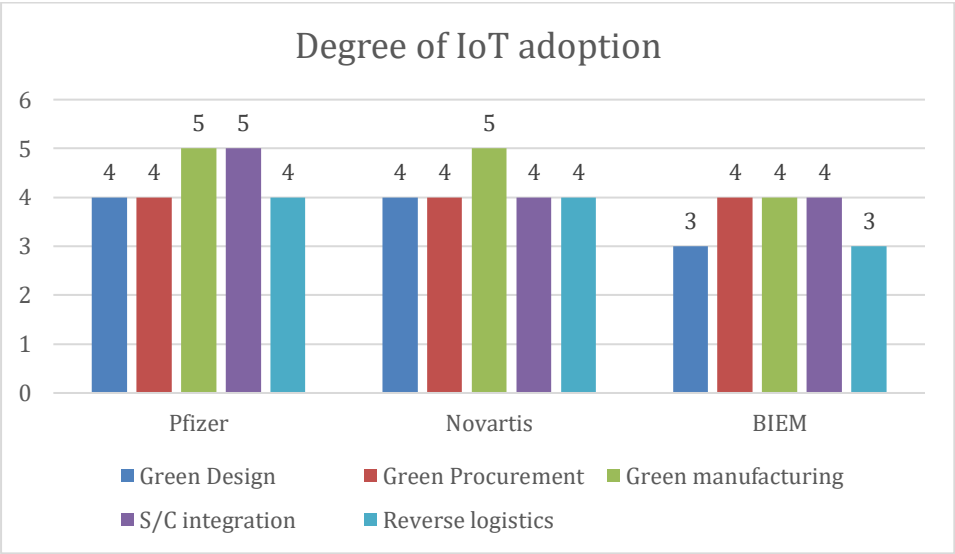

Chart 2: Degree of IoT adoption

In order to analyse these results, the author utilized a mean value for each company:

$$Degree\ of\ IoT\ utilization = \frac{Sum\ of\ all\ likert\ results\ for\ each\ Company}{Number\ of\ GSCM\ practices}$$

Pfizer's *Degree of IoT utilization* is of about 4.4, Novartis's *Degree of IoT utilization* is of about 4.2, BIEM's *Degree of IoT utilization* is of about 3.6. This quantitative data proves to the author that larger pharmaceutical companies as Pfizer and Novartis have a higher degree of IoT utilization, to support supply chain operations. This is easily confirmed by the fact that smaller companies have lower funds and possibilities to invest in innovative technologies such as IoT.
Moreover, from the above Chart (3), the author was able to identify Green Manufacturing and Supplier Customer Integration as the practices with higher attention and investment.

In term of IoT impact on GSCM, the second question was used by the author to obtain the following chart, which shows the degree of IoT impact on each GSCM practice.
From the below chart, the author extrapolate the Mean value for each practice, in order to understand on which practice IoT has higher impact.

$$Degree\ of\ IoT\ impact = \frac{Sum\ of\ all\ likert\ results\ for\ each\ GSCM\ practice}{Number\ of\ companies}$$

Green Design's is of about 4. Green Procurement's *Degree of IoT impact* is of about 4.67. *Degree of IoT impact* on Green Manufacturing is of about 4.34. *Degree of IoT impact* on Supplier customers integration is of about 4.67. *Degree of IoT impact* on Reverse Logistic is of about 3.67

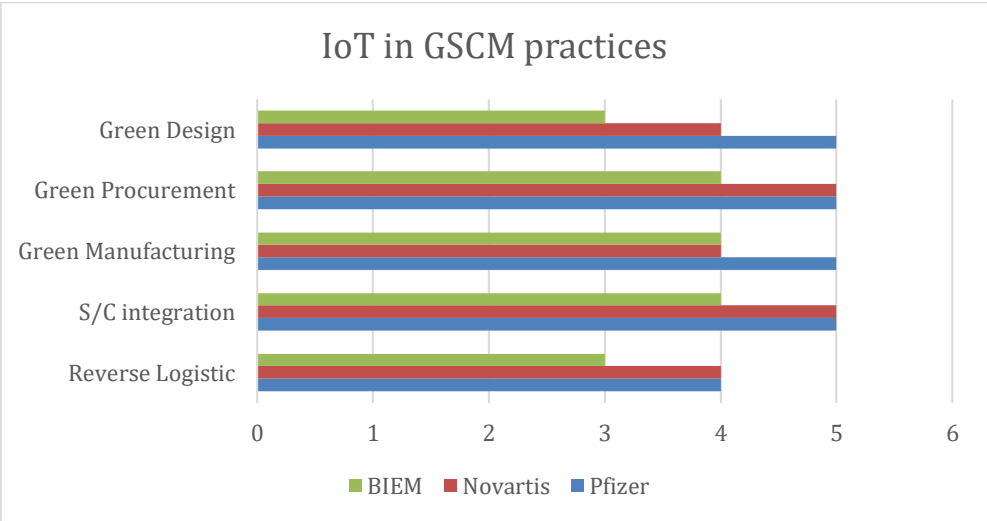

Chart 3: IoT in GSCM practices

From the calculated data the author established that Green Procurement and Supplier Customer Integration were the practices with the higher IoT impact factor. Similarly, the author identified that IoT technology is slightly less effective on Green Design and Reverse Logistic.
The overall impact of IoT on the totality GSCM practices is relatively significant with a Degree of IoT impact equal to 4.27.

10. Future Possibilities

This finding was the result of the following questions:
Does the company plan to implement this technology to improve any other aspect?
Do you think the company will intensify the use of IoT to improve GSCM practices and sustainability?

The author was able to gather insight on future possible implementations of IoT from Pfizer. The contact in the company expressed possible involvement of such technology in the next big pharmaceutical development, DNA-based diagnosis and drug development, which will create personalized medicines. In regard of sustainability and environmental impact the interviewee expressed a strong interest to continue investing in this technology, due to IoT flexibility and the contribution to fight carbon emission, improve waste management, reduce energy consumption and reduce trial times (Pfizer, 2019).

In terms of Novartis, the interviewee did not express how the company plan to implement this technology in the future, but he clarified that if the technology brings value to sustainability and cost is justified, there is no reason to not consider IoT for future implementations.

According to BIEM employee, the company is aware of IoT potential, for this reason expanding the use of such technology on a wider range of operations is under consideration. Furthermore, the company firmly support sustainability conscious that it does not only protect the environment, but it also adds value to the business, to achieve sustainability technology is essential (BIEM, 2020).

The Table (6) below illustrates six essential matters of IoT implementation which are: when, major drivers, how, cost/effort, impact, problems/challenges, future possibilities for each company and public health care centre.

	Pfizer	Novartis	BIEM	Public healthcare
When	Several years ago, but always looking for innovation.	Unsure on start date, but currently expanding it.	Since the company start manufacturing in 2011.	Basic tags before 2010, innovative applications since 2010.
Major Drivers	Improve processes, create a full end-to-end visibility of the supply chain.	Productivity and business grow. Expectation from the sector.	Efficient manufacturing, procurement and logistic activities.	N/A
How	Digitalize the full supply chain, ERP system, 'pick by voice', real-time visibility etc…	Enabling Cloud solution (AWS) and AI. Supporting clinical trials, vision systems, smart package etc…	N/A	Manage drugs and medical devices.
Cost / effort	Expensive	Expensive	Expensive	N/A
***I*mpact**	Logistics efficiency, monitoring and tracking capabilities.	Improve management, strengthen communication.	Positive results where IoT was implemented.	Reduce lost and waste, improve management.
Problems / challenges	Integration of new technology in existing environment,	High expectation, data accuracy in clinical trials.	Training staff, cost and expectation.	Training staff.
Future possibilities	Innovate drug development, support sustainability.	Only if brings actual value to the company and cost is justified.	Expand utilization on a wider range of operations, support sustainability.	N/A

Table 6: IoT technology interview findings

The author was able to produce through interviews the below comprehensive Table (7), which explains how IoT technology actually supports GSCM practices in each company.

The author derived for each GSCM practice common findings between the pharmaceutical companies and the public healthcare. These were used to create a general overview of the current scenario of IoT impact on GSCM practices. The author would like to clarify that data gathered were from three pharmaceutical companies and one distributor centre (public healthcare).

From the findings and consequent Table (7), the author was able to summarize that IoT is enabling a Green Design of pharmaceuticals by reducing clinical trials times and resources, monitoring environmental risk and enabling Artificial Intelligence, which can improve development of new drugs. Instead, in term of smaller company as BIEM applying IoT to develop new drugs can result in high cost and uncertain results.

With regard of Green Procurement: IoT enables monitoring of suppliers / 3rd party companies for sustainable benchmark, monitoring inventory levels and tracking assets. IoT allows also the companies and distributor centres (public hospital) to reduce costs and waste. Finally, IoT enables supplier collaboration, in this way the companies effectively reduce overload and shortage.

IoT intervene in several manufacturing aspects, creating a sustainable manufacturing, such technology allows monitoring and reduction of water and energy consumptions; in general, it can help reducing the company carbon emission through monitoring and control. Furthermore, monitor capabilities can actually help the company to identify pharmaceuticals level released in the environment from manufacturing sites so to undertake corrective measures.

Supplier and customer integration can be achieved using IoT technology in conjunction with unified system such as ERP, which enables the company to cover all business sides and create an end-to-end supply network. Furthermore, thanks to IoT solutions information can be collected worldwide and integrated in real time through internet. The sustainable value of the company resides in the visibility and transparency across the value chain and this can be achieved using IoT along the supply chain. In terms of public healthcare, the integration of supplier to customer information is enabled by pharmaceutical companies with the use of IoT solutions. Such implementations on drugs and medical devices support sustainability, improving inventory management and reducing loss of medicines and devices.

Finally, IoT is impacting Reverse Logistics indirectly, this GSCM practice is successful when a fully digitalized end to end supply chain is in place, and such ambitious achievement can be possible using IoT. This is confirmed by two companies, IoT can actually facilitate the reverse logistic process when the supplier customer chain is integrated and digitalized.

	Pfizer	Novartis	BIEM	Public healthcare
Green Design	Reduction of clinical trials times and resources.	Environmental risk assessment, safe disposal, enabling AI.	Not implemented due to high cost and uncertain results.	N/A
Green Procurement	Benchmark external facilities and 3rd party companies	Monitoring and tracking assets, supplier collaboration.	Reducing costs and waste monitoring and tracking	Monitor of inventory levels, reduces overload and shortage.
Green manufacturing	Water and energy consumptions, carbon emission.	Reduce energy and water wastes, pharmaceutical in the environment.	energy efficiency, identify quality issues, warehouse inventories, assets management	N/A
Supplier / customer integration	Unified ERP System covering all business sides and create a E2E supply network	Gather information worldwide and integrate info.	Visibility and transparency across the value chain.	Inventory management reduces loss of medicines and devices.
Reverse logistics	Reverse logistics thrives with a fully digitalised E2E supply chain.	N/A	Facilitate the process from distributor centres. Not implemented on customers.	Reducing lost and waste

Table 7: IoT findings in GSCM practices

CHAPTER FIVE: CONCLUSION

The primary goal of the research was to explore Internet of Things technology and its role in Green Supply Chain Management practices. The empirical study was conducted in the pharmaceutical industry through examination of three pharmaceutical companies and one public healthcare centre. Moreover, the study focused on the practical challenges faced by pharmaceutical companies when adopting and implementing IoT technology.

The author compiled a series of conclusions, based on the findings derived by primary and secondary sources.

Implementation and Drivers of IoT

Adoption of IoT technology in pharmaceutical companies has started several years ago, but the revolution in this sector has not concluded yet. Companies are constantly looking for innovation, and IoT is an essential enabler of novel solutions such as Cloud Computing and Artificial Intelligence.

The major drivers for adopting such technology in the pharmaceutical industry were related to the competitive advantages that organizations aimed to achieve. The goals that pharma organisations pursued range from creating end-to-end visibility of the supply chain to increase productivity and efficiency of manufacturing or logistic activities. For such scope, companies have implemented several solutions involving IoT: ERP system, 'pick by voice', real time visibility, AI to develop new drugs, smart warehousing, cold chain sensors / actuator etc.

Barriers Against IoT

A common finding of this research was that innovative technologies always required great effort, time and expense for the company. Moreover, it has been identified that when considering innovative technologies such as IoT, an extensive cost-benefit investigation is essential to achieve successful results. In some practical cases, the outcomes when using IoT technology did not meet the expectation all the time. This was the case of data accuracy of IoT solution in clinical trials. This clearly means that the company expectation is not always achieved when implementing innovative solutions. In conclusion, qualitative data provided additional challenges related to IoT that the author did not considered. Instead, the analysis of both quantitative and qualitative data confirmed management of IoT technology and skill gap as the most challenging matters. A common finding within all the interviews was that introducing a new technology in a well consolidate infrastructure inevitably creates challenges and technical issues.

IoT and GSCM practices

The primary and secondary data established that there is a positive and significant impact of IoT on Supplier and Customer Integration in a successful GSCM practices. IoT helps to improve visibility, transparency of the entire supply chain and it enables to gather data worldwide.

Multinational organisations such as Pfizer and Novartis have a complex supply chain, flexibility and possibility to interconnect worldwide sites and various number of stakeholders is extremely important. The exploratory data proved that IoT has an overall positive impact on sustainability initiatives such as tracking and reducing carbon emission, resource conservation and waste management. Although, Reverse Logistic is a challenging subject for pharmaceutical industry, IoT improves the digitalisation of E2E supply chain and reduces loss and waste in the distribution. Moreover, the specific technology helps to monitor in real time warehouse and logistic operations e.g. monitoring and tracking sensitive drugs in controlled zones.

This research also states that challenges of IoT implementation are strictly related to the technology and not to application of such technology in GSCM practices. A series of additional issues were discovered due to IoT technology, but none of them were exclusively related to GSCM practices. This suggests that when technological challenges are resolved, the overall negative influence of using IoT to support GSCM practices is reduced to minimal.

Sustainability and Business Value

This research started to explore the major drivers for IoT technology adoption within pharmaceutical companies, proving that organizations were generally looking to increase business value.

This was useful to understand that IoT implementation was not initially driven by sustainability, but it is undeniable that IoT resulted to be a great supporter of GSCM practices and sustainability of the company. To summarise, IoT technology supports business growth, and indirectly enables sustainable practices.

Based on this research, business value can be achieved when the company adopts sustainable practices enabled by IoT. For example, a highly orchestrated E2E supply chain network has a positive contribution to increase business value, but at the same time improves sustainability of the company. The same pattern can be recognized in every GSCM practices and IoT application. The overall positive impact of IoT on the GSCM practices, confirmed that exists a strong relationship between sustainability and business value, when using IoT. From a practical point of view, pharmaceutical companies can seek business value, establishing GSCM practices enabled by IoT technology.

Limitation of The Research and Future Work

This research was based on qualitative and quantitative data, which was obtained from small and large pharmaceutical organisations. The mixed method approach gave to the author a detailed and comprehensive view of IoT impact on GSCM in the pharmaceutical industry. Qualitative data was extremely useful to gather detailed information on IoT solutions, and how such solutions support GSCM in real scenarios. Instead, through quantitative data the author was able to obtain a high view prospective of the research topic.

Future research can use a different methodology or can include a wider statistical sample. It is important to clarify that achieve a high response rate in the pharmaceutical sector was a challenge, due to the technical nature of this research and the availability of interviewees to disclose organization's practices.

A possible development of this research could be obtaining only quantitative data from a more detailed Likert-Scale questionnaire; this would require a larger statistical sample. More specific research can be done separating the findings between small and big organizations and compare these results.

Other possibilities are performing the same research in a different sector or including innovative IoT based technology such as AI and Machine Learning.

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