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Impacts of Industry 4.0 to Supply Chain Management

Case: Automotive Industry

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Abstract

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This research-oriented thesis investigates the manufacturing and supply chain management changes produced by the adaptation of new technologies, with an especial focus on the Internet of Things implementation into operations.

This Bachelor's thesis examines in detail the possibilities for predicting demand, finding the right Forecasting Model, the possible integrations into Inventory Management and other possible business opportunities obtained by implementing Internet of Things technology.

The Business case is the automotive industry, analysing its current status, points of improvement, practical implementation cases and potential obstacles faced for operations and business implementation.

The thesis consists of five elements, an introduction to the thesis, a theoretical part using quality sources, the research methods explained in detail, the presentation of the findings and as the last area of analysis the reader can find the conclusions to the thesis.

The research and analysis methods used were desktop research and qualitative interview. The desktop research was the method used for supporting the theoretical framework, including a systematic literature review to present the desktop findings. Additionally, the qualitative interview was the method used to obtain different angles and perspectives to the desktop findings and recommendations.

As a result, the thesis offers a general overview of Industry 4.0 with a focus on Internet of Things, supported by quality and validated sources. When analysing these disruptive technologies, the author emphasised on the business applications.

Keywords

Industry 4.0, Internet of Things, Inventory management, Smart manufacturing.

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1 Introduction

The method of study for this project is a research-oriented thesis using high-qualitative research bibliography. This thesis is included in the evening Degree Programme in International Business held at Haaga-Helia in which the author is majoring in Supply Chain Management.

Through this thesis, the reader will find useful information referenced to high-qualitative sources, following the main research question and the investigative questions necessary to reach the conclusions for the topic. The background of the study, along with the demarcation, main concepts, international aspect, and theoretical concepts will be explained in order for the reader to get a broad idea of what is this thesis about.

1.1 Background

After analysing the market and looking into what is making the difference nowadays between innovative leading industrial companies and those that aren't making a proper use of the technologies available, the author decided to research more on this topic.

The fourth industrial revolution is taking place nowadays and it is essential for companies to understand it and to adapt themselves to the latest trends if they want to be able to compete in equal conditions with the companies in lead. That is why the concept of Industry 4.0 has been used in order to talk about these changes.

The term Industry 4.0 means "digitization of the manufacturing sector, with embedded sensors in virtually all product components and manufacturing equipment, ubiquitous cyber physical systems, and analysis of all relevant data" (McKinsey 2015.)

There is an increasing gap between edge companies, already adapting these systems, and the traditional companies. This gap needs to be tackled if companies want to keep up on manufacturing efficiency and cost-savings. There are a number of new technologies that companies are using in order to achieve the excellence in production. Technologies like Internet of Things (IoT), sensors, Cloud-based manufacturing, are being implemented nowadays. The focus of this study will be on IoT and its implementation in manufacturing and decision-making for businesses.

In the following years there are going to be massive changes affecting companies and societies, and this is a good opportunity for companies to not only be efficient in cost-saving and increase sales, but also to reduce waste and make a lean Supply Chain.

Lean Suppy Chain is a strategy based on cost and time reduction to improve effectiveness. This strategy emphasises in seeking for simplification, reducing waste and activities that do not add any additional value. (Afonso & Cabrita 2014.)

1.2 Research Question

The aim of this thesis is to explore industry 4.0 on supply chain operations. Through the theoretical part the concepts were analysed in order to achieve clear guidelines on how to apply these technologies from a business perspective. The results are a mix of theoretical studies and a series of interviews that would result in an easy guide to adapt the changes in the industry and improve the SCM channels. Therefore, the main Research Question (RQ) for this project is: **How new technology influence the supply chain demand forecast?**

Being a broad topic and a theoretical thesis, the focus of this study is in three different topics, inventory management, IoT in business and demand forecast. Therefore, the Investigative Questions (IQ) are:

IQ1: What are the common challenges in the inventory management?
IQ2: How does internet of things affect the accuracy in supply chain demand forecast?
IQ3: What are the new sources of revenue for manufacturers implementing Internet of Things?

Table 1 below introduces the Overlay matrix which analyses the theoretical framework, the research methods, and the results to each investigative question.

Table 1. Overlay matrix.

Investigative question	Theoretical Framework*	Research Methods	Results (chapter)
IQ 1. What are the common challenges in the inventory management?	General overview of inventory management and challenges to adapt the latest technologies.	Desktop study using quality sources.	4.1.1
IQ 2. How does internet of things affect the accuracy in supply chain demand forecast?	Trends in demand forecasting. Empirical studies and theories on IoT integration into operations.	Desktop study and qualitative interview.	4.1.2
IQ 3. What are the new sources of revenue for manufacturers implementing Internet of Things?	IoT Implementation benefits in manufacturing and after sales.	Qualitative interview with IoT expert. Desktop study.	4.1.4

1.3 Demarcation

The main theories that are revised in this research-based thesis are the demand forecast, Inventory management solutions, lean manufacturing and new sources of revenue based on the implementation of IoT and Data Management setting the focus in the vehicle manufacturing industry.

The technical analysis of automation and data science is excluded since that would be more for a technical and engineering point of view. The focus is set on the business perspective and the benefits and challenges for companies and societies. There is currently a lack on practical studies that could help a company to understand IoT benefits from a business point of view.

1.4 International Aspect

This paper analyses the possibilities that new technologies are offering companies when it comes to decision-making.

Manufacturing is currently the most international part for automobile companies, being factories allocated overseas, the author will gather information not only from local markets but also from international manufacturers and SCM specialists. The allocation of products and factories is a key element in manufacturing and distribution process and if this could be understood and measured, it can have an enormous impact on businesses.

The leading countries in global car manufacturing in 2019 were China with about 28% of the global production, US with 13% and Japan 10%. (Investopedia 2020.) Regarding the European market, the first manufacturer is Germany, followed by Spain and France (Statista 2020.) These locations are manufacturing most of the vehicles and spare parts to be shipped everywhere in the world. Having a proper data management system and the possibilities that IoT offers in terms of access to real-time information can be a turning point in the vehicle industry.

1.5 Benefits

By understanding these disruptive technologies and their application on business operations, stakeholders might have an overall view of the multiple benefits for the company such as keeping lower inventory levels, improving delivery times, and reducing waste and costs in their facilities. It is clear, especially during the corona pandemic, that automobile companies with efficiency in production have taken the impact in a completely different way that traditional manufacturers.

The aim of this thesis is for companies and in particular SCM and logistics professionals, to understand from a business perspective the benefits that could be implemented by the use of IoT. The benefits among others would be to improve data collection in real-time for decision making, implementing proactive maintenance, predicting different scenarios and sales, and even enhancing product utilization. By having a functional production system this could lead to improve efficiency in processes and to increase customer satisfaction.

As a result of these beneficial aspects, the main advantages for the company are to create new ways of revenue and to reduce costs and waste.

The environmental aspect will be tackled, as a consequence of these changes. Reducing waste, improving delivery processes and managing inventory will have a positive impact for companies and societies.

The benefits for myself would be to gain knowledge in new techniques and inventory management that would be beneficial for my career.

1.6 Risks

The main risk will be in data collection, during this Corona situation, reaching the responsible in decision-making could be challenging. Frequently, the decision for manufacturing allocation and technology implementation is taken from the company management and it could be hard to get in contact with.

Another risk would be when performing the quality interviews to get personal opinions from professionals that aren’t matching their current company strategy.

1.7 Key Concepts

Smart manufacturing, meaning fully integrated, collaborative manufacturing system and process responding in real-time to meet changing demands and conditions in the factory, in the supply chain environment, and in customer needs (Kusiak 2017, 509.)

Internet of Things (IoT) is a network of physical objects, evolved into a network of connected devices of all kinds, communicating and sharing information in order to achieve smart reorganizations, process control & administration, positioning, status tracing, safety enhancement control, and even personal real-time online monitoring (Patel & Patel 2016, 6122.)

Inventory Management in business supervises the flow of goods from manufacturers to warehouses and from these facilities to point of sale. Therefore, it holds detailed records of products or parts as they enter and leave warehouses and points of sale (Pointius 2020.)

Make to Order (MTO) It is a manufacturing process in which the production of an item begins only after a confirmed customer order is received (Investopedia 2020.)

Machine Learning is the concept that a computer program can learn and adapt to new data without human intervention. Machine learning is a field of artificial intelligence (AI) that keeps a computer's built-in algorithms current regardless of changes in the worldwide economy (Investopedia 2020.)

Big data is a term that describes the large volume of data collected that can be structured and unstructured and that affects a business on a daily basis. And that companies need to analyse for taking decisions (SAS 2020.)

1.8 Case Industry

The author’s focus on the topic was set on the automobile industry, and a series of literature studies relevant information were collected and added to the study.

The author decided to research on this field because it is one of the sectors that has had one of the biggest impacts during the pandemic situation and that is influenced among other factors for the large amounts of inventory that some companies had, the different levels of data analysis between them and the changes in lifestyles of consumers.

IHS Markit estimates that due to the pandemic, 2020 global auto sales were declined by 19,8%, decreasing from the 90 million units sold in 2019 to 72 million for 2020 (IHS Markit 2020.)

This research study provides useful information for companies in order to automatize processes, save costs and have a positive impact on societies and the environment by implementing green manufacturing processes.

The areas of implementation of technology in vehicle manufacturing will be focused in this study in predictive demand and trends, Inventory Management and new possible sources of revenue.

The main focus of some manufacturers has been solely the vehicle sale, ignoring the after-sales process and some other sources of revenue. The implementation of technology during the manufacturing process and its implementation in vehicles offers a wide new angle of opportunities for vehicle manufacturers that the author will present for the reader to understand the possible benefits. The implementation of technology in vehicles has been mostly focused on the driver’s and passenger’s comfort and safety (Angelova, Kiryakova & Yordanova 2017, 409.) but could have plenty of new business opportunities.

2 IoT in Business Operations

In this chapter different literature reviews will be discussed in order to understand the opportunities and challenges for IoT application, the technology behind it and benefits for companies based on previous literature analysis and theories.

There are currently plenty of technical analysis of the IoT as a technology, but there is currently a lack of a holistic review of the business applications of IoT for companies. This suggest that this technology has still plenty of open factors to analyse and enormous adaptability.

In this chapter different theories will be presented for a better understanding of the implementation of IoT as a tool for companies in decision-making, manufacturing possibilities and data integration. Possible business model theories to include IoT as part of the core business for companies will be introduced. This is a key element for future applications.

2.1 What is Internet of Things (IoT)?

The concept of Industry 4.0 was a German Government's initiative to gain stronghold in global manufacturing. By applying information and communications systems in manufacturing, the factory environment becomes smart and allows mass customization. (Sanders, Elangeswaran & Wulfsberg 2016, 812.)

One of the pillars of Industry 4.0 for the creation of a fully integrated, automated and optimized production system is the IoT (Vaidya, Ambad & Bhosle 2018, 233 – 236.)

IoT, also known as Industrial Internet, is a new technology paradigm envisioned as a global network of machines and devices capable of interacting with each other (Lee 2015, 431.) These networked smart sensors can identify, network and process vast amount of data which offers new possibilities for business. This technology can collect personalized and optimized customer behavioural data (Ju, Kim & Ahm 2016, 884.)

This global interaction of devices was previously envisioned by Nikola Tesla (1926), during an interview with Colliers magazine.

> "When wireless is perfectly applied the whole earth will be converted into a huge brain, which in fact it is, [...] and the instruments through which we shall be able to do this will be amazingly simple compared with our present telephone" (Postscapes 2019.)

But the term IoT it is considered a creation of Kevin Ashton in 1999 while doing a presentation as executive director of Auto-ID for P&G.

> "I was talking about the supply chain being a 'Network of Things,' and the Internet being a 'Network of Bits,' and how sensor technology would merge the two together. Then I thought of an 'Internet of Things,' and I thought, 'That'll do – or maybe even better.' It had a ring to it. It became the title of the presentation." (Elder 2019.)

The IoT is and will be key to improve people's lives and businesses by streamlining operations. The true value can be understood when connected devices are able to communicate with each other autonomously, and integrate with vendor-managed inventory systems, customer support and business analytics (Lee 2015, 1.) IoT offers a revolution in communications, from human to human, into a thing to thing paradigm.

It is predicted that by 2022 over 18 billion IoT devices will be active around the world. They will provide a global reach across those simple and tiny devices (Novo 2018, 1.)

Firms are investing in IoT to redesign factory workflows, improve tracking of materials, and distribution costs optimization (Gartner, 2014.) IoT is a combination of Internet, connected sensors and near field communications. By joining these technologies, it leads to new business opportunities such as smart homes, real-time logistics planning and factory automation (Ju & al., 2016, 883.)

2.2 Elements for IoT Implementation

IoT is a very complex technology that needs to be understood for business purposes. This technology generates thousands or even millions of interactions and inputs that need to be properly analysed. The information by itself gives no value to the company if it is not interpreted as a mean to obtain the right data for taking decisions or knowing customers better. In this chapter the technologies needed for the deployment of IoT are explained.

The essential technologies will be reviewed such as sensors, software, Cloud services, Radio Frequency identifications, Middleware, and the combination with the increase speed possibilities of 5G networks and the Blockchain technology.

2.2.1 Essential IoT Technologies

According to Lee (2015, 432) there are five essential technologies or categories required for IoT deployment on products or services: These five technologies are:

- Radio Frequency identification (RFID). This technology allows to automatically identify and capture the date by using a tag and a reader. This allows to store more information than a traditional barcode. There are three kinds of tags that can be used for the identification of the data. The passive RFID based on radio frequency, does not require batteries and it is commonly used for example in item-tracking in Supply Chain. The active RFID on the other hand, do require a battery supply tag and can create communications by itself with the reader, and it is used in manufacturing. The third kind is a mix of previous types and it is called Semi-passive RFID, this type requires batteries to power and takes this energy usually from the reader. Having more advanced and powered based technologies, causes a higher price for active and semi-active tags.

- Wireless Sensor Networks (WSN). This technology enables the company to obtain sensor data in IoT environment in order to understand the outside environment information. It plays one of the most important roles in data collection. (Chi, Yan, Zhang, Pang & Da Xu 2014, 1417.) This technology has been used for instance in cold chain logistics to ensure that the temperature has been adequate during the whole transportation process.

- Middleware. This is the software that enables the communication and data management, and allows developers to perform data inputs and create the outputs (Lee 2015, 2.)

- Cloud services. This technology allows the information to be stored and accessed anywhere needed with the help of the powerful computing performance. It is an affordable, secure and efficient technology that allows companies to pay only for the storage of information needed to support their operations. (Belgaum, Soomro, Alansari, Alam, Musa & Suud 2018, 1-2.)

- IoT application software. It facilitates the device-to-device and human-to-device interactions. It needs to make sure that communications are done in a timely manner and that the software process the information in an intuitive way for better decision making. (Lee 2015, 1.)

2.2.2 5G

In this global communication of autonomous devices, the Fifth Generation of cellular networks (5G) plays an extremely important role as an enabler for the deployment of IoT.
The 5G technology promises to download in under one second, the same amount of data that would take 10 minutes with the current 4G. This would be a peak of 20Gb per second (Nordum & Clark 2017, 1.) This internet speed is key for connected devices to connect with each other and to process data effectively.
The 5G technology increases data-rates and improves coverage and performance of the devices. (Shafique, Khawaja, Sabir, Qazi & Mustaqim 2020, 23028.)

2.2.3 Blockchain

Khan (2018, 405) defines blockchain as a decentralized, distributed, shared and immutable database which enables to store registry of inputs and transactions across a network. It provides integrity to the data shared, and protection to the data storage which allows the transparency process. (Wüst & Gervais 2021, 1.)

The secure, decentralized, and autonomous blockchain capabilities make it a pillar for IoT evolution and deployment. It is a distributed database that does not require a central authority to function, or even a third-party verification. Blockchain contains a set of information linked to the previous block where all transactions are visible in the chain (Novo 2018, 1.) The operations are linked to each other via data mining.

It offers a wide variety of applications, from smart-contracts, autonomous trading machine-to-machine transactions, and in Supply Chain is used for tracking automated access control, information sharing and governance of records and data (Khan & Salah 2018, 405.)

When analysed into the IoT context, blockchain is expected to be an essential role in smart contracts by securing the devices and operations (Khan & Salah 2018, 405.) The data generated from the sensors in industrial equipment, automobiles, thermometers or any other digital sensor, is mined in blockchain. This mining operation allows to process and address promptly any possible operational issues, informing managers or machines of short to long term impacts on business activities (Lee 2015, 1.)

2.3 IoT Data Analysis for Business Purposes

Voluminous amounts of data are being collected by the IoT devices. The developing of IoT is rapidly accelerating all technologies and businesses. However, this data is of no use without the analytical power (Marjani, Nasaruddin, Gani, Karim, Abaker, Hashem, Siddiqa & Yaqoob 2017, 2549.)

At this point it is important to understand what data is of use for the company for decision-making. The author Lasse Rouhiainen (2021) creates a categorization of the data comparing complexity and business value:

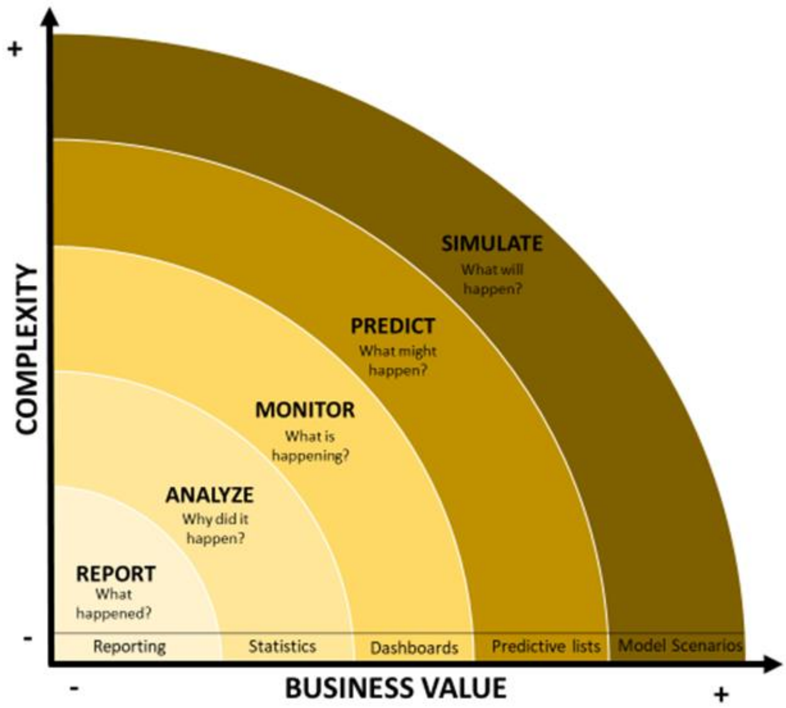

Figure 1. Data Analysis for Business Purposes (Adapted from Rouhiainen, 2021.)

The chart shows how monitoring, predicting, and simulating are the greatest for business value, however, the complexity of the data management obtention is at the same time an obstacle. This is exactly where IoT gives a competitive advantage.

For the volume of data generated by IoT devices, traditional databases are inefficient in storing, processing, and analyzing in real-time vast amounts of “big data” (Marjani & al., 2017, 5248.) Big data analytics is the process of searching, mining, and analyzing data to improve company performance (Kwon, Lee & Shin 2014, 387.)

For analyzing big data, certain technologies and tools are required for transforming those large amounts of structured, semi-structured and unstructured data into an understandable data and metadata for analytical processes. These algorithms have as objective to discover patterns, trends, and correlations in time frames. After analyzing the data, the algorithm is supposed to present the data in real time into tables, graphs and charts for efficient decision making. IoT requires of those algorithms to perform lightning-fast analytics to allow companies to obtain rapid insights, make fast decisions, and allow a smooth interaction with people and between devices (Marjani & al., 2017, 5250.)

2.4 IoT in Manufacturing

Industry 4.0 is combining and integrating physical manufacturing resources with virtual network resources, opening a new manufacturing era. This transformation from traditional to intelligent is being accelerated by the communication technology, virtual technology, and intelligent equipment (Wan, Chen, Imran, Tao, Li, Liu & Ahmad 2018, 1.)

Manufacturing is defined as ”the processing of raw materials or parts into finished goods through the use of tools, human labor, machinery, and chemical processing. Large-scale manufacturing allows for the mass production of goods using assembly line processes and advanced technologies as core assets”. (Investopedia, 2020.)

To understand how this transformation from raw materials, through manufacturing sequence into a product which would be afterwards recycled. The sequence could be divided into three phases. (Hillis & DuVall 2012, 3.)

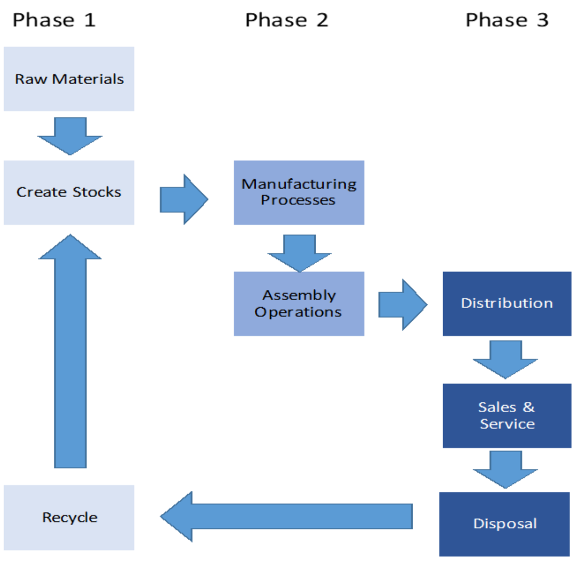

Figure 2. Manufacturing Sequence (Adapted from Hillis & DuVall 2012, 3.)

In this transformation from traditional to intelligent, and in the current process of the fourth industrial revolution, the IoT and Big Data are playing a major role. This digital transformation allows the industry in implementing new ways to create value and adapting data-driven strategies. Forward-thinking companies are using this strategy based on data as a competitive advantage to create value and increase competitiveness through predictive analysis (Mourtzis, Vlachou & Milas 2016, 290.)

The IoT network leads to an informed environment for manufacturing were the basic elements such us people, processes, products, and infrastructure are connected (Santhosh, Srinivsan & Ragupathy 2020, 2.)

To know exactly where to implement the IoT in smart manufacturing, Santhosh & al. (2020, 6-7) identify, the main segments where IoT has the potential to be implemented. In their study about IoT in Smart Manufacturing four segments for IoT implementation are explained in the value chain process:

- Transportation and logistics. The IoT can be incorporated into the products with sensors and tags so that when the product changes location, organizations and participants in the supply chain are able to trace in real-time the location and any other valuable information from the product. This ensures that the product is in the right place at the right time and optimal routes for each product are selected optimizing delivery times. This is a new paradigm in warehouse management.

- Factory visibility. By adding IoT equipment into the production system, it provides a real time information flow and efficient collaboration. The information can reduce the downtime in case of malfunction and even be prevented for ever happening. Knowing the problem beforehand, facilitates that the product waste is eliminated. It enhances safety and an overall operational experience.

- Energy management system. Despite of being the second major operating cost, many industries are lagging management tools for their energy plans in their industrial operations. Here is where IoT plays a key role. By monitoring and controlling the energy status in real time, machines can detect possible inefficiencies and pinpoint the devices that are under performing.

2.5 IoT Implementation Benefits

In this chapter, different benefits from IoT implementation will be revised. These considerations based on literature reviews are common to most industries and it is a starting point to understand the importance of IoT as an investment for manufacturers. The main benefits are:

- Automation and efficiency. IoT collects and processes data from the factory devices. This data can be used to automate workflows in order to design production systems without human interaction. The algorithm tries to generate optimal decisions, increasing the level of autonomy using machine learning technology. This generates minimum user interaction (Yang, Shen & Wang 2016, 2.)

- Energy management. Manufacturing accounts for one third of the global energy demand and along with the increasing prices on energy costs this is a key part for every company (Yang & al., 2016, 4.) Implementing IoT on devices where performing data can be accessed is a way to save on energy costs by visualizing which ones are under performing (Santhosh & al., 2020, 7.) or even entering into lower power modes automatically based on needs (Shafique et al., 2020, 23029.)

- Proactive maintenance. IoT replaces the traditional maintenance methods based on mere guessing from historical data, into a requirement based on the devices needs and data. This helps in keeping the components in good condition and minimizing the risks and downtimes. The efficiency gain predictions in companies using IoT is of 25% - 30% (Santhosh & al., 2020, 7-8.)

- Connected SCM. By enabling IoT devices throughout the supply chain, companies are able to share real-time information on inventory, shop floors, purchases and sales, logistics, etc. By providing the information in real-time IoT eliminates the asymmetry problem in accessing the information by all parties. This is a key element on lean manufacturing when all stakeholders are aware of the stage on the production cycle (Yang & al., 2016, 5.)

- **Product quality**. IoT can help in improving the quality of the product by avoiding performance degradation in a faulty system, lowering warranty costs (by early detection of faults) and increasing service contract profitability (optimizing the appropriate service time) (Santhosh & al., 2020, 9.)

- **Informed decisions**. Previously the manufacturing industry was based on statistical control, by adding IoT technology, companies can make decisions in a proactive way based on the status of things (Santhosh & al., 2020, 7-8.)

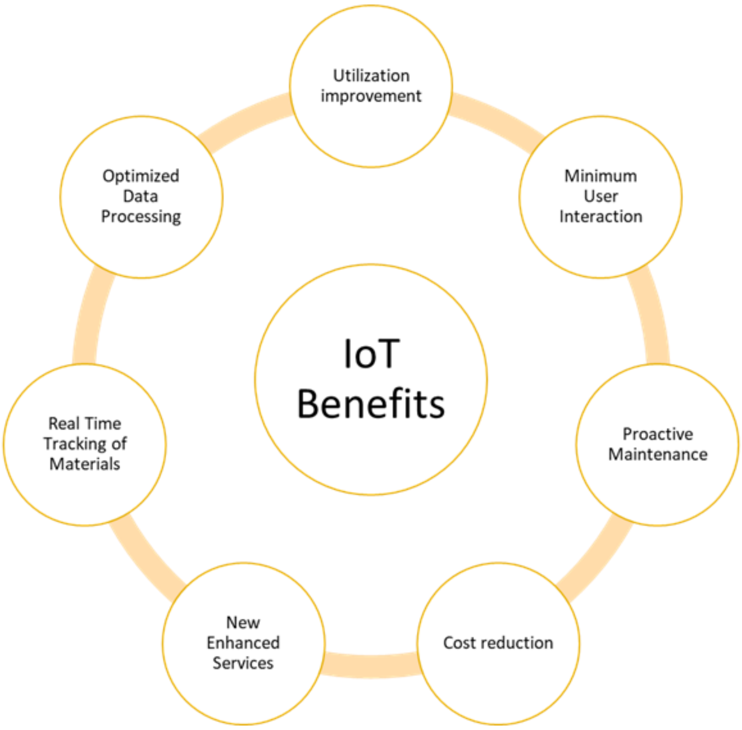

Figure 3. IoT Application Benefits (Adapted from Shafique & al., 2020, 23025.)

2.6 IoT integration in Inventory management

Inventory management is one of the most important elements of any product-based business and it is essential to ensure that the adequate amount of stock is stored for the optimum time (Riad, Elgammal & Elzanfaly 2018, 1.)

Inventory management involves the optimization of key resources and holding stock of various materials. Lack of inventory can lead to stock-outs, causing stoppage of in manufacturing, and in the other hand a very high inventory can result in an increased cost of production (Bose 2006, 2.)

Narayan and Subramanian (2019, 3-4) indicate that a good inventory management system provides information effectively in order to manage the flow of materials and help managers in a timely manner to manage their operations.

Inventory is classified into three categories according to the nature of the product itself. These categories are (Riad et al., 2018, 1.):

> **Perishable inventory**: meaning inventory that deteriorates over time, either on a fixed or unfixed date, such as medicines or dairy products. These products are sensitive to storage conditions.
>
> **Non-perishable inventory**: this type of inventory does not deteriorate over a short and medium period of time such us clothes and home equipment.
>
> **Service inventory**: meaning intangible resources such as hotel rooms or flight tickets.

According to Willemain, Smart & Schwarz (2004, 376), most of the studies on inventory management lead into the approach on the economic order quantities (EOQ), which determines two amounts for each item: a reorder point and an order quantity. When the inventory level reaches the reorder point, new orders are done on equal amount to replenish the stock. To calculate the order quantity, it is needed to forecast an average demand per period. On the other hand, when the reorder time is calculated, it is required to calculate the entire distribution of demand over a period of time from the creation of the replenishment order and its arrival in inventory, this is known as the lead time.

With the current evolution of businesses and quick changes in product demand, traditional warehouse management models are lacking in efficiency to adapt the uses of technology. The proper use of warehouse information along with IoT inputs is presenting a new warehouse and inventory model called Smart Warehouse Management System (Ding 2012, 204-207.)

Traditional inventory models and warehouse operations based on a manual interpretation of large amounts of data, is time consuming, inefficient and can cause tremendous losses caused by errors. Therefore, an intelligent warehouse and inventory model are key to succeed for current businesses (Ding 2012, 204-207.)

According to Riad & al., (2018, 1-2) due to the critical role that inventory management plays throughout the entire supply chain, businesses are looking for new opportunities to improve their efficiency of inventory. There are several positive factors from linking IoT to the inventory management such as location and quantity tracking, environment monitoring, production machinery damages and errors prediction or Shelf-life prediction and remaining life estimation.

In addition to the previous paper where the focus was set on the positive aspects in the manufacturing process itself; other authors focus on the benefits of IoT from the perspective of accessing data in real-time in order to predict the demand which would affect the inventory management and the company's needs.

In their paper based on the impacts of IoT on demand forecasting Yerpude and Singhal (2017, 3-4) analyse the forecasting methods which fundamentally get classified in two types, the qualitative / judgemental type, based on the collective intelligence and common experience on individuals that together predict the outcome of an event. This method is commonly used when there is not enough data to predict future events or when the information can not be set into a numeric model. The second type in demand forecasting is quantitative. Quantitative model analyses past data in order to predict the future; this is also known as Time Series.

Time Series in forecasting, is a collection of data gathered over a period of time whose aim is to predict future values. The outcome on that variation observed is called Trend. The data collected by the IoT devices is mainly Primary data, which refers to data that is collected for the first time from the sensors and does not have any prior existence. This reliable data is needed to validate and verify a quantitative model (Yerpude & Singhal 2017, 2.)

2.7 Theoretical framework

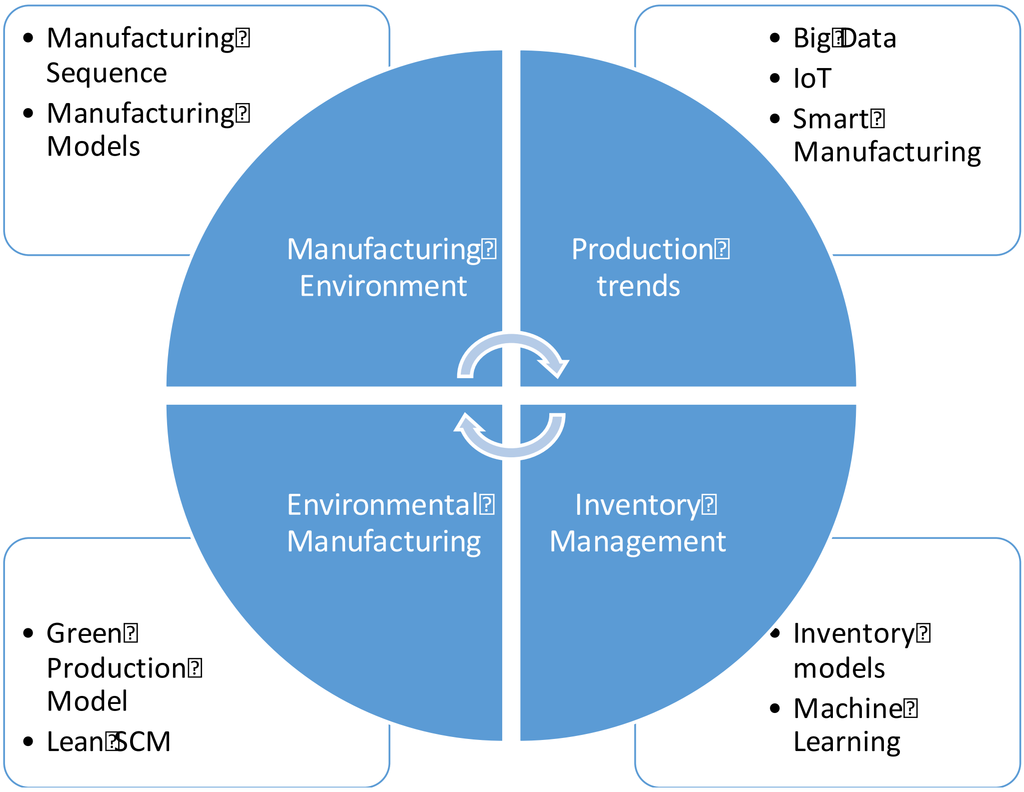

Figure 4. Theoretical framework of the thesis

3 Research Methods

In this chapter it will be discussed the research approaches to this study, the reasons behind the selection of the research method, the data collection system and analysis of previous studies. However, before diving into the detailed research methods, it is essential to understand what systematic literature review means.

Systematic Literature Review (SLR) is defined by Kitchenham (2004, 1) as a mean of identifying and interpreting previously available research studies relevant to a research question or topic of interest. When the study is individual, contributing to a systematic review, these studies are called primary, when on the other hand a systematic review of previous studies is a form of secondary study.

Secondary data has a prominent role in this research. This data obtained by another person or institution, consists of book, online sources, conferences, or any other relevant information that was considered trustworthy for the thesis. The majority of sources are, however, scientific research articles. The author considered that these articles give a better understanding of Industry 4.0, being this a new topic in constant change. These articles are in constant evolution and some sources had to be discarded due to new theories and studies that matched better the current circumstances of the industry.

Data is divided into two categories according to their characteristics, basically whether they can be reduced to numbers or interpreted only in words. Numbers and studies used to measure and reach figures and statistics are called quantitative. On the other hand, the qualitative approach can be expressed in words but not in numbers, basically human activities, and attributes (Walliman 2010, 70-72.)

I, as a researcher, would need to identify, select, and extract the information available on Industry 4.0 with a focus on IoT. It is precisely in this selection of studies when the author critically analyse what studies could be of good use to the research and to the reader. Hart (2018, 10) mentions how it is not sufficient to merely compile previous articles, there must be an element of analytical criticism and rigor. He identifies the main skill required to research on a topic as critical awareness; it is required information skills and intellectual capability to justify the choice of relevant ideas and the ability to set them in a context.

In this study I have an interest in analysing and approaching IoT edge technology into the automotive industry, finding new sources of revenue and approaching IoT as a technology to businesses, facilitating decision making for non-experts in the field. Having that in mind, and being that the goal of the study, the systematic review must be in accordance to this goal, which is also known as search strategy. Kitchenham (2004, 2) analyses how researchers performing a systematic review, must not only identify and report the information that supports their preferred hypothesis but also the theories that do not match.

Primary data has also been utilized in this research phase. Primary data is defined by Hox and Boeije (2005, 593) as data originally collected for a specific research goal, using procedures that fit the research problem best. Primary data includes different research methods such as surveys, interviews, or any other direct collection data method.

A qualitative interview was performed during this research. Qualitative interview encourages the interviewee to share rich descriptions or phenomena while leaving the analysis and interpretation to the investigators (Dicicco-Bloom & Crabtree 2006, 316.)

Although the primary data and in this case the interview is not the main source of information for this research, the researcher considered that different perspectives from experts in the field could be a great asset in order to discover new trends or focus on topics that were not included in the original protocol.

Okoli and Schabram (2010, 16) mentions the importance of having a plan or protocol before starting the literature review. This initial plan will certainly find some limitations in future stages of the research, but it is a critical step to ensure that researchers cover all topics and subsequently the study is structured and of high quality. After having the protocol set, it is time to select the articles. Once the articles have been considered valid for the literature review by excluding non-applicable content, it is the moment to examine the studies closely to assess their quality.

When it comes to the selection of articles for this research, being this topic multidisciplinary, it is of great importance to find articles and sources of quality that approach the topic from a business perspective, and not only a technical analysis on IoT. This research of articles was in this case very time-consuming, because most of the literature is oriented into an engineering or IT point of view and finding the data that could be of use to businesses required a thorough analysis of technical sources. All the data and articles included in this research are peer-reviewed.

3.1 Thesis Writing Methodology

In this chapter the application of different research techniques used for this study will be discussed. This research is a combination of primary and secondary research sources. As previously mentioned, the author believed that the Systematic Literature Review research method was the most suitable to obtain a general overview of Industry 4.0 from different professional perspectives, sectors, and business insights. However, the author believes that qualitative interviews would be a great asset in order to open the study to new perspectives.

3.1.1 Source selection

Searching for valid and reliable sources is in the authors opinion not an easy process. The vast amount of available online sources makes this process to be time-consuming. The key elements when looking for new sources is the validity and quality of the content. the type of articles used by the author were mostly coming from well-known companies reports, peer-reviewed articles or scientific magazines.

Being IoT a changing technology in constant evolution, some sources were to be left out of the study because either the data was dated, or the technology has evolved in a different path that the author expected at the time. But apart from the dated sources, some others were left out of the study because they were based on merely field enthusiast opinions without any reference sources to back those opinions up.

The basic criteria used by the author to identify weather an author was appropriate for this study was based on characteristics like number of publications on IoT (Books, articles or reviews) , number of times other authors have used that source or even the comments and reviews to the source itself.

The Systematic Literature Review was organized by the author so, that each article was added into an Excel document with a link to the source if available, and the first date of its review. This table can be found in the Attachments part of this document as Attachment 1. This document consists of 51 articles based on the different topics covered by this research.

The search engines utilized for searching articles were mainly Google Scholar and Haaga-Helia's library tools. These search engines are easy to use and they provide only quality sources peer reviewed. Especially Google Scholar has a very intuitive interface, easy to use, and were the search criteria can be easily modified. This was precisely needed when searching for latest trends, so the search could be modified and for instance select articles that had been released from 2020 onwards. Additionally, it offers an easy way to find references and add them into your research.

The outcome of this research part in Systematic Literature Review is for the reader to have a quick guide into Business perspective literature on Industry 4.0 with a focus on Industrial IoT. This guide makes the visualization of articles and sources easy for the reader to find the information of their interest.

3.1.2 Interview Techniques

The interview was conducted via e-mail, allowing the respondent to plan his answers with time. The response time was from the date when the questions were sent was 8 days. The people contacted were experts on IoT integration in manufacturing from the "Reboot IoT Factory" project, and based on the scope of this study, I was indicated to proceed with the interview with one of them.

The interviewee selected to perform the interview was:

- Marko Jurmu. Dr Tech., Senior Scientist and Technical Manager working for VTT Technical Research Center of Finland. He is a member of the Reboot IoT Factory project which aims to bring together forerunner factories, IoT service providers and research institutions to revolutionize the competitiveness of Finnish manufacturing industry (RebootIoTFactory 2021.)

He was selected to the interview based on his previous education, and experience on the field helping companies adapting their manufacturing process into Industry 4.0 with an especial focus on IoT. Currently, this project is collaborating with several industrial operators acting as forerunner factories in Reboot IoT Finland such as ABB, GE, Ponsse Oy or Nokia.

The research questions below were sent by email and are open-ended allowing the respondent to explain more in detail his opinions and providing more flexibility to the responses.

Table 2. Interview Questions

Question	Field of Analysis	Objectives
1. Can you describe the benefits and challenges in IoT implementation?	IoT implementation barriers	To understand better what types of challenges and benefits can arise when implementing IoT
2. Can you give examples of companies that are currently leading IoT in manufacturing?	Leading manufacturers	Examples for further reseach on leading companies
3. Is IoT suitable for medium and small size companies, or the investment required makes it unreachable for them?	Investment required	From an investment perspective, to understand if this technology is viable for all kinds of enterprises or not.
4. Can the demand of products or services be predicted by using IoT technology in order to reduce stock levels? If so, could you provide an example?	Predictive demand	How can IoT affect Inventory Management and examples
5. How do you see the future of manufacturing and IoT as a technology?	Future trends	To better understand new possibilities and technologies in manufacturing

Table 2 introduces the 5 questions that were sent for the interview. These main five questions have as an objective for the interviewee to explain more in detail his views about this topic. These questions are matching the general goals of analysis for this research. The study however is not based only in their opinion; however, the author believes that different opinions and even possible practical examples could be an asset to the research aspect.

In this chapter, the different research methods were discussed, the Systematic Literature Review approach and the interview questions. The next chapter will present the outcome of this research and recommendations based on literature and the interviews.

4 Presentation of the Findings

In this chapter, the main objectives of the research will be discussed with an especial focus on the automotive industry. The methods to obtain the data are literature studies and an interview with an expert. The scope of the findings will be focused on demand forecasting based on IoT technology and the possibilities to Inventory Management and business opportunities.

4.1 Desktop Findings

In this chapter, different literature theories will be analysed for the reader to understand the new opportunities IoT offers in Demand Forecasting, Inventory Management and new business possibilities.

4.1.1 IoT Integration in Inventory Management and Logistics.

Currently, a shocking amount of resources and capital are being tied up in inventory. Just in the US, $1.1 trillion dollars have been stored in inventory, accounts receivable and accounts payable, which is the equivalent of 7% of the United States Gross Domestic Product (GDP). The total volume of inventories is larger than the real volume of sales by roughly 43% (Riad et al., 2018, 1.)

Only 54% of small and medium size Enterprises (SMEs) are currently tracking inventory, while the other 46% are using ordinary methods or not tracking at all. Therefore, the purpose of **Inventory Management** is that the optimum volume of inventory is stored for the optimum time (Riad et al., 2018, 1-2.)

In Europe, rental prices for warehouse locations are very diverse. It can go over 200€ sq m next to Heathrow airport in London which is the most expensive in Europe, to other locations with more affordable prices like Barcelona 84€ sq m or Prague 58€ sq m (Savills 2019.) That being said, Inventory levels and warehouse efficiency are key in business operations. Inventory Management aims to find the right amount of inventory in order to have a positive impact on company's finances, not only for the value of the products in storage, but also for the possibilities that can come for keeping the right amount of inventories such us energy efficiency or adapted warehouse size to the real company's needs.

Not only the volumes of inventories are to be considered in Inventory management. As mentioned before not all companies are tracking inventories and here is where IoT plays an important role. It can be implemented in distribution too in order to help reducing the product miles by detecting the optimal route for the products to reach the final destination. This would make the product to reach the destination faster, efficiently and in a sustainable way (Santhosh et al., 2020, 5.)

Tracking containers, pallets, and crates, by applying data analytics to logistics is set to improve the shipment process and the customer's experience (Marjani & al., 2017, 5256.)

During transportation and logistics, the items are incorporated with sensors and embedded tags, so that participants in the supply chain can have the obtained information autonomously and in real time. The product becomes autonomous and it is ensured that the product is in the right place at the right time. This assures a full visibility of the supply chain and facilitate decision making in warehouse management (Santhosh et al., 2020, 6.)

Implementing IoT into inventory management can be considered in several areas. According to the study on Efficient Management of Perishable Inventory Utilizing IoT, Riad et al., (2018, 3-8) analyse possible areas for IoT integration in Inventory Management. Even though, their focus is on perishable products, the implementation areas can be adapted in any industry:

- *Tracking Inventory's Location and Quantity.* It is used to track the location of the products and to enhance customer service. Offering the right delivery time estimation and relaying less on manual inspection of the goods can lead to reduce human errors and can have a positive impact on customers' expectations.

- *Storage of the Products and Environment Monitoring.* This refers to the environment conditions that need to be monitored such as temperature or humidity in order to avoid environmental damage to the goods during transportation and their future storage in the warehouse. Sensors can keep track of the environment to warn stakeholders in real-time of fluctuations out of the ideal parameters.

- *Production Machinery Malfunctioning and Errors Prediction*. This area seeks to monitor and evaluate the manufacturing process and machinery as such. IoT is added to machinery to avoid future failures and evaluate the right maintenance frame.

- *Products Shelf-Life Prediction and Remaining Life-Time Estimation and Re-routing Depending on Remaining Lifetime.* In cases when the product has a certain life-time estimation, using sensors in packaging can avoid the deterioration of the product and find a possible new destination for the product before the conditions are not optimal to put that product in sale. It analyses what should be done with a product considering its current circumstances.

4.1.2 Demand Forecasting Models

Traditional SCM has been driven by planning and communication, in a process where the future demand is calculated based on historical data and current demand. This information is sent to the stakeholders involved that need to analyse it in order to correct possible delays, changes or errors. In this traditional SCM model, companies are deciding what and when the product is to be released, and customers indirectly drive the demand (Wüst & Gervais 2021, 4.)

On the other hand, in **Demand Chain Management (DCM),** the focus is set at the core of customer's interest, by reducing costs, improving customer service, being able to go faster into market with a minimum viable product (MVP). DCM allows stakeholders to have a real-time visibility of what customers want. It requires a connected network with visible data to be able to make accurate decisions. The information flow evolves from a push perspective into a pull approach where the stakeholders can have real access to information and to an overview of the supply chain (Wüst & Gervais 2021, 4.) In order to have a real approach to customer's needs, IoT appears as a key player and a link between the source of information and the stakeholders.

Willemain & al., (2004, 375) considers an accurate **demand forecasting** a fundamental aspect of supply chain in industries with intermittent or irregular demand (as the automotive industry). Items with intermittent demand might include service (Spare) parts or the vehicles themselves. These items are considered as *slow moving or lumpy.* In these types of items, an accurate demand forecast is important in inventory management.

When customer's demand is monitored and proactively responded, not only inventory management gets a positive impact, also the service is improved. Obtaining insights on real-time lead to better revenues and can help companies in achieving higher customer satisfaction improving serviceability (Yerpude & Singhal 2017, 2.)

In order to favour an accurate demand forecasting, the inputs from IoT devices play an important role. IoT enables the communication between human and machine, providing real-time insights gathered from the devices. "'Informed people' leads to smart design, intelligent operations, maintenance, quality service and safety" (Santhosh & al., 2020.)

When selecting the right forecasting method, the decision is based on the recent vintage of historical data available. The non-selected methods are analysed comparing the resultant forecast errors. This method for companies offers two advantages: the model is selected and built based on richer data, and the data revision and accuracy can be analysed overtime. (Yerpude & Singhal 2017, 4.)

Simulation is a powerful tool in the process of evaluation of a new system implementation or proposing changes to an existing one It allows the identification of problems and bottlenecks before implementing a new system (Carson 2005, 16.)

Simulation is a very commonly used technique within business operations management and business processes. It can be applied to solve internal logistics issues that may arise or into production lines among others. (Vieira, Dias, Santos, Pereira & Oliveira 2018, 377-378.)

A **simulation model** incorporates time and changes that happened over time. When those state changes produced at a concrete time and not continuously is called discrete model. When an event that might trigger new events or activities occurs at a point in time is called Discrete event-model. (Carson 2005, 16-18.) This simulation process used to be time consuming and very expensive for companies because of the lack of access to information, but IoT offers tremendous possibilities in simulation.

According to Vieira & al., (2018, 377-378) **Discrete-Event Simulation (DES)** is the second most used technique globally in operations, it offers the possibility to simulate years of operations in a much shorter time. It allows a better understanding of possible events to all stakeholders involved. It can study possible alternatives without the risk of incurring into major costs or dangers that could compromise business operations. It allows also to monitor and control the system and help in decision-making and is key in Industry 4.0.

DES can become a solution in Industry 4.0 because of the following aspects (Vieira & al., 2018, 380.):

- **Automated data exchange**. IoT offers the possibility to receive data in real-time from objects and automatically insert it into the simulation model adapted in the company. This data is of great importance in order to have a realistic approach.

- **Automatic model generation**. In the context of Industry 4.0 where smart factories are very dynamic, the model may require frequent changes, and DES can be the link to build automatic models in a way that is effortless and affordable for the company.

- **Visualization**. It is a key element in decision-making, when data can be transformed and interpreted by human and other machines. It offers the ability to interpret complex systems with the help of instruments like virtual reality or augmented reality.

With the vast amounts of data coming from devices, we can conclude that in order to predict the future decisions and gaining a competitive advantage, it is key to adapt a simulation model and a data-driven strategy. **Data-driven decision making (DDD)** refers to the practice of basing companies' decisions according to the analysis of data and not on intuition or personal human believes (Provost & Fawcett 2013, 5-6.)

As a final review of this chapter, the author has learned from the review of different literature that predicting trends and possible actions occurring after certain events has always been one of the main desires for companies. Making informed decisions based on data analysis is the present and future of manufacturing and businesses operations. Data science is key in the analysis and interpretation of the data coming from the IoT devices placed in products or in the factory itself, that is why data without a proper analysis, model or strategy can be costly and of no use to business operations. The predictive and simulation model implemented needs to be able to adapt itself, include new data and visualize the outcome properly for a correct decision-making.

4.1.3 IoT Successful Business Integration Examples

IoT facilitates organizations and customers when it comes to decision-making, improving the outcome by collecting directly information from the devices (Khan, Pohl, Bosse, & Hart 2017.) In this chapter different practical implementation examples from successful companies will be reviewed for the reader to understand the great variety of opportunities this technology offers.

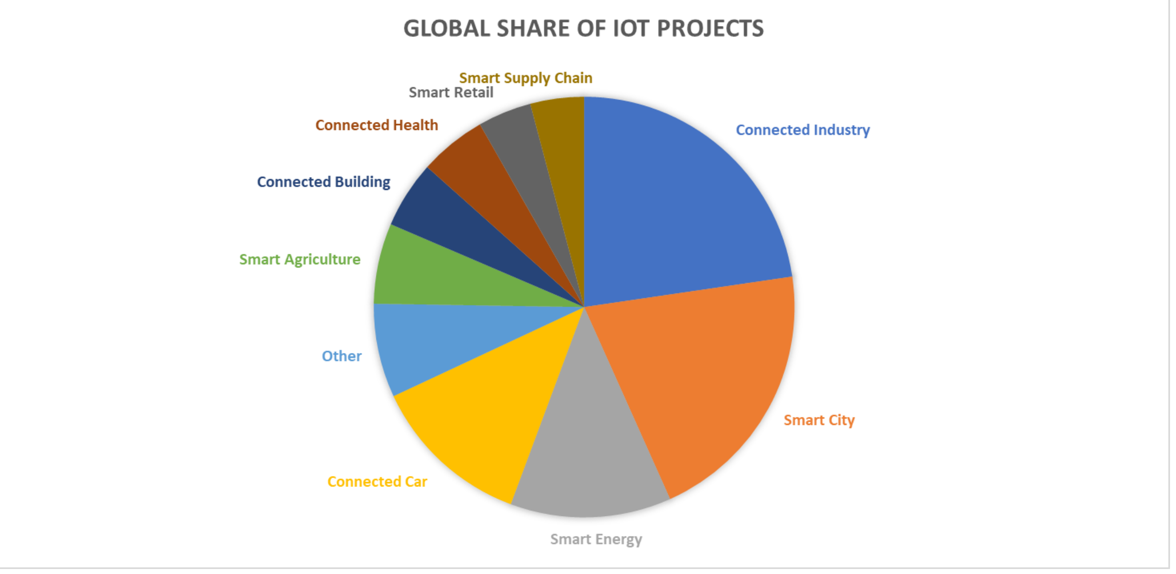

Figure 5. Global Shares of Iot Projects (Adapted from Kumar, Tiwari & Zymbler 2019, 14.)

As pictured in the figure above, the main fields of implementation globally are manufacturing, smart city, energy and the car industry.

Smart city refers to the integration of IoT devices into our everyday life products, transforming the traditional structures of the society into high tech structure with the help of supporting technologies such as machine learning and Artificial Intelligence (Kumar & al., 2019, 14.) An example of IoT in Smart City integration would be the Smart Lightning located in cities that when the natural light is not enough, the city lights will automatically start functioning. This generates major savings for cities and has a positive impact in the environment.

In **Smart Manufacturing** there are several cases of successful application of technology. One of the brightest cases is General Electric (GE). They have released two lines of work in predictive maintenance. One focused in purely measurements, and the other focused on monitoring the hardware and software of the plant (Santhosh & al., 2020, 8.) Additionally, GE has launched Predix Cloud, a system based on monitoring industrial equipment into an analytics platform. It has been implemented in sectors such as aviation, manufacturing or healthcare. It enables real-time visibility of the equipment's condition in order to be proactively managed. An example of its implementation would be in aero engines, where the performance and historical data can be observed and analysed before the problems even occur integrating devices into the engines. This brings benefits to the company like increased revenues, tracking or predictive maintenance (Ju & al., 2016, 882-883.)

By implementing predictive maintenance monitoring and tracking performance, the lifetime of the product can be significantly increased. The maintenance of the product itself is easily determined and this can lead to enhancing the efficiency of the product (Santhosh & al., 2020, 5.)

Providing Agility-real time data in decision making, managers can do corrections and output forecast in order to mitigate operational problems in manufacturing and mitigate further losses (Yerpude & Singhal, 2017, 4.)

In **Smart Energy**, companies like Nest are implementing a connect network of devices (Interconnected-things), to improve life-quality by helping consumers to remotely save energy with their Nest thermostat. This thermostat can be implemented in business and homes, and it can be programmed by itself, learning from customers' habits in order to reduce energy consumption during energy rush hours (Ju & al., 2016, 887-888.)

In **connected car** industry, IoT has been implemented in companies like Tesla for the autonomous driving purpose for instance. Also, companies like Car2go (an electric car-sharing company) are implementing IoT to monitor individual vehicle performance through the sensors. This company has plenty of vehicles around the city that customers can take and pay only for the time used. Through data use, they obtain benefits such as predictive maintenance and optimization of service. Additionally, the customer's data is used to implement partnership with adjacent industries or share the driver's performance to the partner insurance company to provide customized policies according to their vehicle use (Ju & al., 2016, 887-888.)

4.1.4 New Sources of Revenue

IoT brings new possibilities of revenue for companies and industries. This technology can offer endless possibilities and new ways to obtain additional profits and cost savings.

The main new source of revenue for companies is data. Companies can earn additional profit when analysing customer data in order to predict trends and demands of goods, but not only that, it offers enormous possibilities to **customize prices or seasonal promotions** based on customers' behaviour (Marjani & al., 2017, 5256.) This allows companies that traditionally were selling their products and then didn't have any future interactions with the client to build a longer relationship and improve customer engagement.

From this process of data analysis and adapting business operations to customers' needs, another new source of revenue for some industries is the **service agreement**. This method determines the appropriate time for service for the product and minimizing costs for the customer (Santhosh &al., 2020, 9.)

Avoiding the product deterioration is possible to by applying sensors with a remote software that can inform faulty performance and inform the customer and the manufacturer in order to take the proper actions. This offers the possibility to adapt warranty costs and refine the service contract terms. Early detection of issues in the system lead to an increased customer satisfaction (Santhosh & al., 2020, 9.)

This method of service contract has been offered for years now in the elevator business. Embedded sensors can communicate bi-directionally and facilitate remote access for manufacturers and service collaborators. The data obtained is used by technicians to run diagnostics and provide suitable service solutions and a personalised customer service which enhances customer satisfaction and customer engagement (Marjani & al., 2017.) For instance, the Finnish elevator company Kone, made in 2020 sales of new equipment for a total of 5,340.2 million €, and with their service sales additionally 4,598.4 million €. This shows how profitable can the service contract be, even matching the sales of new products (KONE 2020, 10.)

Despite its multiple applications for manufacturers and clients, the IoT hardware development and fixed costs are very high and need to be analysed before the investment. Additionally, operating costs are generally costly and there has to be an important analysis of each customer's willingness to pay those recurring service fees (Bilgeri, Brandt, Lang, Tesch & Weinberger 2015, 27.)

4.2 Interview Findings

The interview conducted on the 25th of May with Mr. Marko Jurmu, Senior Scientist and Technical Manager, expert in IoT brought new insights to this research. It provided an idea on how IoT is developing as a technology and how it is being adapted into businesses ecosystems. The interview was done via email.

The first question was based on the benefits and challenges in IoT implementation. His approach to this question was very much related to the desktop findings of this research. He identifies the main opportunities as transparency for the company in manufacturing processes and an asset in data collection in order to improve operative and strategic planning. Furthermore, this transparency could help identifying bottlenecks in operations or optimizing productions conditions.

> "The main benefits are transparency and formation of a company-wide data lake. With transparency, company operations that were previously 'invisible' in terms of data can be made visible, and real-time information on company operative performance is available"

His insight on the disadvantages were basically on the practical implementation of IoT for companies and the data management from the devices. It is of great importance to have experts that can manage the data obtained from IoT, this is rather not a simple task and before implementing this technology the manufacturer needs to have a clear vision of what data is needed for the operative and strategic planning of the manufacturing processes in order to avoid operational costs

> "The main challenge however is the lack of utilization of collected data. Many companies measure and gather data, without realizing that data collection is only the first step."

The next question was based on examples of that are currently leading IoT in manufacturing. His answer to this question was:

> "In Finland, for example the following: Nokia, GE Healthcare, Valmet Automotive, Valmet Technologies, KoneCranes, Ponsse, ABB, KONGSBERG. I recommend the Reboot IoT Factory web pages for further information: www.rebootiotfactory.fi"

These companies are leading in Finland together with the companies mentioned before in this study.

The aim of the third question was to identify whether IoT is suitable for medium and small size companies, or if the investment required makes it unreachable for them, to what Mr. Jurmu's perspective was that IoT implementation for SMEs is critical when facing such an important decision. The initial investment needs to be considered carefully as adapting IoT in manufacturing can become critical in the overall cost structure. The cost is significant and needs to have clear goals in order to match the ROI which is significant especially for SMEs.

The idea of partnership with IoT expert companies would seem like a good idea for companies starting from scratch, because it is not only important the initial investment, but also the data analysis after IoT has been adapted.

The fourth question aims to identify if the demand of products or services could be predicted by using IoT technology in order to reduce stock levels. His answer was very interesting and matches the research objectives of this thesis. In his answer He creates a division between predicting a market based on trends and predicting the market based on data generated by products. The first type is less reliant on IoT while the latter is. In this case when applying this information to the automotive industry, IoT offers very interesting opportunities for manufacturers. By placing IoT devices in the vehicles (Data generated by products) It could create a new source of information enabling predictive maintenance. When obtaining performance information, it could help predicting certain future situations for example when it comes to spare parts. Having that information, manufacturers could predict on a geographical area how many units will be needed. This could help adapting Inventory Management by having real-time updates leading into an optimize inventory based on the current circumstances and not based on previous year's estimations.

Furthermore, not only in vehicles, but if IoT is integrated in the factory itself, car manufacturers and spare parts manufacturers could share this ecosystem of wide sharing data to have access in real time to inventories or malfunctions in the shared Supply Chain.

Regarding the final question based on his insights about the future of manufacturing and IoT as a technology, the interviewee emphasizes in the aspect of implementing IoT to gain competitive advantage, especially in the export markets.

Regarding the future, he believes that data sharing ecosystems will be key in Supply Chain optimization, reaching sustainability and circular economy goals. Sharing collected data between partners would be beneficial in achieving common business objectives.

5 Conclusions

The objective of this chapter is to apply the investigative questions into the case industry, including some recommendations obtained from the literature and the interview performed.

Additionally, the author will comment on his personal learning and the restrictions occurred during the writing process.

5.1 Recommendations

In this chapter the investigative questions applied to the vehicle industry will be analysed, focusing on three areas of study: Predictive demand, Inventory Management and New Sources of revenue. The answers to the Investigative questions will be oriented applying the information obtained in the interview with Mr. Jurmu and the literature theories previously explained.

The purpose of the first investigative questions was to understand the common challenges in Inventory Management. As mentioned in the desktop findings currently there are large amounts of vehicles globally being stored in stock, this is very costly, in terms of maintenance of the vehicles and warehouses, having the risk of incurring in even more costs when facing an economic crisis as the current one.

It is clear that the main challenge in Inventory Management is to have the optimum quantity of products for the optimum period of time. Therefore, the use of IoT is so important for vehicle manufacturers. IoT allows to have real-time inputs from the products that can be used to optimize inventory based on the current circumstances and not as traditionally was done according to previous years' estimations.

Another main challenge faced in Inventory Management was to find the right route for each product and having visibility on operations. Here is where IoT plays a key role when implemented in the factory and logistics. Real-time tracking of products allows full visibility of the supply chain and helps reducing product miles which helps reducing transportation and warehousing costs and has a positive environmental impact, helping to reduce emissions.

Implementing IoT in factories and machinery, has also a positive impact for Inventory Management because machine malfunctions are immediately detected in order to avoid faulty products and reducing down-time in production.

During the transportation process one of the challenges faced is the environmental damages to the product. This can be easily analysed by IoT devices in order to avoid environmental damages by measuring and analysing the environment. Additionally, the self-life estimation of a product can be also measured by IoT and AI in order to find a new route or destination for the product and avoid deterioration of products.

For the second investigative questions about demand forecast models it was required a literature research and the expert's feedback obtained from the interview.

The aim of demand forecasting models is to plan the future operations according to real data and customer's insights obtained from the devices instead of previous years' estimations. The automotive industry, being an irregular demand item, requires a demand forecasting model to monitor and proactively respond to customers need.

Basing the company's strategy into a Data-Driven Decision making (DDD) would be the core of the demand forecast model, improving decision-making based on data analysis and not intuitions, estimations or personal believes. This is why IoT plays a key role in demand forecasting, being the link between the customer and the decision-making stakeholders.

By implementing a Demand Chain Management (DCM) into the industry, manufacturers will be able to have real-time visibility of customer's insights. This way the demand forecast would be most accurate, and companies would be able to go faster into the market with the information obtained.

With the help of a simulating model and specifically the Discrete-Event Simulation, years of operations could be simulated in short time, helping stakeholders to understand better possible events without incurring into costs.

For the third investigative question, the goal was to find some new ways of revenue for vehicle manufacturers based on IoT implementation in vehicles. The current implementation of sensors in cars is mainly focused on safety and passengers' comfort. However, data obtained from vehicles and driver's performance could be used for creating new channels of customer engagement.

By applying IoT in vehicles engines, the same way as GE is currently operating in aeroplane engines, could allow manufacturers to predict future maintenance services, and offer the client the best possible service adapted to customer's needs, and precisely forecast the spare parts needed. This could be a new era for the service contract where the client would be offered just what they need and with individualized offers. As shown for example with KONE where the service contract represents approximately half of the company's business, vehicle manufacturers have still plenty of room for improvement.

Data is nowadays one of the most valuable assets for a company. Monitoring driver's performance could additionally bring new sources of revenue by simply sharing driver's data. Furthermore, sharing the data with partners would increase the revenue for the company, the same way as explained in the case of Car2Go where the company shares the driver's performance data with the insurance company to offer personalized policies.

5.2 Suggestions for further research

Being Industry 4.0 a broad field of study and a "new" concept, there are plenty of areas for further research. The author realized that especially applied to Inventory Management there are only a few high-level studies dedicated to study the practical implementation of IoT into IM. This disruptive technology can change the traditional operations, and therefore, further studies focused on this topic are needed.

From the list of recommendations, this study opens the possibility to investigate further on the after sales and service contract possibilities when applying IoT. Practical application guidelines of IoT implementation in after sales would be a possible field of study for further research, but in this thesis the author believed that predictive demand and Inventory management were the main fields of analysis, and including additional topics not directly related to I4.0, could deviate the focus of the study, even though they are of great interest to the author.

Applying these techniques to a concrete vehicle company would also be a proposition for further research. Although practical examples were included in this thesis, the practical adaptation of these theories into an operating company would have a positive impact in the study in order to find out on the obstacles and benefits of its implementation and unlocking new opportunities.

5.3 Own Learning

Conducting this thesis has allowed the author to improve the general manufacturing process knowledge skills and in particular the implementation of new technologies and the benefits obtained. The author has always had an interest in how to have an accurate forecasting system for companies. The topic of this thesis was clear from the beginning to the author.

The author believes that the society is facing major changes when it comes to the development of IoT, Inventory Management and demand forecasting, and wanted to obtain a documented knowledge that could be of great help in his future career.

Moreover, the literature research phase and the research of quality sources was a great opportunity to learn further in this topic and as a technique. The author realised that conducting a Systematic Literature Review is very time consuming, especially in this topic chosen for the study. Most of the articles selected were technical analysis of the technology, and the author had to extract the business value in a very detailed manner.

In addition, the performance of an interview was very rewarding, especially knowing that the expert had a very tight schedule, but he wanted to participate anyways and was interested in the outcome of this thesis.

Finally, the thesis objective was to obtain a solid experience and share it with the readers, hoping to develop possible professional opportunities in this field of study.

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Attachments

Attachment 1. Systematic Literature Review Table

Title	link	Date accessed
Angelova, N., Kiryakova, G., & Yordanova, L. 2017. The great impact of internet of things on business. *Trakia Journal of Sciences*, *15*(1), 406-412.		20.5.2021
Ashton, K. 2009. That 'internet of things' thing. *RFID journal*, *22*(7), 97-114.		24.1.2022
Belgaum, M.R., Soomro, S., Alansari, Z., Alam, M., Musa, S. and Suud, M.M., 2018. Challenges: Bridge between Cloud and IoT. *arXiv preprint arXiv:1803.02890*.		10.4.2021
Bi, Z., Da Xu, L., & Wang, C. (2014). Internet of Things for Enterprise Systems of Modern Manufacturing. *IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS*, *10*(2), 1537.	Link	20.1.2021
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