Technical University of Denmark

# Supply chain 4.0: How data is reshaping businesses' supply chains

Master's Thesis, June 2018

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Peter Jacobsen

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# Preface

This thesis is submitted as a partial fulfillment of the requirements for the degree of Master of Science in Industrial Engineering and Management at the Technical University of Denmark. The project is credited to 30 ECTS points. The theme of the project was suggested by the author, however, small adjustments have been made during the process in collaboration with the supervisor.

I would like to thank my supervisor for spending his time with me and for helping me out with valuable advices and tips. To my friends, both in Denia and Copenhagen, for putting up with me this whole time, for listening, supporting and taking me out when I needed a break from everything. But most importantly I would like to thank my family for always being supportive, for believing in me and also for being there, even in the distance.

Kgs. Lyngby May 29, 2018

Guillermo Altuna Faus (s161337)

# Abstract

The main objective of this thesis is the study and analysis of the impact and influence that the innovative and disruptive technologies such as Big Data or the Internet of Things have on the world today. Causing phenomena such as digitalization and globalization. In order to compete under these new circumstances, companies are driven to encourage and adopt new approaches, solutions and technologies in their business models, paying special attention to the supply chain. This report also includes the reasons why these transformations are taking place, as well as the risks, challenges and benefits of implementing them in companies. In addition, the thesis addresses all of the above focusing on the shipping industry.

To do so, the literature and the most recent and relevant articles and reports have been collected, read, studied, analyzed and reviewed. At the end of this thesis, the reader, in addition to having a clearer and more up-to-date view of the current situation, will understand better what all these innovations entail and their influence on the world of today and tomorrow.

**Keywords:** technologies, digitalization, globalization, supply chains, shipping industry

# Resumen

Esta tesis tiene como objetivo principal el estudio y análisis del impacto e influencia que tienen en el mundo hoy en día las innovadoras y disruptivas tecnologías como el Big Data o el Internet de las Cosas. Causas de fenómenos como la digitalización y la globalización. Para poder competir bajo estas nuevas circumstancias, las compañías se ven empujadas a fomentar y adoptar nuevos enfoques, soluciones y tecnologías en sus modelos de negocio prestando especial atención a la cadena de suministro y logística. En este informe se recogen también las causas por las que estas transformaciones están teniendo lugar así como los riesgos, desafíos y beneficios que conlleva su implementación en las empresas. Además, la tesis aborda todo lo anterior centrándose en la industria del transporte marítitmo.

Para ello, la literatura y los artículos e informes más recientes y relevantes han sido recogidos, leídos, estudiados, analizados y revisados. Al terminar esta tesis, el lector a parte de tener una visión más clara y actualizada de la situación actual, entederá mejor lo que suponen todas estas innovaciones y su influencia en el mundo de hoy y de mañana.

**Palabras clave:** tecnología, digitalización, logística, globalización, cadena de suministro, transporte marítimo

# Contents

CHAPTER 1

# Introduction

## 1.1 Structure

This thesis is written aiming to build a coherent narrative in order to ease and guide the reader along of all of it. Therefore, it has been structured in six different but interrelated chapters. The 1st one, *Introduction*, is a presentation and a summary of the content of the thesis. It also states the purpose of the it by the formulation of some questions. In the 2nd chapter, *Current State*, the present world situation is introduced to the reader, stating the problems and challenges to be faced and advancing as well the concept of supply chain. Along the 3rd chapter, *Industry 4.0*, all the new technologies, changes, risks, challenges, benefits and impacts are presented and explained, putting special effort on both of them, Big Data and Internet of Things. The 4th chapter, *Supply Chain 4.0*, explains this new concept, born from the implementation of these innovations to the supply chain, together with the two main requirements to be fulfilled by companies not to fail in the attempt of carrying them out. The 5th chapter, *Shipping Industry*, tackles the present situation of the shipping industry and focuses on the consequences and impacts that all these transformations have on the sector. Lastly, the 6th chapter, *Conclusion*, is the recapitulation of the whole thesis where the key facts, inputs and outcomes are presented.

In addition to this, all the literature, articles, journals and websites used to build and write this report can be found at the end of the last chapter.

## 1.2 Summary

In today's world, globalization is a fact. For a couple of decades, more and more interactions between people, companies and countries are taking place. The Earth has become an interdependent and connected system where the acceleration of technological changes, the trade liberalization and the importance of supranational rules, among other phenomena, have exposed national economies to much more intense competition than ever before [1]. And the trend indicates that this process is unlikely to be reversed.

Nowadays it is common that commerce and trade occur between people and companies that are geographically distant from each other. This constant flow of information, goods and funds involves, directly or indirectly, many different parties. All of them play a significant role in the supply chain aiming to fulfill the customer's request. From the supplier to the customer, there is a notable number of complex operations handled by many stakeholders such as manufacturers, transporters, distributors, retailers and warehouses among others [2]. Moreover, customers are demanding quality products to be delivered faster, customized and at the lowest possible cost [3]. They expect more choices, more variety of products and the ability to trace them all along their journey. This will lead to an increase of the market volatility and also to have shorter product life cycles.

These two facts, complex supply chains and grand expectations from customers, combined with the disruption that digitalization has caused, are the main challenges that companies must face if they want to be successful in a competitive and interconnected environment as today's. To do so, companies should migrate from a traditional perspective of the supply chain to a digital one by adopting and implementing the technologies and practices that Industry 4.0 brings. The improvements of this transition will help firms to create an integrated planning and execution allowing visibility across the whole supply chain, to raise their performance and to respond flexibly and faster to changes in the supply or demand [4].

Digital technologies have changed and evolved dramatically in recent years, driven largely by three key developments: lower computing costs, cheaper storage, and less costly bandwidth. The confluence of these with the increase of computing power and technological capabilities has led to exponential changes, enabling organizations to gather, store, and analyze greater amounts of data than ever before [5]. The use of new technologies like Big Data, Cloud Manufacturing, Business Intelligence and the Internet of Things will exploit those developments and transformations to enhance the data-driven decisions of companies [6]. All these solutions and changes will create a new whole standard for what used to be a supply chain. From a linear perspective to a dynamic, flexible and interconnected system [5]. However, there will be challenges to overcome in order to complete successfully this migration.

Every organization consists of people, tasks, structure and technology. Therefore, the interaction between them will determine the success of these organizational changes and their implementation as well as the success of the company in the new global environment [7]. To achieve a fully integrated supply chain, a new strategy has to be defined, new processes designed, new skills and capabilities will be required and also a new organization structure implemented allowing and encouraging a supportive environment [8]. Regarding this last, collaboration, trust and knowledge sharing all along the supply chain and between partners is a must so as to avoid lack of information visibility and promote transparency, coordination and integration [9]. On top of that, the available data that enterprises can use to improve their outcomes is growing at significant rates [10]. Nevertheless, the challenge that companies must face is how to use this data and how to transform this information into a useful asset. Here is where the Industry 4.0 technologies applied to the supply chain will play a key role.

In order to provide a more specific and deep view on this matter, this report will focus on the shipping industry. First, it will be analyzed the industry and the current context and afterwards, an analysis on this field regarding the implementation of data into their supply chains and its consequences will take place. The reason of choosing this industry is because apart from being essential for the world economy, it is working in an old fashion way and it is currently facing all these disruptive innovations. Moreover, the big players are starting to adopt and implementing measures in order to overcome them and the firsts to do it will stand out from the rest and be the leader of the industry.

The purpose of this paper is therefore to answer the following research question as well as some others derived from it:

- How are the new technologies reshaping the shipping industry?
  - What is the current global situation?
  - Which are these new technologies and how they emerged?
  - How can these technologies be applied into supply chains?
  - Which are the challenges faced by the shipping industry nowadays and how can these be overcome by exploiting these new technologies?

Every sub question is answered through one of the chapters in which the thesis is divided.

CHAPTER 2

# Current State

## 2.1 Globalization and Digitalization

Globalization is no longer a challenge to be faced the future, rather a recognized fact in the daily business [11]. It is a phenomenon characterized for the interaction and integration between people, companies, and governments of different nations [12]. Globalization has also a social, cultural, political and legal impact. In social terms, it represents greater interconnectedness among global populations. Culturally, globalization represents the exchange of ideas and values among different cultures. It is also a trend towards the development of a single world culture. Politically, it has shifted the political activities of countries to the global level through intergovernmental organizations. Regarding the field of the law, globalization has altered how international law is created and enforced [13], encouraging the creation of common laws that facilitate trade and regulate conflicts between companies from different nations.

Furthermore, globalization is an economic process driven by the internationalization of production, the expansion of international trade and the enablement of services that expand and deepen international capital flows. All this is aided by the accelerating and disruptive technological changes, by the decrease in the prices of consumer goods and transport services, by the liberalization of the trade and by the growing importance of supranational rules and organisms [1]. As a result of globalization, competition between companies has risen rapidly, becoming overwhelming and much more intense. Every product to be sold must match the quality of products made in other countries to meet the requirements of the customer because now they have access to variety and are able to distinguish between good and just satisfactory products. Hence, companies are required to provide the best of their products and services to their customers by having a global procurement network able to support their supply chains, provide quality and compete effectively in the market [14]. The international trade, the new ways of production and sourcing from different parts of the world are enhancing the interdependence between all the players along businesses' supply chain all over the globe. Markets are demanding shorter lead times, traceability and flexibility at the lowest possible cost [11]. In addition to this, customer expectations are growing moving towards further individualization and customization [4]. To build on these trends, it is required a reliable, faster, precise, efficient, and collaborative response from the entire supply chain, because logistics acts as the main artery of the world's economy. Today, Supply Chain Management (SCM) is playing a significant role in corporate efficiency [15] because the cost and service improvements which cannot be achieved by individual firms can be achieved by firms which cooperate with others [16].

Information technologies are the key tool to maintain the needed coordination between supply chain participants but also to provide solutions and strategic support to optimize the use of resources [17]. Improvements in transportation networks and technology are reducing the costs of transportation while improvements in information technology have made an increasing volume of information available close to zero cost [1]. Consequently, there is an increasing realization in many industries and companies that data is a valuable resource [18] and should be managed as an asset [19]. This digital revolution is creating new ways of doing business [20] and different ways to create value through the leverage of innovative and disruptive technologies. Opportunities are appearing in unexpected places and ways, originating a whole new paradigm for what used to be the supply chain [3].

## 2.2 World Context

For the last couple of decades, USA and specially the majority of European countries have outsourced a great deal of their factories to other countries, specially Asiatic ones, keeping only the high value adding stages of their processes like the design or management. Among them, China was and still is the producer of the world. This meant that western companies have adapted, incorporated and implemented to their supply chains the requirements needed for their production to be outsourced and far from the countries they are supplying. Dealing as well with the problems and challenges that this imply. However, Chinese people are increasing their standards of life and are starting to demand the same high value products and high skill jobs that in western countries. The consequence of this will be the migration of most the industry to other places like India or some African countries where the labor costs are lower. This will have a huge impact in the supply chain of many companies, new routes will emerge with new challenges and problems to be solved. Therefore, flexibility and resilience are characteristics that the supply chains of the companies should have if they are to stay in business and adapt to the new changing and disruptive environment.

## 2.3 Supply Chain

Reliable and fast transportation, as well as efficient logistics services play decisive and relevant roles in the activities of many companies. Consequently, the performance of the supply chain is not only a source of competitive advantage, but it can also decide whether the firm will exist in the market at all [21].

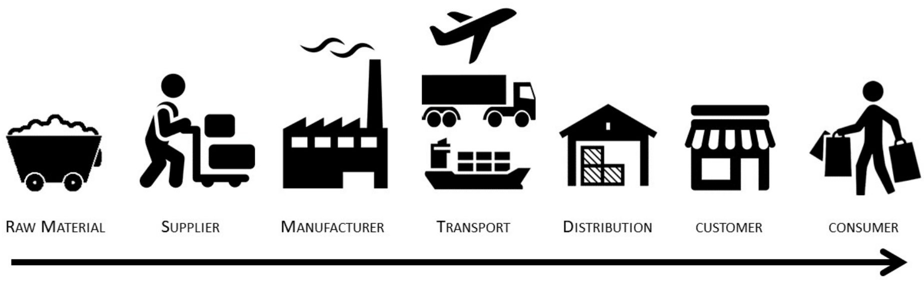


Figure 2.1: Supply Chain stages

A supply chain can be defined as a network consisting of suppliers, manufacturers, warehouses, distributors and retailers who coordinate their plans and activities in order to transform raw materials into finished goods. It is indispensable that the required materials and products are provided to the customers in the right quantities and best quality, at the right location, at the right time and at the lowest cost [22]. Therefore, the better the product, the faster its production, and the cheaper its cost, the better the supply chain is performing.

It is the SCM the responsible for supervising the relationships in the network of organizations, from manufacturers to end customers, using key cross-functional business processes to create value for customers and other stakeholders [23]. Among these processes are included product development, procurement, manufacturing, physical distribution, customer relationship management and performance measurement. Therefore, SCM aims to support the organization providing the means to link technology and people, aligning them with the capabilities of the organization as well as enabling the coordination of processes and information sharing between the different players along the supply chain [22].

Despite the fact that cost, quality, delivery, and flexibility are important competitive capabilities within supply chains, modern SCM cannot be only about getting products faster, cheaper, and of better quality but also about getting the right information at the right time, so that companies can make better and informed supply chain decisions [24] as well as create value.

CHAPTER 3

# Industry 4.0

## 3.1 Concept

Industry 4.0 is the sum of all the new technologies that blur the lines between physical and digital worlds [5]. It brings disruptive changes to supply chains, business models, and business processes [25], enabling the creation of a digital value chain [26]. Among these novelties can be found Cyber-Physical Systems (CPS), Internet of Things (IoT), Business Intelligence (BI), Robotics, Big Data (BD), Cloud Manufacturing or Augmented Reality, among others. These innovations are implemented by suppliers and manufacturers to address the trends of digitalization, automation, transparency, mobility, modularization, customization of production, network-collaboration, human machine interaction and automatic data exchange and communication [7], [26]–[28].

It is also considered to be the $4^{th}$ industrial revolution.The $1^{st}$ one took place around the end of the $18^{th}$ century with the invention of the steam engine, a new kind of energy that enabled the mechanization of many processes. Later on, at the end of the $19^{th}$ century with the appearance of new energy sources, like electricity, gas and oil, the combustion engine was designed. Also with the development of new ways of communication like the telegraph and the phone and with the development of innovative means of transport, the $2^{nd}$ revolution happened. The $3^{rd}$ industrial revolution occur in the second half of the $20^{th}$ century with the development of the nuclear energy, which potential surpassed their predecessors. Moreover, during these years, electronics, telecommunications and computers rose, leading to a high level of automation in production. Therefore, this new revolution to come involves the arrival of a new industrial paradigm that integrates all elements in a value-adding system leading to the development of more intelligent manufacturing processes. It is motivated by the rise of the Internet, the massive use of data, the digitalization of processes and the allowance of devices, machines, production modules and products to independently exchange information, trigger actions and control each other, enabling a smart manufacturing environment [26].

The key principles of Industry 4.0 are interoperability, virtualization, decentralization, real-time capability, service orientation, data integration, flexible adaptation, intelligent self-organization and secure communication [29].

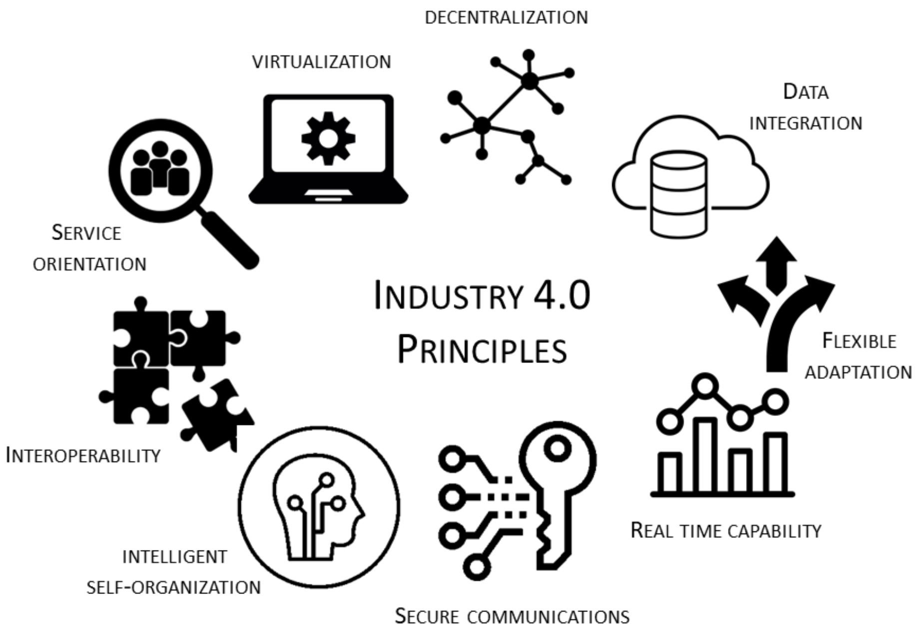


Figure 3.1: Industry 4.0 principles

Interoperability refers to the capability of humans, machines, processes and technologies to connect, communicate and work together. It requires an environment which allows a fluid interaction and a flexible collaboration between them. Virtualization stands for the process in which a factory or a supply chain is designed and built virtually, allowing the enhancement of the existing processes, the modification and customization of some elements and enabling test changes or upgrades. By decentralization it is understood that different elements within a system are enabled to make decisions autonomously complemented with the ability to do so in real-time. Finally, flexibility and intelligent self-organization means that the systems can easily adapt autonomously to changing environments and requirements ensuring minimum disruptions within the system when doing so. In addition to all of this, companies should have in mind the data security and also being oriented to offer the best service to the customers.

Based on these principles, the goals of Industry 4.0 are to provide an IT-enabled mass customization of manufactured products; to make automatic and flexible adaptation of the production chain; to track parts and products; to facilitate communication among parts, products, and machines; to use the available data properly; to apply human-machine interaction (HMI) paradigms; to achieve IoT-enabled production optimization in smart factories; and to provide new types of services and business models. Summarizing, to achieve a higher level of operational efficiency and productivity through a higher level of automatization [25], [29], [30].

Moreover, the opportunities and benefits that are anticipated to come along with Industry 4.0 seem to be manifold, resulting in highly flexible mass production, real-time coordination and optimization of value chains, reduction of complexity costs or the emergence of entirely new services and business models [31]. It is a shift from optimizing physical assets to optimizing how data and information are leveraged along the product life-cycle [32]. Digitalization and Industry 4.0 are opening up new cost savings. However, in order to achieve the benefits of Industry 4.0, companies should make some changes because many aspects are involved, and many types of difficulties and challenges faced. It will be vital to combine data, integrate systems and processes, and make decisions based on cross-functional information [6].

## 3.2 Changes and Consequences

This new industrial paradigm will lead to deep changes in industry, manufacturing sectors and transportation, having strong impacts along the whole value chains and providing a set of new opportunities [26].

Therefore, to manage efficiently these large and complex systems, networks need to be standardized, reliable but also avoid being a threat to people and environment. These networks will allow interconnectivity between different players through the supply chain and within a company, while preventing unauthorized access to production facilities or confidential data [33]. Moreover, companies should attract digital talent. They need to seek data scientist and process experts who can operate at the interfaces between functions and systems. Always having the data as an asset and managing it strategically [6]. The introduction of Industry 4.0 will have a huge impact in the logistic area. There, the most relevant benefits will focus on increasing flexibility, quality standards, efficiency and productivity. This will enable mass customization, allowing companies to meet customers' demands by creating value through constantly introducing new products and services to the market. Furthermore, the collaboration between machines and humans could socially impact the life of the workers of the future, especially with respect to the optimization of decision making [6].

Industry 4.0 practices and technologies will bring new challenges that will significantly change the production and manufacturing systems regarding design, processes, operations and services. It will allow the appearance and rise of new business models, having large effects on industry and markets. It will provide a new way of doing business [26] where time to market and customer responsiveness will be the key factors of competitiveness [32].

The introduction of these new technologies will have a profound impact in different areas:

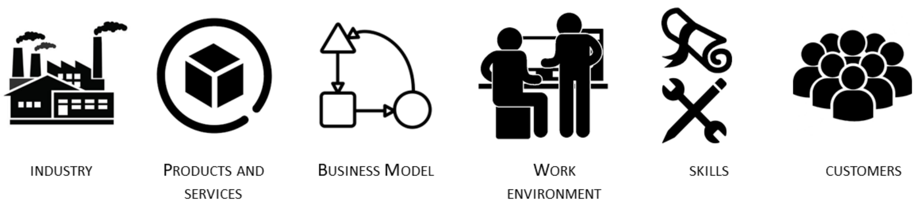


Figure 3.2: Fields where Industry 4.0 will have an impact

- **Industry.** A new manufacturing vision will appear. It is characterized by a decentralized and digitalized production, where the production elements are able to autonomously control themselves, trigger actions and respond to changes in their environment [26]. All manufacturing resources (sensors, actuators, machines, robots, conveyors, etc.) will be connected and will exchange information automatically [34] to optimize the production lines, warehouses and transportation services. The products and processes will be fully integrated, shifting the production vision from mass production to mass customization, bringing a higher level of complexity. Basically, Industry 4.0 will have an important influence on industrial processes, manufacturing systems and supply chains by transforming the current industrial landscape through three main points: (a) digitization of production, (b) automation and (c) linking the manufacturing site in a comprehensive supply chain [26].
- **Products and services.** Products will become more modular and configurable, promoting mass customization in order to meet specific customer requirements [35]. Moreover, these new products and services will become responsive and interactive, being able to be managed and track their activity in real-time, optimizing the whole value chain and providing relevant information about their status during their lifecycle [36] to companies.
- **Business models.** New innovative business models will arise because of these novel and disruptive technologies. The way products and services are sold and

provided will change, allowing a closer interaction with customers and a faster adaptation to market requirements [26]. Also the elimination of barriers between information and physical structures and the entry of new players will cause an increase in competitiveness, margin pressure [32] and a rise in innovation to keep being on the game.

- **Work environment.** The increasing relevance of human-machine interfaces will promote the interaction between both production elements. The required communication between smart machines, smart products and employees, will be enhanced by the Internet of Things and Big Data. The growing implementation of these new technologies will have an impact on job profiles, as well as on work management, organization and planning.
- **Skills development.** The future work vision will demand new competencies and it will be necessary to create opportunities for the acquisition of the required skills through high quality training [26]. This new industrial paradigm will have a massive impact on labor market and professional roles. Industry 4.0 will lead to an increased automation of tasks, which means that workers should be prepared for performing new tasks. It is expected that employees enjoy greater responsibilities, acting as decision makers and taking on supervising tasks [31].
- **Customers.** A new purchasing method will be given to customers allowing them to order products with whatever functionality they want. In addition, customers will be able to change their orders and ideas at any time during production even at the last minute with no charge [34]. Therefore, production must adapt to short batches and individual needs [27] if the new customers' requirements are to be satisfied.

Companies' biggest obstacles for implementing Industry 4.0 are the know-how of processes and controls of employees, a uniform standard for data transfer and data security and safe-guarding systems. Regarding this last one, some practices like prioritization of protection around key assets or integrate cybersecurity into core processes have started to be implemented. Also, some companies have become reluctant to use foreign IT providers in order to avoid these cyber risks [32].

Implementing new and thus unknown technologies is rather risky. Most of companies will carefully weigh the benefits of introducing modern technologies against possible risks to process reliability. As a result, companies approach fundamental disruptions with caution, so that change will be rather incremental.

## 3.3 Technologies

Once the concept of Industry 4.0 is understood, the players of supply chains must decide how and on which of these recent technologies invest, and identify which ones will drive the most benefit for their organizations [37]. These technologies are similar in that they offer ways of leveraging data to unlock its value potential [32]. Among them, the followings can be found:

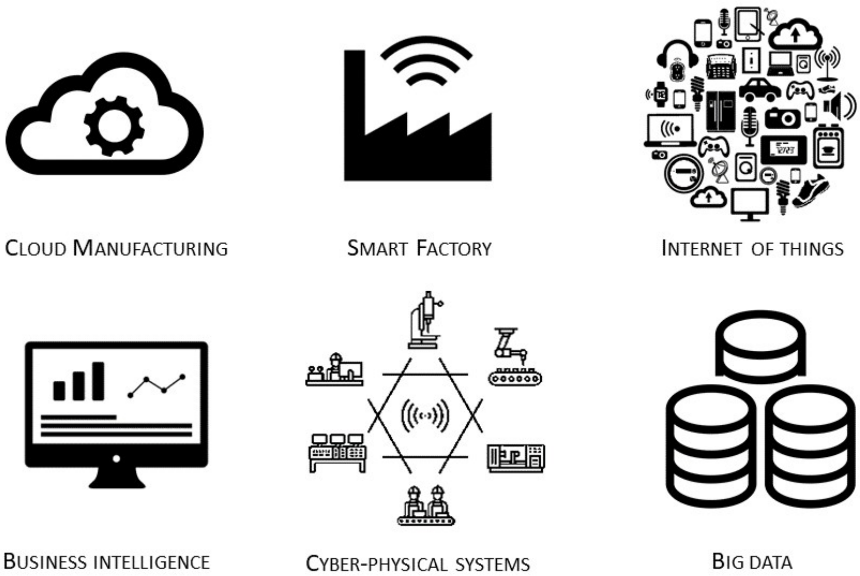


Figure 3.3: Industry 4.0 technologies

- **Cyber-physical systems (CPS).** Industry 4.0 is characterized by an unprecedented connection between systems that can bring the physical and the virtual world together [36]. These systems are called CPS and they can be defined as the integration of the virtual world and computation with physical processes. In other words, embedded computers and networks that monitor and control the physical processes providing a whole new degree of control, surveillance, transparency and efficiency in the production and transportation processes [31]. The proper alignment and integration between the main actors of the supply chain, the introduction of CPS and the increasing level of visibility and transparency will ensure an adequate forecast of resources. This will boost the optimization of resources and processes as well as the time to market alignment, making the supply chain smarter, more transparent and more efficient in every stage [26].
- **Business Intelligence (BI).** BI is often referred to as the techniques, technologies, systems, practices, methodologies and applications that analyze critical business

data to help an enterprise to better understand its business, the market needs and make business decisions on time [7]. BI can be applied in diverse business purposes like measurements, analytics, reporting, collaboration or data and knowledge sharing.

- **Smart factory.** They constitute a key feature of Industry 4.0, a decentralized production system, in which human beings, machines and resources communicate with each other increasing the information transparency and enabling the autonomous control of a manufacturing facility [7]. Smart factories will make the expanding complexity of manufacturing processes manageable for the people who work there and will ensure that production can be simultaneously attractive, sustainable, profitable and efficient in an urban environment [31]. Smart factories will provide an opportunity to create a new workplace culture geared towards the interests of the workforce and also it will allow individual customer requirements to be met, meaning that even one-off items can be manufactured profitably [36].

- **Cloud Manufacturing.** It is a service-oriented manufacturing mode and a distributed system consisting of an integrated and interconnected service pool of manufacturing resources and capabilities that provide solutions all along the life cycle of manufacturing. It is developed from existing advanced manufacturing models under the support of enterprise digitalization, advanced computing technologies, virtualization and cloud computing. This last can be defined as a standard for enabling convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort [38]. In other words, in these cloud manufacturing systems the resources can be intelligently connected into internet and automatically managed and controlled [39].

- **Internet of things (IoT).** The IoT is expected to open up numerous economic opportunities and can be considered as one of the most promising technologies with a huge disruptive potential [31]. Basically, IoT can turn all physical things into so-called “smart things” by featuring and embedding small computers that are connected to the Internet [40]. These smart and connected products and devices offer exponentially expanding opportunities for new functionalities, far greater reliability, much higher product utilization, and capabilities that cut across and transcend traditional product boundaries [41].

- **Big Data.** Big Data refers to the large volume of data, both structured and unstructured, which inundates businesses on a day-to-day basis. It can be analyzed and be treated by companies to improve their processes and performance.

Managing, collecting and storing this massive amount of data, ideally in real time, is very complex and costly.

All these technologies have data in common and it is the core driver of Industry 4.0. Therefore, the last two technologies, Internet of Things and Big Data, will be explained thoroughly because of the wide range of applications and disruptive impact they will have all along the supply chain.

### 3.3.1 Internet of Things

The Internet of Things (IoT) is a concept that refers to the digital interconnection of daily physical objects with the Internet but also all the elements, sensors and actuators in manufacturing lines or transportation vehicles. It is an ecosystem of ever-increasing complexity, fragmented and disorganized but if well managed it could play a vital role in how people live and how businesses are run [40]. The three distinguishing features of the IoT are context, omnipresence and optimization. The first one refers to the possibility of advanced object interaction with an existing environment and the immediate and proper response by it to change. Omnipresence illustrates the fact that today's devices are much more than just objects connected to a user network of human-operators. In the near future, they will also communicate with each other on a larger scale. And last, every IoT object is meant to optimize their functionality in order to fulfill their goals in a more efficient manner [42].

The IoT industry can be broken down into 3 layers interrelated and integrated with each other allowing the IoT phenomenon to happen and each one of them plays a key role [43]:

- **IoT applications.** Enables products and services to end-users.
- **IoT platforms.** Software systems and clouds that allow applications to function and connect.
- **Building block providers.** Physical hardware that lay the foundations of IoT.

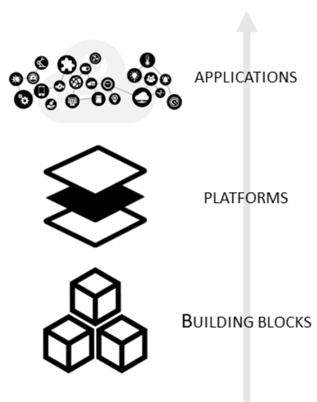


Figure 3.4: IoT layers

IoT represents a creative disruption, something that begins to overthrow the existing processes and technologies and bring forth a completely new way of working and managing electronic network activities [44]. IoT will create a world in which objects of all kinds could sense, communicate, analyze, and act or react to people and to other machines autonomously. IoT will increase the universality of the Internet by integrating every connected object through embedded systems, which leads to a highly distributed network of devices communicating with human beings as well as other devices [45]. The emerging IoT movement is having a huge impact on all the stages and stakeholders of supply chains of various industries and nearly all market areas [46].

The process behind this phenomenon can be summarized into an Information Value Loop with discrete but connected stages [10]:

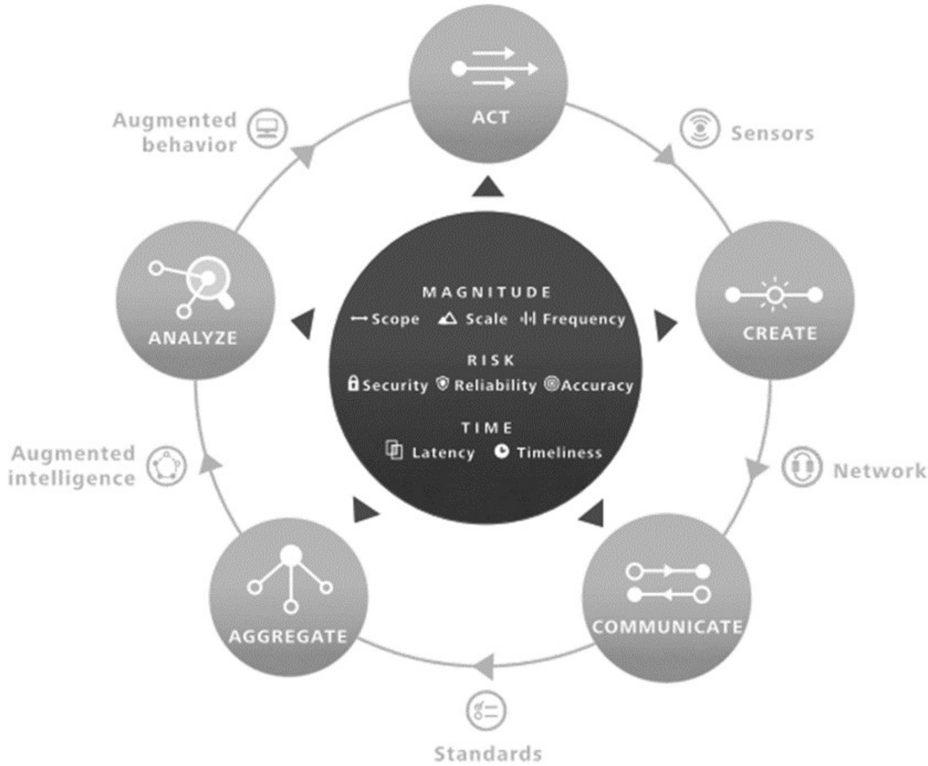


Figure 3.5: Information Value Loop [10]

Basically, an action in the world enable the creation of information about that action, which is then communicated and aggregated across time and space, allowing firms to analyze that data in order to modify future acts depending on the outcome of the analysis.

In the first place, the data is created and collected with the use of sensors and then, is electronically transformed into information that through actuators can be used in the decision making stage. There is a wide variety of sensors with different characteristics that determine the suitability for a specific application. Fundamentally, the choice of a specific sensor is based on the signal to be measured. The three primary factors driving the deployment of the sensor technology are price, capability, and size. As sensors get less expensive, “smarter,” and smaller, they can be used in a wider range of applications and can generate a broader range of data. The data gathered from the sensors is communicated to other locations to be aggregated with other data for further analysis. This involves transmitting data over a network. Here data transfer rates, security and energy requirements are key considerations when selecting a network technology. Once the data is collected, it is also aggregated, increasing the value of data, so that meaningful conclusions can be drawn. Aggregation is achieved through the use of regulatory and technological standards. Regulatory standards will play an important role in shaping the IoT landscape because there is a need for clear regulations related to the collection, handling, ownership, use, and sale of the data. On the other hand, technology standards, comprises three elements: network protocols, communication protocols, and data-aggregation standards. Network protocols define how machines identify each other, communication protocols provide a set of rules or a common language for devices to communicate and the aggregation standards help to collect, combine and process the data so it can become usable.

Extracting the insights from the data requires it to be analyzed. However, there are some limitations resulting from the quality of the data, the inability to develop a proper model or the limited ability to handle unstructured and real-time data. There are different types of analysis that can be applied to data but they will be explained in depth and expanded in the section of Big Data:

- **Descriptive analytics.** They are used to work effectively with much larger or more complex data sets.
- **Predictive analytics.** They exploit the large quantity and increasing variety of data to build useful models that can correlate seemingly unrelated variables [47]. It is the beginning of keener insight into what might be happening or could happen in specific environments and under certain conditions.
- **Prescriptive analytics.** They include optimization techniques that are based on large data sets, business rules and mathematical models trying to create causal models [48].

Lastly, from the analysis, some conclusions will arise leading again to the creation of data and the restart of the Information Value Loop. These conclusions will trigger some actions that could involve human decisions or just machine-to-machine (M2M) interactions.

### Situation and Future

Nowadays there are around 7,5 billion people on Earth and almost 45% of them are connected to the Internet. However, focusing on the young people, the percentage increases up to 70% of the worldwide population. This fact states that in the future, the access to Internet and connectivity between devices will not do other thing but increase and spread to more people and more industries all around the globe [49]. Today, about 25 billion devices such as mobile phones, tablets, wearables, personal computers, PDAs, data servers and other devices, driven by consumer electronics, medicine and health care, industrial design and automation, and transportation sectors, are connected to the Internet [50]. Based on a research [51], nearly 90% of companies from the logistics and transport sector have already implemented or will implement IoT solutions in these years and more than 50% expect that IoT will improve the supply chains by increasing the safety level and cost-effectiveness. Apart from the good opinion of the industry and willingness of adapting and implementing these changes, there are other factors that are pushing up and encouraging the whole phenomenon of IoT and connectivity.

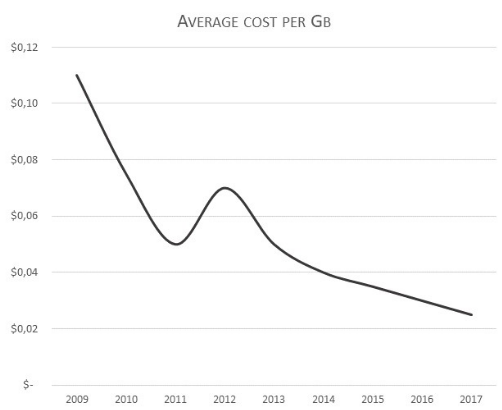


Figure 3.6: Average cost per Gb [52]

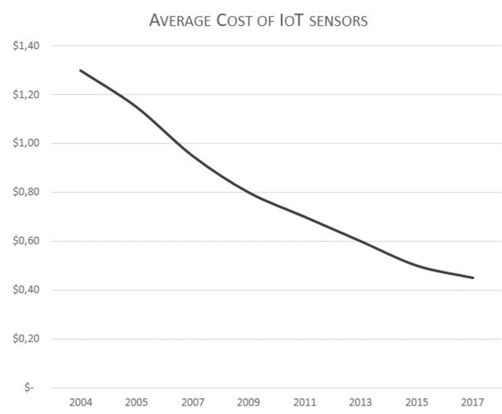


Figure 3.7: Average cost of sensors [53]

The price of the sensors used to gather and collect data is decreasing as well as the price to store this data, to be later analyzed. Not only this, but as stated before, the amount of data generated by people, companies, machines, sensors in different places is growing at fast rates. Even though the computing speed of computers is also rising up, it may not be enough to process all this huge data. That is where the technologies brought by Industry 4.0 play their role, specially IoT and Big Data. They are key to overcome this last by proposing new solutions to treat all this information.

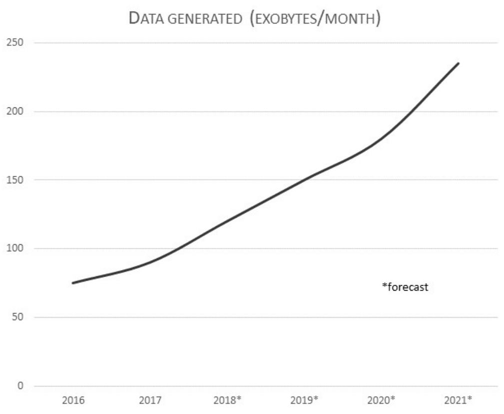


Figure 3.8: Data generated [54]

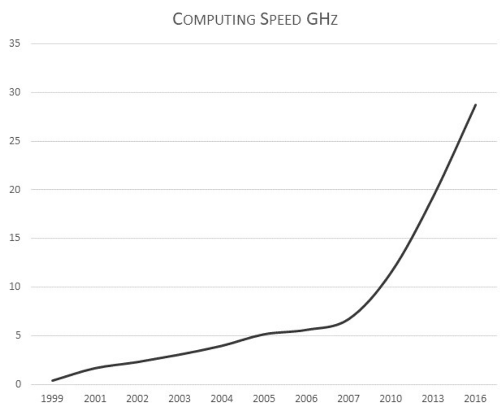


Figure 3.9: Computing speed [55]

Moreover, forecasts from specialized sources and companies started to appear all over the Internet regarding IoT. The number of connected devices is expected to increase during the following years, meaning that the size and value of the IoT global market will be considerable.

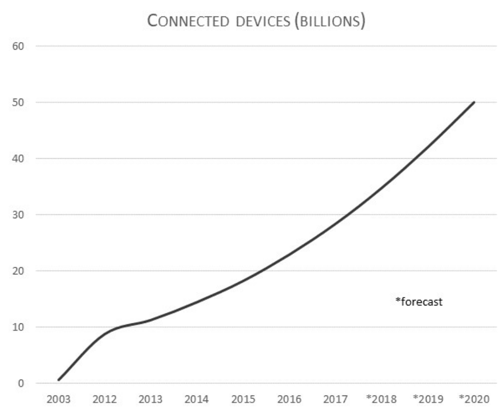


Figure 3.10: Connected devices [56]

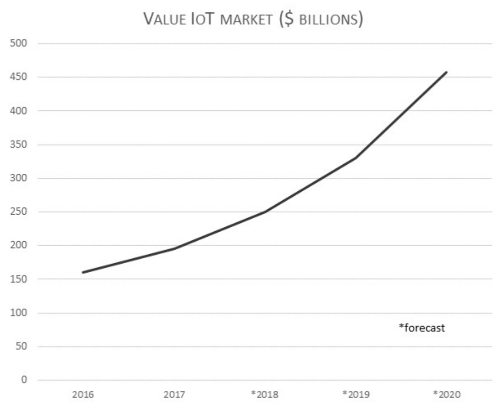


Figure 3.11: Value of the IoT market [57]

### Applications

With the rise of the IoT technology and devices, a wide variety of applications can be developed in many different fields [58]. Regarding infrastructures, with the use of smart sensors in roads, bridges or railways, safety can be improved and a predictive maintenance can be implemented. In healthcare, data will be collected to automate processes and provide insights that will enhance the medical workflow automation, enable better analytics and provide personalized treatments. In the agriculture field, IoT can help by tracking the soil temperature, acidity levels and other parameters that will allow the increase of the crop yields. It can also improve the actual irrigation methods to reduce water and energy consumption. Focusing on housing and hostelry, the IoT devices will enable people to control rooms, save energy, have intelligent surveillance and personalize other kind of services. Moreover, in the area of utilities (electricity, water, gas, oil...) these devices will help to measure and manage rising energy demand, saving energy and minimizing energy transmission losses.

However, a recent report [59] predicts that transportation, retail and manufacturing will be the hottest areas for IoT growth. In manufacturing, the use of smart sensors will increase the utilization of the capacity, will lower the unit cost and allow a predictive maintenance. It will also enable to track movements of products and monitor interactions with them [43]. Regarding the retail field, IoT will make possible to monitor customer behavior and push relevant advertisement to customers increasing the conversion rate and the number of new customers. Lastly, in the transport and logistics areas, by placing tracking sensors on parcels and shipping containers the costs associated with lost or damaged goods will be reduced and the speed of order processing increased. In addition to these applications, in transportation, the travel routes and the fuel usage will be optimized as well as enhance automotive analytics, improved traffic conditions, optimized fuel usage and travel routes.

Summarizing, the applications in which IoT could be applied can be categorized into three big applications: (a) enhancing situational awareness, (b) sensor-driven decision where large amounts of data of the environment or events from sensors will be used to take decision that will enable optimization of processes and resources [60] and (c) automation and control of processes and systems.

### Benefits

The IoT will facilitate the integration of processes and systems across sectors and technologies and will contribute to a better communication and cooperation between manufacturers and consumers in a new intelligent way. It will revolutionize the production, services provision, logistics and resource planning in a more effective way and cost-efficient manner [61].

Focusing on the supply chain field, IoT can suppress the variation and deviations by exploiting them, opening new paths through the ability to see and react to them. This ability to make visible previously unseen information, allows companies to achieve a greater efficiency. Moreover, by integrating IoT devices all along the supply chain companies can transform push-driven order systems to pull-driven ones improving the customer experience, offering a greater differentiation and opening the possibility of new and innovative business models [24].

IoT will affect mainly four dimensions of businesses [62]:

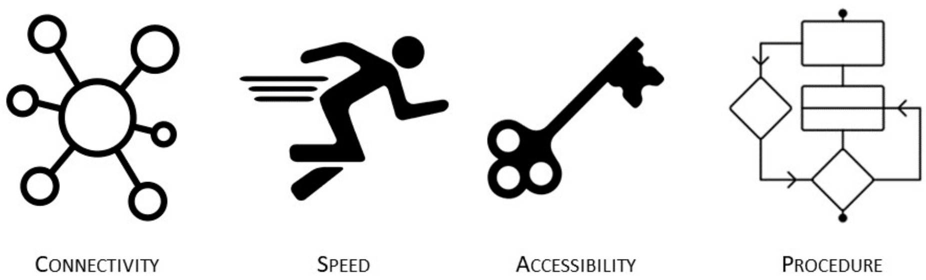


Figure 3.12: Areas where IoT will have an impact

- **Connectivity.** The different stages of traditional production systems will be much tighter and more automated. These fast digital connections will allow the whole system to operate as a seamless, cohesive whole. Integration will change the production systems in two ways. First, performance measurement and management will be based on precise data. Sensors will monitor the entire production process, from the inspection of incoming materials through manufacturing to final inspection and shipping. Consequently, all this amount of data will be combine to set the production system's targets and measure its performance continually. Second, connectivity will support better fact-based decision making due to the access to comprehensive and up-to-date production information, together with a complete historical picture.
- **Speed.** The aim of production systems is to maximize responsiveness and quick adaptation by emphasizing and implementing discipline and standards. Therefore, with the introduction of comprehensive, real-time data collection and analysis, production systems can become more responsive. Deviations from standards can immediately be flagged for action and the root causes of those deviations can be identified faster and also potential countermeasures.
- **Accessibility.** Access as well as data storage will be unified, simplifying and accelerating the operation of the production system. Employees at every level of the organization will get the tools and data they need through a single application that will be the organization's window into the system's data. Moreover, using secure and tightly controlled interfaces, the production-system application can also be accessible beyond the organization's boundaries, increasing the knowledge sharing and collaboration among the players of the supply chain.
- **Procedure.** The IoT will have a significant effect in the organization mindset, allowing companies to adapt to changes in the environment. Future production

> systems will help the organization to collaborate more effectively leading to an end-to-end view of performance that will break down barriers among functions and ensure that decisions reflect the interests of the business as a whole. In addition, the communication and information sharing will be greatly enhanced, since a central knowledge hub and social-media tools will let staff in one area access support, ideas, and expertise from another. Finally, future production systems will make performance far more visible, allowing employees to know how the organization is performing, as well as the precise value of the contribution of their businesses, plants, or production cells. The result will be not just about where the value is being created, but also about how.

Finally, IoT will drive the high growth of data both in terms of quantity and quality, providing the chance to Big Data to develop [44] within the firms part of the same supply chain.

#### Challenges and Risks

As IoT is based on the use of data and its transmission, the challenges and risks are very similar to the ones faced by Big Data. These include lack of standards, the ability to scale globally, information security and privacy, management of massive amounts of data, immature ecosystem or machines' judgment among others [10], [63], but focusing primarily in the transmission and connection in real time of the different devices. Therefore, in order to avoid redundancy they will be explained in depth during the next section along with the challenges and risk of implementing Big Data.

### 3.3.2 Big Data

Before digging into the technology of Big Data and develop its characteristics, its benefits and its risks, the concept of data should be explained.

Data can be defined as a set of characters that has been gathered and translated for a specific purpose. It can be classified into two categories based on the quality: intrinsic and contextual. Intrinsic data refers to attributes that are objective and native to the data. Among these attributes can be found accuracy, referring to the degree to which data are equivalent to their corresponding real values; timeliness, related to the degree to which data are up-to-date; consistency, meaning that data match in terms of format and structure; and completeness, described as the degree to which data is full and complete in content, with no missing data. On the other hand, contextual data refers to attributes that are dependent on the context in which the data are observed or used. These attributes are relevancy, value-adding, quantity, believability, accessibility and reputation [64].

Big Data emerged as a term to describe large datasets that could not be captured, stored, managed nor analyzed using traditional techniques. Big Data does not only refer to the data itself, but also to the set of technologies and techniques that enable the aforementioned functions as well as solving complex problems and unlocking the value in a more economical way [65]. It allows to quickly and efficiently manage, use and analyze the constantly growing database, separating the important data from the less important.

Big Data can also be defined taking these 5V concepts into consideration [42], [66]:

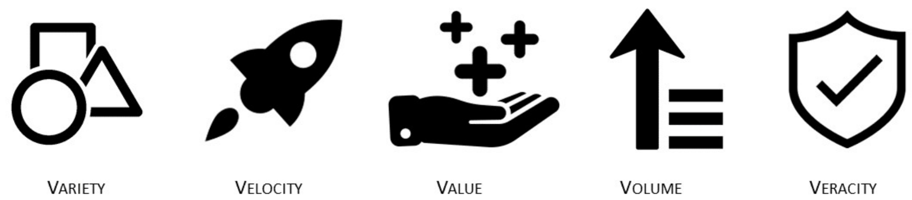


Figure 3.13: 5Vs of Big Data

- **Variety.** Usually, data comes from heterogeneous sources and can be generated in structured or unstructured formats, being these lasts not suited to traditional forms of analysis.
- **Velocity.** It refers to the generation speed of new data and how fast it is analyzed. This data can be analyzed in batches, real-time, nearly real-time, or streamlines.
- **Value.** It is related to the process of revealing underexploited values, isolating from the whole mass of information what is the most important in order to support decision making in businesses.
- **Volume.** The magnitude of data, which has exponentially increased, poses a challenge to the capacity of existing storage devices.
- **Veracity.** It stresses the importance of data quality and level of trust due to the concern that many data sources inherently contain a certain degree of uncertainty and unreliability.

The technology of Big Data is based on four pillars: Infrastructure, Storage, Processing and Analytics. First, Big Data needs an infrastructure able to be scalable and flexible to handle the huge amount of data. The cloud could be a solution. Secondly, this data will require to be storage. Therefore, new methods will arise solving these challenges. Third, a new framework needs to be design so as to process this quantity of data. Finally, new methods and techniques will be developed in order to analyze the data and extract the value from it [65].

However, Big Data without analytics is just a massive amount of data. To capture, store, aggregate, analyze data and then extract value is becoming a mandate for all organizations. Therefore, through the combination of Big Data and analytics, the ability to extract meaningful insights and turn information into intelligence is enabled [64]. This blending leads to a new concept, Big Data Analytics (BDA). It can be defined as the application of advanced analytic techniques including data mining, statistical analysis, predictive analytics, etc. on big datasets as a new business intelligence practice [67], [68]. It refers to the processes of examining and analyzing a huge amount and variety of data to draw conclusions by uncovering hidden patterns and correlations, trends, and other business valuable information and knowledge, in order to increase business benefits, increase operational efficiency, and explore new markets and opportunities [67], [69].

Summarizing, the goals of Big Data analysis are to develop effective methods that can accurately predict the future observations [70] and at the same time to uncover hidden patterns and insights using large sources of data [71].

### Situation and Future

Data has the role of changing the world as it is known now. It is becoming essential to the society. Information is instantly required regardless the location or time and it also allows the improvement of systems and processes [72]. Moreover, data-driven decision-making has been prevalent for more than three decades [73], [74] and therefore any improvement or change in how data is treated will have a significant effect when taking decisions.

Society is becoming increasingly more instrumented [75] and monitored. As a result, the magnitude of data generated and shared by businesses, public administrations, numerous industrial and nonprofit sectors, has increased immeasurably [76]. The volume of digital data is growing exponentially and it is becoming a challenge for the actual technologies to handle it. Data is generated much faster and it is bigger than ever before. Today, people are bombarded with data from every conceivable direction. The availability of data has rapidly grown in recent years as a result of the globalization of the world's economy and also due to the adoption and diffusion of various disruptive digital information technologies [73]. However, the key issue here is how this data is used in a constructive way and how it can be calibrated.

The continuous growth of sources is accompanied by significant improvements in data processing capabilities [77] that is allowing enterprises across various industries to embark on a path to digitally transform their organization. These changes can range from the introduction of data processing at every step of existing business processes, innovative ways to analyze data, new ways to apply the analysis to the business, exposition to new knowledge, facilitation in responding to emerging opportunities and challenges, all the way to pivot the enterprise's business model towards the monetization of its data assets and the finding of new channels of revenue [63], [65].

Forecasts, surveys and reports from specialized companies [75], [78] predict that by 2025 the data generated globally will grow to 160 Zettabyte (ZB). To put this in perspective, the total amount of data generated globally in 2016 was around 16ZB and just 1ZB equals to $10^{12}$ GB. Additionally, it is expected that every day the world produces around 2.5 Exabytes (EB) of data from which the 90% of it is unstructured . Despite this vast amount of data available, it is required determination and skill to be able to put it to use to unlock a new world of business opportunities. In 2013, only 22% of the information in the digital universe would be a candidate for analysis with the actual techniques [9]. Moreover, it is estimated that at least 40% of this new data generated will require some level of security, from privacy protection to full-encryption lock. And the amount of data needing protection will grow as more of the IoT devices comes online [63]. Among the data in need of security, it can be found corporate financial data, personal information, medical records, user information accounts or KPIs from supply chain partners.

Listed below there are some interesting facts and numbers about data nowadays [79]–[81]:

- The total amount of data being captured and stored by industry doubles every year.
- Every minute 204 million emails are sent.
- Google alone processes on average over 40 thousand search queries per second, making it over 3.5 billion in a single day.
- Around 100 hours of video are uploaded to YouTube every minute and it would take you around 15 years to watch every video uploaded by users in one day.
- Facebook users share 30 billion pieces of content between them every day. Facebook stores, accesses, and analyzes 30+ Petabytes of user generated data.
- 570 new websites spring into existence every minute of every day.
- Walmart handles more than 1 million customer transactions every hour, which is imported into databases estimated to contain more than 2.5 petabytes of data.
- In 2014, there was over 1.2 billion smart phones in the world, and the growth is predicted to continue.
- 12 million Radio-frequency identification (RFID) tags – used to capture data and

track movement of objects in the physical world – had been sold in by 2011. By 2021, it is estimated that number will rise to 209 billion as the IoT takes off.

Despite challenges relating to privacy concerns and organizational resistance, Big Data investments continue to gain momentum across the globe [65]. Data analytics software is already a $40 billion market and it is growing 10% a year. Security products and services are a $50 billion market whereas Cloud computing accounts for 5% of total IT spending, growing to 10% by 2020 [63]. Big Data is expected to be one of the top 10 prosperous markets in the coming century [82].

The next graph (*Figure 3.14*) shows a revenue forecast for the global big data industry from 2011 to 2027:

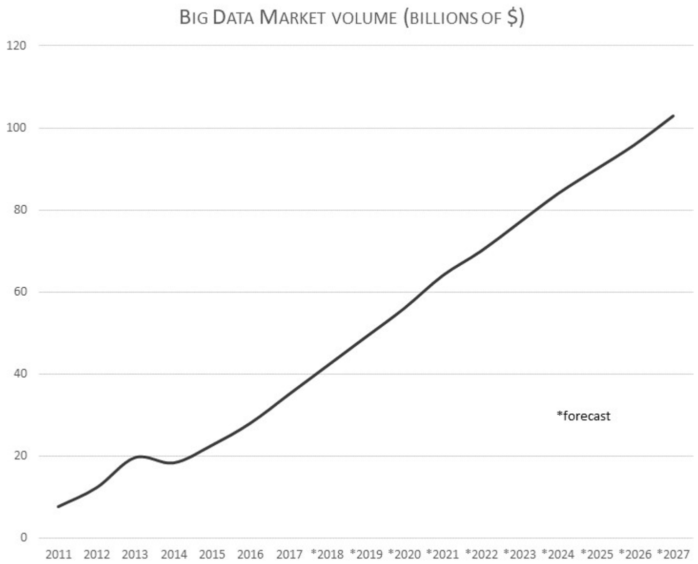


Figure 3.14: Revenue forecast of the Big Data market [83]

### Applications

However, data itself does not have an inherent value, and therefore, all data collection should be approached with the objective of maximizing concrete value drivers across the business [32]. The use of analytics on Big Data will benefit from large volumes of data [84] and will become the basis of competition and growth for individual firms, enhancing productivity and creating significant value for the world economy by reducing waste and increasing the quality of products and services [85].

The widespread use of digital technologies has led to the emergence of BDA as a critical business capability. It is meant to provide companies better means to obtain value from an increasingly massive amount of data and gain a powerful competitive advantage [86].

Companies are using new approaches, moving from descriptive to predictive and prescriptive analytics and doing data analysis in real-time. They are also increasingly adopting self-service business intelligence and analytics, giving executives and front line workers easy-to-use software tools for data discovery and timely decision-making [63].

BDA can help organizations to make better decisions and to improve their strategy, operations efficiency, and financial performance. Such improvements can be realized by a deeper understanding of business dynamics, intensifying customer engagement, optimizing daily operations, and capitalizing on new sources of revenue [68].

The diverse ways to analyze data within Big Data are the following [86]:

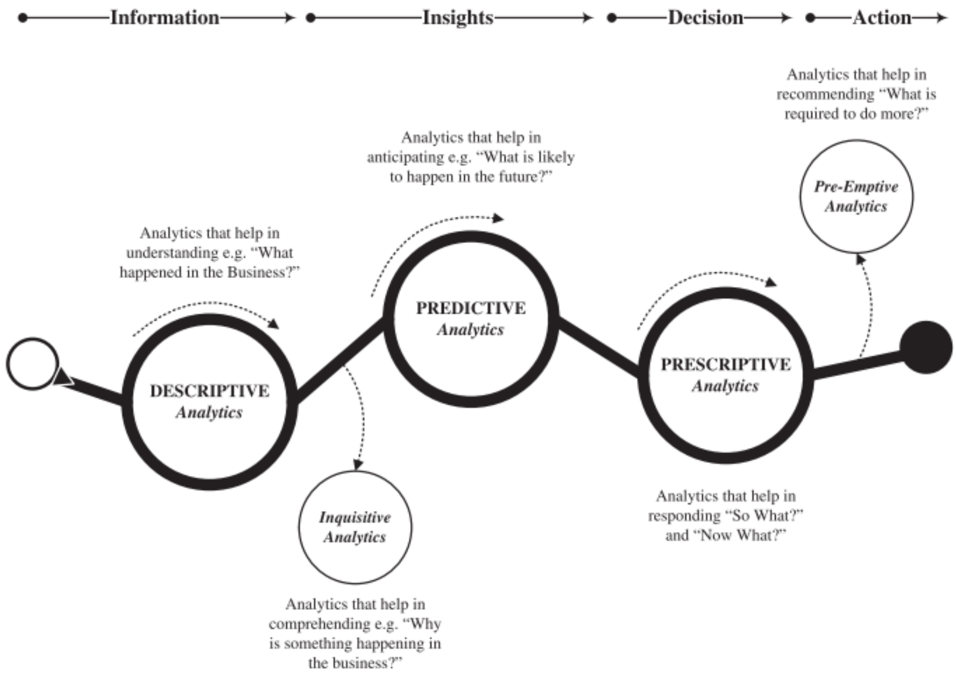


Figure 3.15: Methods of analysis [87]

- **Descriptive analytics** scrutinizes data and information to define the current state of a business situation in a way that developments, patterns and exceptions become evident, in the form of producing standard reports, ad hoc reports, and alerts. They are the simplest form of BDA method, and involve the summarization and description of knowledge patterns using simple statistical methods, such as mean, median, mode, standard deviation, variance, and frequency measurement of specific events in Big Data streams. They are considered a backward looking and they reveal what has already occurred allowing businesses to discover useful patterns or unidentified correlations that could be used for making business decisions [75].

- **Predictive analytics** involve the use of mathematical algorithms, programming and statistical methods [75] to discover explanatory and predictive patterns within data. The aim of this type of analytics is to accurately project what will happen in the future and provide reasons as to why it may happen. All this, being highly reliable and having a high explanatory power [84]. Predictive analytics is enabled by the use of techniques such as data/text/web mining, forecasting [88] and learning models. Because of supply disruptions and demand uncertainty, predictive analytics tools are essential to design supply chain flexibility into logistics operations.
- **Prescriptive analytics** involves the use of data and mathematical algorithms to determine and assess alternative decisions that implicate objectives and requirements characterized by high volume and complexity, with the aim to improve business performance. It is about is about optimization and randomized testing to assess how businesses enhance their service levels while decreasing the expenses [89]. It includes multicriteria decision-making, optimization, and simulation.
- **Inquisitive analytics** is about probing data to certify or reject business propositions [87].
- **Pre-emptive analytics** is about having the capacity to take precautionary actions on events that may undesirably influence the organizational performance [75].

Predictive and prescriptive analytics play a vital role in helping companies make effective decisions on their strategic direction [88]. They both can be applied to address problems related to the changes in organizational culture, sourcing decisions, supply chain configuration and with the design and development of products or services. On the other hand, descriptive analytics are simpler and they answer questions related to what happened and/or what is happening.

BDA is reported to be an emerging supply chain game changer [66] of the global logistics industry. The market has been flooded with real time and a large ever-growing amount of data, enabling companies to excel in the current fast-paced and ever-changing market environment. BDA will not only affect SCM operations but will also have an impact on supply chain performance, relationships and social structures. It is expected that BDA will be the key driver of digital supply chains by improving the quality of demand planning, the accuracy of predictions and forecasts, improving the resilience and robustness of the supply chain and also enabling the transparency along the value chain, facilitating fast decision making and responses to possible disruptions. Consequently, data will become a crucial strategic asset [73]. When BDA is used in strategic management, where the plan of the company and the supply chain strategies are aligned, it can provide an overall direction for the entire organization, and a guidance on the operations and supply chain strategies.

Due to the adoption of Information Technologies (IT), supply chains are enabled to monitor the information flow and also inclined towards the collection and analysis of a variety of data for an improvement in management efficiency [9]. The five main sources of big data in supply chains are Radio Frequency Identification (RFID), Global Positioning System (GPS), Point of Sale (POS), Suppliers and Manufacturers. RFID and GPS can help in real-time inventory positioning and warehousing while POS data is one of the main enablers of demand forecasting and customer behavior analysis. Suppliers Big Data can help manufacturers monitor supplier performance, and manage risk and capacity whereas Manufacturing Big Data will help identify production bottlenecks and imminent machine failures [71].

Supply chains need to be aligned with the changing preferences of customers to enable the provision of products and logistics services [73]. Therefore, Supply Chain Analytics (SCA) is fundamental. SCA are the analytical applications available along the entire supply chain spectrum that helps to identify areas for optimization. They can be differentiated into qualitative and quantitative. Qualitative methods are based on subjective judgment of consumers or experts and are appropriate when past data is not available whereas quantitative approaches are used to make predictions as a function of past data [64]. For example, marketing could be one where SCA can help to optimize. Marketing analytics applications are customer oriented and are on the sell side of the supply chain. The nature of marketing has driven the development of Big Data applications that focus on capturing customer demand, enabling micro-segmentation, and predicting consumer behaviors and patterns to achieve a better understanding [64], [82]. Another important marketing application could be in price optimization [90]. Through SCA, price optimization allows real time analysis at a high granularity of data on pricing and sales using a variety of data sources [64], [82]. Moreover, it can enhance the user experience through sensor enabled applications [32].

Focusing into the logistic field, SCA can be used to predict and proactively plan different supply chain activities [71]. It can help to design inventory optimization systems [73] that are able to handle complex challenges or help in the prediction of these inventory needs allowing to respond properly to the changing customers' demands as well as reducing dramatically the inventory costs [64]. SCA is used to predict supply disruptions, to forecast the demand and to extract demand patterns that will allow companies to adopt a proactive response when planning and scheduling as well as when dealing with supply chain risks or network design problems [71], [73], [91]. It will help to enhance the visibility by enabling the ability to adjust their production and operations under demand and capacity fluctuations in a real time basis.

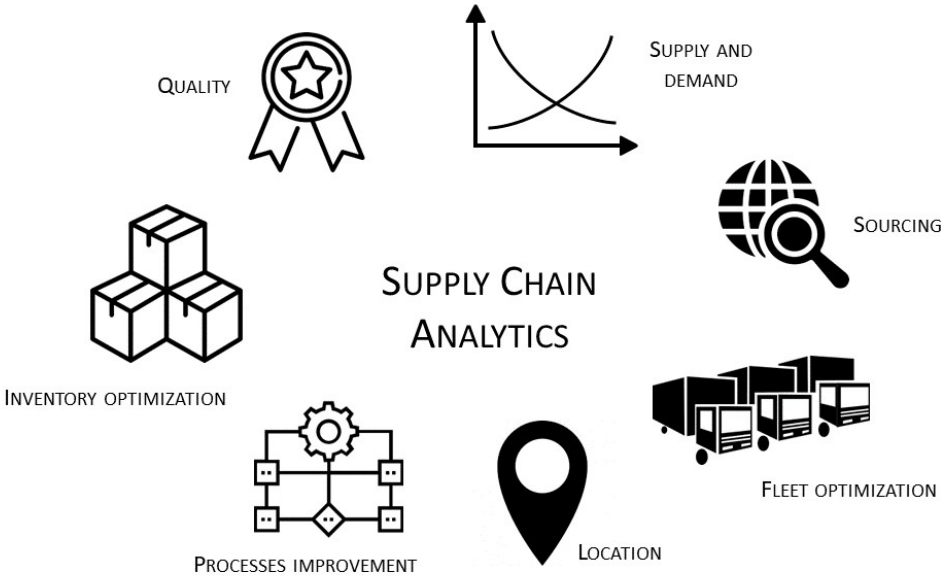


Figure 3.16: Focus of SCA

The insights extracted from the data will assist in the identification of optimal distribution center locations, improve the fleet performance, minimize the transportation costs and also implement reverse logistics [32], [64], [73]. SCA will allow companies to put the right products with the right dealers at the right time avoiding delivery delays, offering alternative routes for distribution vehicles in real time based on unforeseen events and allowing the tracking of goods throughout the whole supply chain [32], [64], [71]. Manufacturers can also benefit from SCA to produce high-quality and competitively priced products that can outperform their competitors [91]. This can be achieved through the optimization of asset utilization by tracking their conditions, identifying and fixing system failures as well as anticipating to design flaws. Processes can be improved by ensuring that the right mix of resources is allocated to the right production lines making the work flow smoother. Moreover, it enables manufacturers to understand the different production costs involved and how they influence the bottom line. In other words, SCA evaluates potential trade-offs by performing what-if scenario analysis to assess the effects of product conception and development costs, achieving the most economical design that meets the quality and reliability criteria [91] giving to their products a competitive edge. Analytics applications are becoming increasingly important in sourcing since in most manufacturing organizations, sourcing represents the largest single category of spend for the company [64]. Therefore, SCA can yield great savings as well as facilitate the development of optimal sourcing strategies by measuring, analyzing, managing and evaluating supply market trends and suppliers' inputs but also ensuring that the sourcing strategies are aligned to the organizations strategic goals and objectives [86], [91].

Summarizing, SCA enables companies to adopt a proactive rather than a reactive response to supply chain risks. It helps companies to make the correct decisions providing a better understanding of the influence of different factors, reducing the risks associated, enabling them to benchmark industry best practices, set performance targets, and implement customized metrics so that they can easily achieve their goals in less time [86]. However, a prerequisite for any of these BDA applications to succeed is the availability and quality of the data as well as the existence of trust between supply chain partners to promote information sharing [73] having as a goal the integration of the supply chain. This last topic will be developed further in this report.

**Benefits**

Big Data holds the key to enhance the supply chain maturity and increase the agility and responsiveness by ensuring data integrity, increasing visibility and control through the whole chain [71]. Usually, companies want to retain a customer and make them come back; they want loyal customers. To do so, firms have to offer new and better services and products that customers want. BDA will help on improving the customer service by collecting data about them, exposing people's hidden behavioral patterns allowing organizations to have the proper knowledge about their consumers. Using this knowledge, the appropriated offers and services could be pitched to the customers making them feel like they are receiving personal care [92], [93].

The benefits of applying BDA to supply chain specifically are the ability of monitoring delivery routes, traffic data or the weather in real time. Also allowing to reroute if necessary for capacity and asset sharing as well as being more accurate when estimating the demand by accessing data of sales, market trends, competitors' data and relevant local and global economic factors [71]. Another benefit of BDA could be in the warehouses. It will help to identify inventory levels, delivery mismatches and incoming deliveries, allowing, in real time, the optimization of complex networks of distribution hubs, plants and warehouses based on the material flow data. All this will facilitate, ease and increase the accuracy and optimize the production, distribution scheduling [71] and levels of inventory. Basically, the inventory is used as a buffer in case of disruptions in the demand, shortage of essential materials from suppliers or break downs of the production lines. The use of Big Data can significantly reduce the level of inventory needed to be maintained and save wealth and space [92] by providing full transparency and by developing automated replenishment systems [71]. This transparency empowers partners to share data, encouraging trust and allowing only one version of truth through the whole supply chain [94]. Historic data from past demand can be used to accurately predict future demands. The same case can be applied to supply patterns of the suppliers to predict future situations. In addition to this, by analyzing performance data of the machines, companies will have the capacity of developing preventive algorithms to maintain the machines before they break down and consequently keeping delivery times unaffected. BDA can play a decisive role when trying to improve the operational efficiency and reduce waste and operational costs. These costs are associated with multiple factors and variables and an alteration in any one of them might have an adverse effect on the others. Therefore, BDA will help in the prioritization of variables by balancing the reductions in each factor so that they do not increase others. Analysis of these data would give the firm insights into the independent cost functions as well as the relationship between the different variables [92].

### Challenges and Risks

Big Data offers substantial value to organizations willing to adopt it. It is also the key to competitive advantage, but at the same time poses a considerable number of challenges [95]. There is too much information, it is too diverse, too complex and it is too effervescent [65], meaning that new data do not stop appearing, making the previous one obsolete if not used on time. This may be an obstacle for companies to leverage BDA, to become data-driven [63] and to transform their supply chain operations [64], because if this data cannot be interpreted or used, it is useless and of no value [82]. However, it is a source of opportunity for those with the proper tools, skills and attitude to take advantage of it [63].

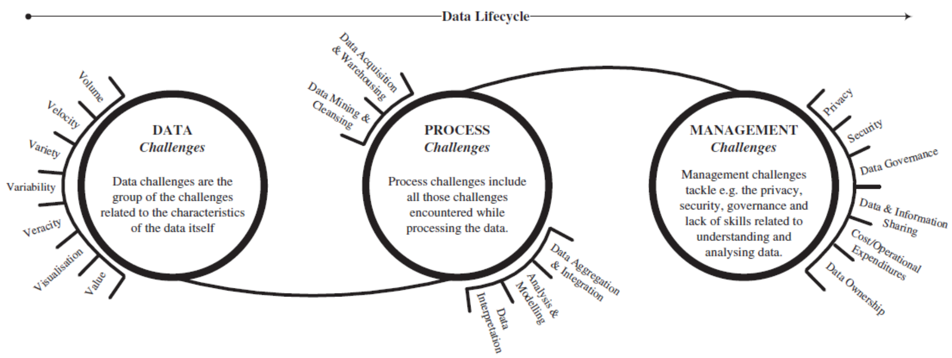


Figure 3.17: Big Data Challenges [87]

There is limited understanding of how Big Data technologies are going to affect the development of BDA in supply chains as well as their impact in social changes regarding the functions and tasks of employees involved along the supply chain. Companies need to understand the capabilities and requirements to translate them into value propositions, process optimizations [73] and something they can understand and measure.

There are three main concerns or obstacles in the path of achieving an effective application of Big Data:

**1. Data**.

As stated in the *Situation and Future* section, it is a fact that companies are increasingly generating huge amounts of data and this data has to be analyzed to extract value that could offer some benefits to them. This growth rate is fast exceeding the ability to both design appropriate systems to handle the data effectively and to analyze it to extract relevant meaning for decision making [96]. The large scale and the sheer volume of data is a big challenge in its own right, but also the management of the high influx rate of non-homogeneous data, which results in either creating new data or updating the existing data [97]. However, many challenges emerge regarding the data itself: data integration complexities, security and privacy issues, inadequate infrastructure and synchronization of large amounts of data, among others [75].

Big Data presents several concerns related to privacy and security when storing data or sharing it all along the supply chain [9]. If the economic benefits of Big Data are to be achieved, these challenges should be addressed. To overcome the unstable reliability and security issues [82], [85], trust has to be develop as well as an effective data governance initiative regarding the process of data integration and management in the value chain.

Data scalability is a major technical issue when adopting BDA. Most of the time, organizations have to dump and discard their data after a particular period so as to store newly generated data. This can be tackled with the use of more advanced infrastructure, distributed databases, parallel computing or cloud computing. However, leveraging these capabilities could mean a financial burden and therefore, other strategies to optimize data collection and reduce unwanted data generation from the source could arise as the solutions [9], [94].

As supply managers rely on the insights extracted from data to obtain a competitive advantage, this should have quality [9]. Moreover, quality issues are increasing as firms' desires and capability for the analysis of ever larger amounts of acquired data similarly increase [98]. Consequently, data collection plays an essential role because without an efficient and effective approach for capturing the data, it is impossible to carry out data-based analytics, make decisions and induce continuous improvement in the data production process. The data captured tend to be incomplete, inaccurate and untimely. The results of decisions based on poor quality data could be costly. It would obstruct the data analytics activities and affect management decisions [9], [98], leading them to be unreasonable, unexecutable, and unpresentable. Thus, the necessity to deal with inaccurate and ambiguous data is another facet of Big Data, which is addressed using tools and analytics developed for management and also mining unreliable data [75], [99]. Moreover, to assist firms in diagnosing supply chain risks and uncertainties (SCRU) from a sustainable development perspective, there is a need to first identify, assess and analyze these diverse data sources [91].

There are also many technological issues that need to be resolved to make the most of Big Data. Diverse collectors such as sensors, and digital devices, have their own specific data formats which are commonly heterogeneous, unstructured, and incompatible. These different forms and quality of data clearly indicate that heterogeneity is a natural property of Big Data and it is a big challenge to comprehend and manage such data [75], [100]. All this, along with being large sample size, makes data integration extremely difficult, computational costly and therefore, data standardization is crucial for the succeed of DBA applications [70], [82].

**2. Process**

Basically, there are two main concerns here, the implementation of BDA inside companies and the lifecycle of the data itself within those companies.

The implementation of any BDA technique is costly and therefore, companies must choose where to direct these efforts. Focusing on applications that try to tackle many areas can lead to lose sight of the purpose of the implementation itself. First of all, organizations who are better informed of their current state of BDA capabilities are in better position to work on the challenges while the adoption is taking place [9], [69]. Therefore, before implementing anything, an assessment of their capabilities should be done by using maturity models. These can help organizations to measure their current state of technological competence benchmarked against the industry standards. Once this is done, the implementation can begin.

Regarding these capabilities, the following dimensions can be identified [9]:

- **Data Generation.** The ability of organizations to seek, identify, create, and access data from heterogeneous sources across organizational boundaries.
- **Data Integration and Management.** The ability of organizations to utilize tools and techniques to collect, integrate, transform and store data from heterogeneous data sources
- **Advanced Analytics.** The ability of organizations to utilize tools and techniques to analyze supply chain data in batch wise, real-time, near-time, or as it flows and

extracts meaningful insights to be used in decision making.

- **Data Visualization.** The ability of organizations to utilize tools and techniques to render information visuals and deliver the data-driven insights intuitively in a timely manner to the decision makers.
- **Data-driven culture.** Intangible resource that represents the beliefs, attitudes, and opinions of people towards data driven decision-making.

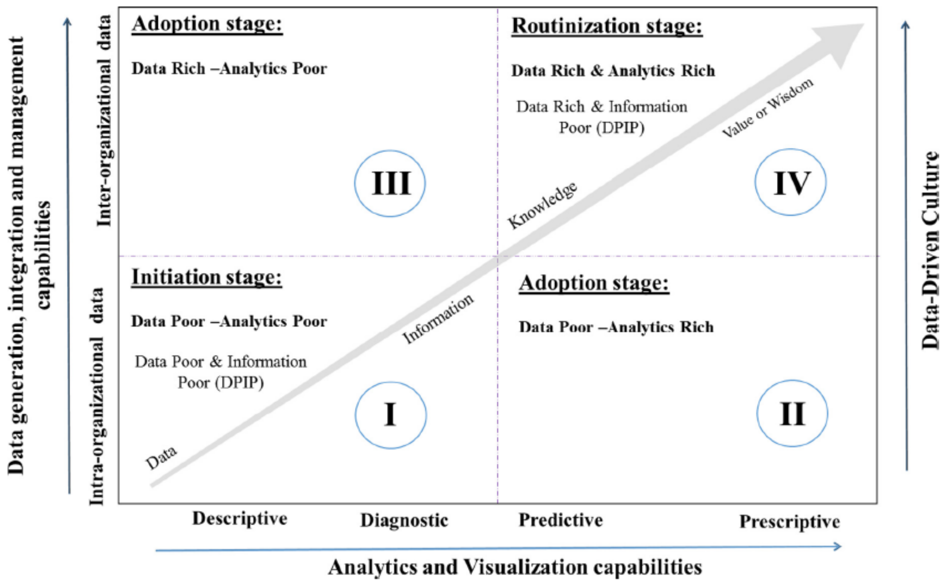


Figure 3.18: Implementation stages of Big Data [9]

The previous image (*Figure 3.18*) shows the evolution in terms of BDA maturity. First, companies are in the incognizant stage, meaning that they lack the knowledge about BDA and its benefits. In the initiation stage, firms are aware of BDA and considering it for leveraging, but have not implemented it yet. Then, the adoption phase starts and it can be divided in 3 steps. The first step is digitizing and structuring the data. This process ensures that the data generated is clean, structured, and organized in such a way that it can be used for further analysis; removing errors and guarantying data quality. The second step requires making the data available to all who need it when they ask for it. However, to be successful in this step, organizational functions should be aligned and processes and data integrated along the supply chain. And finally, the third step is applying basic analytics to the data, identifying the right metrics, such as basic data comparisons, correlations, and regression. Many companies can success and improve from this stage without investing in more advanced technologies because these techniques can provide powerful insights. The fourth and highest stage, the routinization stage, takes place when the company is mature enough to introduce and apply advanced analytics, such as predictive analytics, automated algorithms, and real-time data analysis, into businesses processes that can create radical new insights. Nevertheless, leveraging Big Data at this level often requires the expertise of deep analytical talent [9], [64]. It is a mistake for companies to try to jump to the last stage of the maturity map without first going through the first three stages. Companies need to go through the organizational adaptation, learning, and continuous improvement required to move through the stages. Successful use of BDA does not only depend on the availability of data and the analytical tools. It also depends on the ability of organizational members — leaders, managers, and employees — to be able to use them [64].

The lifecycle of the data inside a company could be summarized into five steps with their own challenges. First the data has to be acquired from diverse sources and be stored for value generation. But being the data usually heterogeneous, varying in speed, frequency, volume, and complexity, and lacking standards, the speed and resolution in the collection and processing of the data can be compromised involving a challenge. Second, from a collected pool of large scale unstructured, diverse, interrelated and unreliable data, the right portion of it has to be extracted. Developing and maintaining this extraction method is a continuous challenge but also, Big Data users face the dichotomy of quantity versus quality. Third, these portions, from different sources, have to be aggregated and integrated for further analysis. However, this data will not be stored in one or few locations, it will not be just one or even a few types and formats; it will not be amenable to analysis by just one or a few analytics; and there will not be just one or a few cross linkages among the different data elements [96]. Once this is done, the fourth step is to analyze and model to handle the Big Data, but new methods need to be developed for this purpose. And the last step is the interpretation of the results and findings from the analysis [75].

**3. Management**

The technological benefits that BDA will bring are going to influence the workplace, tasks and responsibilities of SCM. As operational tasks and decisions are being automated due to data driven approaches, their job profile and functions would transform from the creation of forecasts to the maintenance and control of demand planning systems [73]. A pressing challenge is a most likely shortage of data scientists with the necessary skills, a combination of analytical skills and domain knowledge, to analyze and extract value from large volumes of data. Therefore, inexperienced employees, time constraints, lack of integration and issues with change management are the potential barriers of the implementation of BDA applications to have into account [9], [71], [85]. Lack of skills is not the only problem, there is an inability of techniques to exploit this data properly. For example, most of forecasting techniques do not consider exogenous variables and information sources as well as expert judgment, being these of great influence [9]. Big Data also presents new ethical challenges, such as privacy or location-based information being collected by Big Data applications and transferred over networks is resulting in clear privacy concerns [75]. Moreover, the fact of tracking employees and continuously measuring their performance introduces a level of oversight that can repress the human spirit. In fact, one of the major challenges of Big Data is preserving individual privacy [93].

All these techniques of analysis are time consuming and they include different stages like developing, testing and adaptation. In complex systems like a supply chain, BDA implementation, getting the data, combining it and validating it, might take a year or more to see some results [9]. Moreover, holding, storing and processing these sets of huge amounts of unstructured or heterogeneous data as well as modify or update it is time consuming. This cannot be solved by using bigger and faster computer but new approaches should be developed as well as more sophisticated data centers. Among these it could be found smart cloud-based storage, biological storage, new decision-making mechanism, self-learning models or intelligent processors [82]. Moreover, growing volume, variety and velocity of data is overwhelming conventional computing capacities, simulations or statistics [73]. These last challenges, will increase the operational expenses due to a high investment on these new technologies. The lack of IT resources and capabilities to share and analyze data in real time across the supply chain could cause discrepancies and disruptions. Therefore, collaboration and cross functional teams should be set up as well as encourage a data driven culture along the supply chain network [9] in order to maximize its effect and to establish closer relationships [75].

To effectively deal with the diffusion of BDA technologies into the supply chain, organizational and behavioral issues related to the adoption and practices have to be addressed. Despite the potential provided by Big Data, many companies are unable to generate useful insights from their data for their businesses. Some of the hurdles that prevent companies from taking advantage are that they suffer a paralysis due to either lacking the capabilities to analyze large sums of data or to the fact that they are overwhelmed with the rapid change of technological capabilities. To avoid this paralysis, supply chains need to correctly identify potential problems, the right set of data and the proper metrics wanted to be measured. Once the amount and type of data needed to solve the problem and the correct type of analyses is considered, skills and tools must be selected to enable the problem to be tackled in the most cost-effective manner. Also, some companies focus on a specific process leaving the rest unattended or they analyze erroneously a portion of data causing the supply chain to incur into significant costs without achieving the desired outcomes [64], [71]. From the behavioral perspective, the use of real-time data and information could be challenging because decision makers may excessively react to even small changes in the physical world which would worsen the bullwhip effect, which will be explain later on this report, and increase supply chain risk and cost of inventory [9]. Moreover, there are some risks related to security. Big Data is vulnerable to be attacked and the lack of the adequate security controls is an important challenge to be solved.

SCM will face many challenges that can potentially result in inefficiencies and wastage in supply chains and there is no perfect Big Data management solution yet [96]. However, BDA presents an opportunity to overcome those challenges [86] and confront the future to come.

CHAPTER 4

# Supply Chain 4.0

## 4.1 Concept

Supply chains are traditionally linear, discrete, separated in silos and rely on periodic forecasts and plans that usually become outdated and inaccurate as this information moves along the supply chain. Nevertheless, today supply chains are transforming into dynamic, integrated and interconnected systems, that are fully transparent to all the players involved [8], changing the way of how companies work and compete [5]. Previously in this report, it has been stated the different innovations and technologies that Industry 4.0 brings. These, once applied to the supply chain field, characterize and describe the new concept and definition of Supply Chain 4.0 (SC 4.0) or Digital Supply Chain (DSC), which will face the new challenges of today's environment.

The function of any supply chain centers on the movement of materials, finished goods, capital, and other assets from place to place, as well as the production of finished goods always having on mind the satisfaction of the customer. But by connecting all the stages to one another via these new technologies, the latency, risk, and waste found in linear supply chains can be minimize. The main characteristics of a DSC or SC 4.0 are that they are always on, meaning that data is continuously being transmitted along the supply chain providing an integrated view. The improvements that SC 4.0 bring will enable a considerable change in service, cost, capital, and agility [4].

By being connected, all the stakeholders and different systems can communicate and share information directly, that later on can be analyzed providing insights from critical areas enabling a better supply and demand balancing as well as decision making [5]. Logistics will take a huge step forward through better connectivity, collaboration and knowledge sharing, ensuring that all stakeholders in the supply chain steer and decide based on the same facts [4]. Additionally, supply chains will become more efficient, effective and flexible, ready to adapt to changes [101].

The goal of the SC 4.0 is to deliver the right product into the customer's hands as quickly as possible but also to do so responsively and reliably, while increasing efficiency and cutting costs through automation [8]. The result will be full awareness and collaboration along different time horizons on strategic, tactical, and operational levels as well as a considerable improve in the level of customer service and the proper adjustment to the market needs. However, this goal cannot be achieved unless the supply chain is fully integrated, connected and driven by data, key element of SC 4.0 [8], [61]. And apart from this, the increasing complexity and interrelation within the supply chain will make hard to implement any of these technologies.

## 4.2 Challenges

There are some challenges associated to traditional supply chains that are still there and will continue to exist in the future. One of the most common goals in supply chain management includes cost reduction and now with shorter product life cycles and changing market demands, companies are forced to embark on a lean journey to tackle it. Moreover, now it has become essentially a requirement for the companies and natural for the customers to have their goods delivered within a limited period of time and also to provide the same or even more quality as their competitor to stay in the market. Therefore, companies that are too reliant on one supplier are vulnerable. Firms should mitigate and have contingency plans regarding their supply chains to ensure minimum disruptions in supply due to external and natural factors [92], increasing the resilience of the chain. Resilience it is understood as the ability of a supply chain to return to normal operating performance, within an acceptable period of time, after being disturbed. It is considered a critical capability to maintain the continuity of the operations since supply chain have increased in length and complexity [102].

Nevertheless, the introduction of Industry 4.0 practices and technologies into companies has many impacts on the whole supply chain, and one of them is the transformation from a linear and traditional supply chain into a DSC. This process requires three key enablers: a clear definition, new capabilities, and a supportive environment. Defining the DSC starts with an understanding of the current operation's digital waste [4]. To do so, collaboration has to be encouraged and the lack of information visibility along the supply chain has to be tackled. If not, the ability of companies to access to relevant insights, make proper business decisions, mitigate risks and satisfy the customers will be compromised [103]. On the other hand, capabilities regarding digitization need to be built and they typically require to recruit specific and specialist profiles [4]. Even though the number of engineers trained in handling unstructured data and big data tools is gradually increasing, it still falls far short of anticipated demand [37]. Moreover, leaders could feel uncomfortable with advanced manufacturing and technologies resulting into the unwillingness to adopt new approaches [37]. Therefore, companies should take a proactive attitude and anticipate to these scenarios by encouraging this kind of knowledge among their actual and future employees. The final prerequisite is that the establishment of the organization and IT landscape must be accompanied by creation of an innovation and collaborative environment [4].

Many of the systems and applications that SC 4.0 will bring can present challenges when trying to integrate to the actual ones. Therefore, companies should encourage the creation and application of standards in order to maximize the value of their investments [37]. Moreover, as data starts flowing through the supply chain, questions will arise regarding who owns the data generated, how to ensure appropriate privacy, control, and security and so on. Usually, new technological solutions always carry vulnerabilities, but those standards will help with these issues [61].

## 4.3 Approaches

Summarizing, in order to achieve a SC 4.0, it is required a proper IT system that can handle the new technologies mentioned before in the report, specially IoT and Big Data, and also to encourage collaboration and knowledge sharing among the stakeholders within the supply chain.

### 4.3.1 Collaboration

Knowledge has become a key determinant of enhancing competitive advantage in supply chains, and therefore it has to be manage properly to facilitate effective sharing among stakeholders and extract all the potential value [104]. As stated above, in order to transform a supply chain into a DSC, knowledge sharing and collaboration should be spread and encourage all along of it. However, collaboration practices are not well understood among supply chain partners and there is not a one-fits all solution. The right approach for companies that are planning to join efforts in the supply chain depend on some factors like the geographical dispersion of customers and suppliers, the demand pattern of the products and the characteristics, conditions and value of their products [105].

Successful supply chain collaboration or coordination happens when the following components take place: information sharing, goal congruence, decision synchronization, incentive alignment, resources sharing, collaborative communication, and joint knowledge creation [90]. When relevant, accurate and complete information is willingly shared among the members of the supply chain to make a strategic and tactical joint effort like aligning their forecast for capacity and long term planning [105], the uncertainty is reduced and the supply chain becomes smoother [106]. There must be a goal congruence between supply chain partners. An objective agreement between them to the extent that each one of them perceive that their own objectives are satisfied by achieving the supply chain objectives. In addition to this, their decisions regarding operations strategy planning, demand management, production planning and scheduling, procurement, promise delivery, balancing change, and distribution management, have to be aligned since any change in their plans may affect the whole system. Moreover, to successfully collaborate there has to be an alignment regarding incentives. Meaning that each partner share gains and loses equitably and also the outcomes from this collaboration should be beneficial to all of them. Another good practice of collaboration is to share resources, assets and capabilities with the partners to make a better use of them. All of these actions can happen only if exists a collaborative, open, frequent, balanced, two-way and multilevel communication. Finally, to succeed in the collaboration effort, each member will understand better and will respond faster to the market and the competitive environment by working together and by creating joint efforts. In other words, by collaborating [90].

But to do so, trust must be built between the partners, because it is key in the success in inter-organizational relationships [107], [108] and also because the knowledge sharing is greater when partners have closer relationships [1]. Trust happens when exists confidence or predictability in one's expectations about others behavior, and also when there is a common belief that another individual makes good-faith efforts to behave according to commitments, is honest and does not take excessive advantage of another even when the opportunity is available [108], [109].

As stated before, relationships among supply chain members include sharing information and knowledge but it means also sharing risks and benefits. By evaluating and understanding these, companies can facilitate exchanges and reduce conflicts that could arise. The factors that characterize conflicts are [110]:

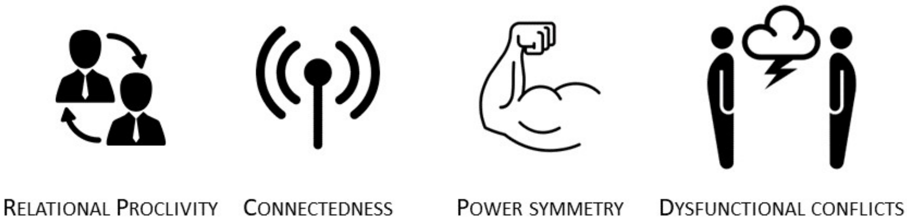


Figure 4.1: Factors influencing conflicts

- **Relational proclivity.** Referring to the general tendency by a company to look out, engage and build close relationships with other companies.
- **Connectedness.** Indicates the dependence between companies for assistance, information, commitments or respect for other behaviors that encourage coordination along the supply chain. The greater interdependence the higher the degree of shared understanding, the stronger and healthier communication and the lower the frequency of conflicts.
- **Power symmetry.** To have power over others means to condition them. Therefore, the more equal the power in the relationship, greater the interdependence. However, if the power is asymmetric among partners, exists a higher probability of conflicts arising.
- **Dysfunctional conflict.** A conflict in a relationship refers to disagreements or incompatibility of activities, shared resources and goals between partners. These can also be harmful behaviors such as manipulate information to harm other decision makers, interacting with each other with hostility and distrust or create barriers during the process of decision-making. All these actions have negative outcomes since the process of assessing the new information provided and analyzing it are no longer enabled.

Enterprises tend to collaborate with others in the supply chain if they perceive that this cooperation will bring benefits and reinforce the knowledge sharing. Usually, valuable and important knowledge is much more likely to be transmitted through strong ties than through weak ones. In addition to this, stronger relational ties could play an important role for process and product innovations because they often entail greater knowledge complexity, which therefore may require greater levels of trust and coordination [36]. Therefore, to succeed in these relationships, the partners should design and plan coordination agreements where there is a stronger relational proclivity within them, the level of connection is also high and exists a symmetry in the power in order to avoid creating superfluous conflicts.

There are many types of information that can be shared in a supply chain: the costs of production and transportation, the demand, orders, etc. In general, the more information is available, the more room for negotiation and cooperation. Moreover, different types of supply chains may require different types of information sharing mechanisms, with different assumptions and conditions [106]. The information can be shared vertically, horizontally, and completely.

- **Vertical information sharing** indicates that buyers and sellers in the supply chain are partners and mutually share information.
- **Horizontal information sharing** refers to the information sharing between buyers and buyers, sellers and sellers, or even competitors and competitors. In other words, sharing information among same type of partners.
- **Complete information sharing** is a combination of vertical and horizontal information sharing. It can effectively raise the performance of supply chains with partners making efforts to increase the profit of the entire supply chain, and thus maximizing the overall profits.

The supply chain partners involved in a collaboration relationship have a common goal. To create a transparent, visible demand pattern that paces the entire supply chain reducing uncertainties and avoiding distortions leading to poor service levels and high inventories [105]. Therefore, by enabling coordination, the efficiency and effectiveness of the supply chain will improve and also the information flow will speed up enabling a faster response to the customers' needs. Because creating a superior customer value is fundamental to a firm's long-term survival and success in supply chains [110].

**Benefits**

The value created by collaborative practices within the supply chain benefits all parties and once the partners begin to see some of those benefits, they will value their relationships and avoid behaving opportunistically in order not to jeopardize that relationships [110]. The trust between them will increase as well as the probability of behaving in the best interest for the partnership enabling that a long-term collaboration strategy is built [111]. By collaborating, supply chain members work together, as part of a single company, toward common corporate goals. Achieving more benefits, facilitating competitive advantages, reducing internal conflict, developing values, reducing potential SCRU, increasing competitiveness and enhancing their performances more than by acting alone [90], [91], [110]. Therefore, developing these collaborative relationships in a positive and strong manner is the key for a successful knowledge sharing in the supply chain [104].

Collaboration plays a decisive role in achieving a higher supply chain performance [111] and as a cost saver. The use of these practices will help firms share risks, reduce transaction costs, enhance productivity, capacity, flexibility, optimize the resources and the utilization of transportation, better decision making and improve profit performance and competitive advantage over time [90], [105]. Moreover, by sharing information, creating common plans for replenishment and synchronizing the supply, the excess of inventory can be reduced, the bullwhip effect can be mitigated, the quality and business synergy will be enhanced, better customer service levels achieved, flexibility will be provided and this joint will increase the innovation among the supply chain partners [90], [105], [112]. However, the value of information sharing depends on the type of information shared, also on the type of the demand, being stationary, constant or volatile [112] and in addition to this, reciprocity has a significant effect on information sharing [111], meaning that if not all the parts cooperate, most of these beneficial effects will not be achieved.

The advantage of collaboration and knowledge sharing could be summarized in the following areas: process efficiency, offering flexibility, business synergy, quality, and innovation [90]. Process efficiency values if the collaboration within the supply chain is cost competitive among their competitors while offering flexibility refers to the support within the supply chain to changes in products or services in response to market needs but maintaining the quality creating higher value for customers. Moreover, business synergy takes place when partners combine complementary resources and they allow innovation changes like the introduction of new processes, products or services.

#### Challenges and Risks

When different companies within the same supply chain collaborate, some risks and challenges could arise as well as higher costs due to these practices [90]. Some of these can be categorized as relational risks and among them are included the probability and consequence that partners do not cooperate in a desired manner [110] and also some risks associated with partners' behaviors [104], leading to undesired consequences as the bullwhip effect.

As has been explained earlier, knowledge and information sharing through close relationships within the supply chain enables competitive advantages. However, there are some reasons like sharing sensitive data, the fear of losing competitive advantage and the arise of problems regarding access and control of information sharing [113] could become major barriers to share data among the members of the supply chain [9]. Allowing these kind of miscommunications causes conflicts and misunderstanding between supply chain partners, leading to collaboration failures [90], ruined cooperative relationships and lowered profits overall the supply chain [36].

Relationship risk can be measured based on opportunistic behavior, loss of competence, and incomprehension between relational partners, among other factors [104]. Usually, these behaviors are governed by formal contracts. However, no contract is always complete. To manage relational risks, it is required a proper relational governance that allows simultaneously flexibility, control and collaboration in a dynamic environment. To successfully manage key relationships across the whole supply chain, the first thing to do is to identify the key members with whom to link processes. Then, those processes have to be determined and which of them should be implemented by each of the supply chain members. Afterwards, the right level of integration and management to be applied to each process link has to be established. In all these steps communication problems may occur due to the fact that each firm has different number of processes, different process definitions or different activities included within each process. Nevertheless, communication is the glue that holds supply chain partners together through balanced, two way, multilevel contacts and message services [90]. Communication is the key, because the long-term success of these organizations will depend on the ability to collaborate with key partners that enable the building of trust and cooperative relationships [23], [90].

The actual business environment, characterized by an increasing competition tend to affect the demand of products and services very volatile. Those fluctuations cause an increase in the variance of the order quantity as the information flows from the end customer to the supplier in a supply chain. The order variability tends to transmit and increase at the upstream suppliers, generating and amplifying instability. This phenomenon, a misalignment between the demand and order signal, is defined as the bullwhip effect and it can be a significant problem for supply chains and cause inefficiencies among various channels [114], [115]. Some of these effects are excess of inventory to face unexpected variations of the demand with a relative increase of stocking costs, inventory shortages, increase of transportation costs due to volatile scheduling and premium transport rates, excess or insufficient capacity, reduction of quality due to unstable production and inefficient production planning and scheduling [114], [116].

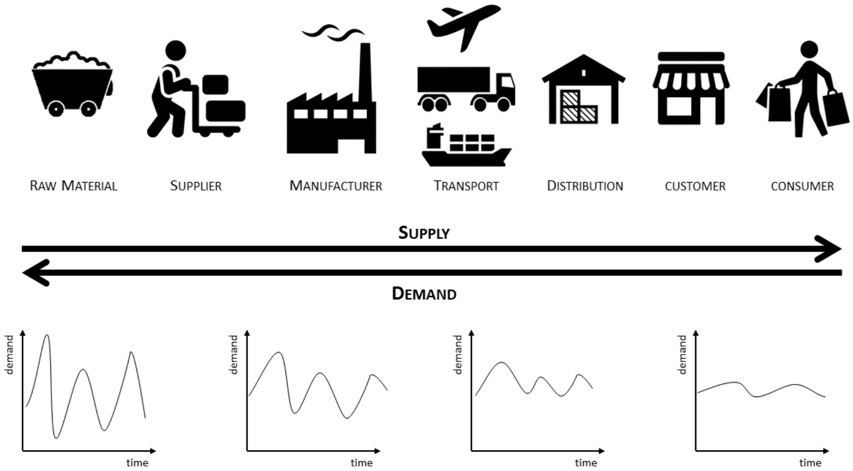


Figure 4.2: Bullwhip effect

The expression of the bullwhip effect consists of two different parts. The first one is common in all the cases and it shows that the bullwhip effect is due to the error in forecasting and takes into account the effect of lead time. The problems could be bigger when the lead-times of replenishment are long and uncertain. Because of the longer lead-time, the uncertainty in the forecasting of the future demand increases, and consequently the variability of the order quantity increases. On the other hand, the second part varies with respect to the use of type of information sharing method. Therefore, the importance of sharing relevant information across various stages of the supply chain is being increasingly realized due to its impact on reducing the overall bullwhip effect [115].

There are two main causes of the bullwhip effect. One is the process by which supply chain decisions, like forecasting, are made. Often, these decisions are taken under uncertainty environments and conditions, lacking the adequate information [114] or influenced by big price fluctuations. Big Data could place a key role to solve this issue. The other one is the lack of coordination and collaborative environment. When this occurs, each partner optimizes their own orders based only on the information provided by the precedent supplier and without considering the consequences on the other members of the supply chain [116]. This attitude regarding replenishment orders tends to amplify to cover this uncertainty leading to reduction in the supply chain performance leading to supply shortages.

To mitigate the bullwhip effect and tackle the two main causes, organizations require strong data, share information, integrate processes, operational linkages and internal cooperation. All these elements can be backed by the use of Big Data and IoT, enabling data to be captured, processed and transferred in real time, avoiding variances in the orders and shortening the lead times [114], [116]. However, to successfully apply these organizational models, it is required specific and important investments in IT systems that not all the partners could generally afford [116].

### 4.3.2 IT requirements

As stated before, to successfully migrate to a SC 4.0, it is required an implementation of a proper IT system, able to handle and process all the data that is collected in real time in different parts of the supply chain. This will enable a firm to develop, accumulate, share and ensure the availability of relevant information and knowledge about its customers, suppliers, and market demands, which in turn influences positively the firm performance [117], [118]. Through an IT alignment among supply chain partners, a better coordination can be achieved [119] along with an improvement in the integration between them. As standards will be developed, firms can dramatically reduce communication and transaction costs as well as combine their resources in an optimized way to make the most of them. Moreover, by sharing the required information, IT systems enables firm to perform better in cost efficiency and customer responsiveness. The more information is shared, the higher the synergy effects are created from it.

By IT alignment, which is a valuable, rare, inimitable, and non-substitutable resource, it is meant the similarity, connectivity, and compatibility of IT infrastructures between supply chain partners [119]. Furthermore, the goals and objectives will be planned together, increasing the efficiency, responsiveness, productivity, and profitability [22] of the overall supply chain. However, huge expenditures in information and communication technology do not necessarily result in much anticipated benefits for a firm [119]. The IT alignment between partners is difficult to achieve due to technology incompatibility and it also needs resource commitment and cooperation all along the supply chain. Moreover, due to the relatively low barriers to imitation and acquisition by other firms, IT-based advantage tends to diminish fairly quickly [119].

CHAPTER 5

# Shipping Industry

## 5.1 Introduction to the Shipping Industry

The technologies brought by Industry 4.0 and specially Supply Chain 4.0, such as Big Data or Internet of Things, are meant to be applied to the whole supply chain. All along this report, the concept of supply chain has been explained and develop extensively. It has been seen the challenges, risks and benefits of the supply chain itself and also when transforming into a DSC or SC 4.0. However, a supply chain can be very wide, broad and complex, and the application and implementation of these innovations have to start somewhere within. Therefore, this chapter of the report will focus on the area that makes possible the connection between producers and customers satisfying the supply and demand of products and services, the transportation.

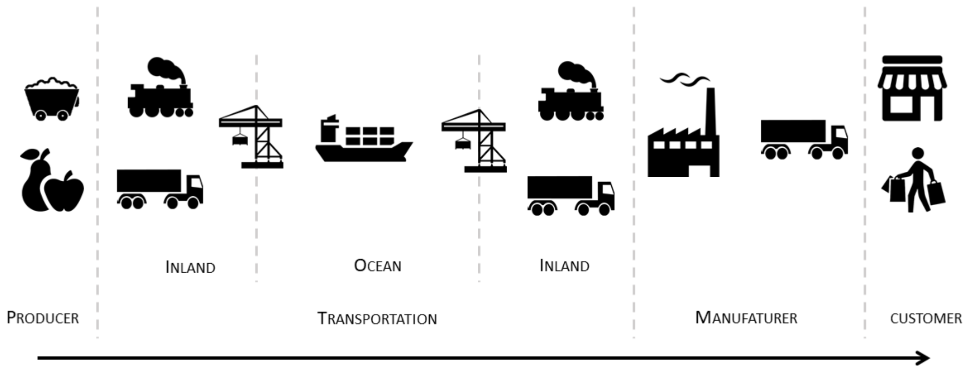


Figure 5.1: Transportation stage of Supply Chain

As it can be seen in the previous image (*Figure 5.1*), from the producer to the customer there are various stages and different parties. But regarding to transportation it can be simplified into two main areas, the inland and the ocean transportation. Even though in recent times, both sides are very interrelated or even merged as a one company due the demand of offering multiple logistic services, this chapter will develop a better understanding of the role of shipping industry in a global supply chain.

The international trade has grown for the last decades, longer and tangled journeys take place carrying goods all around the globe. The shipping industry has the key and essential role for the economy to facilitate these international exchanges by maintaining competitiveness whilst providing efficient and effective services [120]. Around 90-80% of the global trade, more than 10 billion of tons, is carried by sea [121] and only in the EU this industry provides 2.1 million jobs and contributes with 140 billion € to the European Union GDP [122]. It is a volatile industry and nowadays is in a turbulent condition due to the current poor economic situation of the pasts years, energy price fluctuations, technological immaturity and upcoming increases in regulations [123].

Basically, the market of the shipping industry consists of four separated but interrelated areas: (a) the ship building market, (b) the second-hand ship market, (c) the demolition market and (d) the freight market that trades sea transport. The freight market is leaded by the freight rate, the price for the sea transportation services, which it is established trough the relationship between the demand and supply. This link influences the market structure, affecting and guiding decisions to be taken in each of the different areas mentioned before. To illustrate this impact, let's say that the level of demand for sea transport in the freight market is higher than the service capacity, than the supply. Therefore, the prices for the services will rise and this increase will encourage the building of new ships or the buying of secondhand ones to increase the capacity to meet the demand. On the other hand, if the demand is lower than the supply the prices will decrease leading to the demolition of ships or the stop of the services, incurring in severe economic losses and lower performance [124].

The following graph (*Figure 5.2*) shows the global trade by sea, in tons and by type of cargo. Among them can be found oil, gas, raw material and containers. Around the 20% of the total sea trade globally is containerized [121]. The majority of consumer goods that people buy and use every day is carried by containers. Containerization has reduced significantly the transport cost of goods, representing in their final price an insubstantial percentage. The key behind this, is standardization. A container can be transported efficiently from origin to destination by different transport means without the need to reorganize the content within [125]. These facts demonstrate the increasing role of container transportation and its contribution to the global economy reducing the transportation cost [126] and therefore, this chapter will focus mainly in this area of the shipping industry.

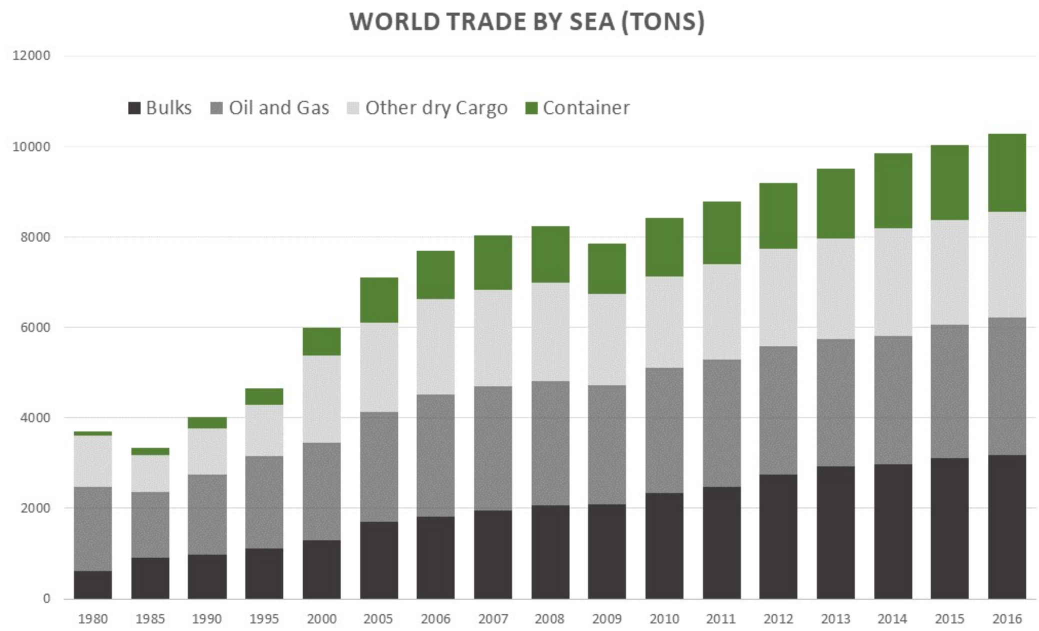


Figure 5.2: Sea World trade by type of cargo [121]

## 5.2 Container Liner Shipping Industry

The business of the container liner shipping (CLS) industry is to offer common carrier ocean shipping services in international trade [127] and they are one the main players in the freight market. There are two key elements in the liner shipping operations: trade demand and the liner shipping network. The trade demand represents the requirements for shipping services to transport cargo and goods from one point to another derived from trade whereas the liner shipping network exists to serve this demand [128]. To serve the demand, CLS companies operate vessels, transporting containers with various but standardized dimensions, that are put into service on a regular basis according to a fixed sailing schedule, loading and discharging at specified ports [129]. As the demand is uncertain and, as seen earlier, in order to increase the service capacity, it is required a considerable amount of time, shipping companies need to plan and decide carefully. They should consider the characteristics of the industry, specially the number and size of shipping service providers, the extent of concentration among the service providers, and the degree of homogeneity of their offerings [124].

The CLS industry is complex not only because of border crossing issues or multimodal transport over long distances, but also because of the huge number of stakeholders and participants involved, each one of them with their own objectives and goals [125]. Consequently, managing these relationships is of strategic importance. Usually, the supply chain where the shipping industry is involved looks like this:

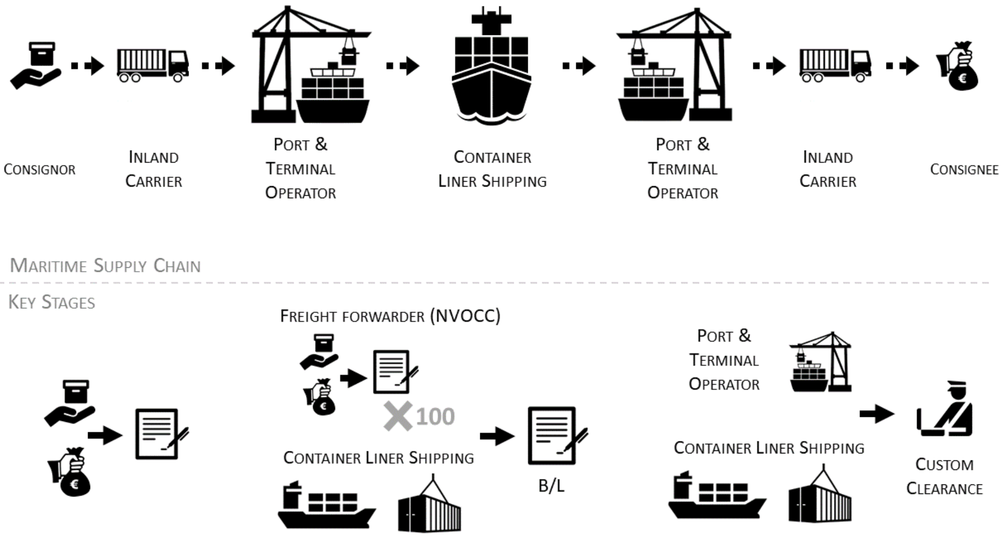


Figure 5.3: Maritime Supply Chain and Key Stages

The process starts when a buy-sell agreement between the consignor (the seller) and the consignee (the buyer) takes place. The physical form of this agreement is a contract where all the terms of sale and payment are covered as well as it is stated who is responsible for arranging the transport and when and where are the goods to be transferred to the consignee. Depending on who is responsible for transporting the cargo, the role of shipper will be the seller or the buyer. In this stage, freight forwarders or also known as Non-Vessel Operating Common Carrier (NVOCC) enter into action. These companies group and aggregate diverse operations and orders, manage their documentation and are responsible for customs clearance. With this huge amount of orders and goods to transport, they usually take the role of the shipper easing the job to the customers.

The shipper will negotiate with a CLS and produce another contract, the bill of lading, that serves as contract of carriage, as a document of title to the goods and as a receipt for them. Usually, big shippers and CLS have long term contracts because of their regular large volume order of containers. Once these agreements take place, the goods are transported to a specific port. There, the vessels dock, are loaded, unloaded and refueled [128] ready to set sail to the next destination port where the exchange of cargo between vessels and shore will take place. In every port, containers are storage waiting to be loaded in future vessels or to be picked up by the consignees if the goods have arrived to their journey's end. Ports have three main functions: landlord, regulator and operator [125]. They manage the port infrastructure and coordinate the activities of different parties present at the port. They also focus on solve collective problems as provide proper training and education, marketing and promotion of the port and also its innovation and internationalization. However, they usually outsource the cargo handling activities to terminal operators. Basically, the CLS industry can be classified into the following segments: (a) Shipment routing and capacity procurement, (b) Container fleet and repositioning, (c) Vessel fleet and operations, (d) Terminal operations and container handling and (e) Inland transport vehicle and container handling [125]. Each of one area is led by one of the stakeholders mentioned before, but all of them interrelated.

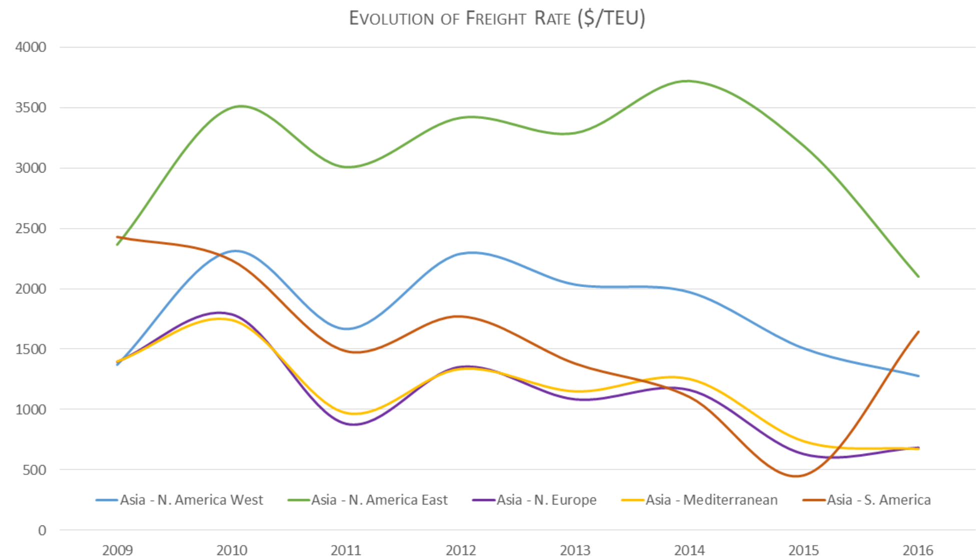


Figure 5.4: Evolution of the Freight Rate [121]

CLS companies have to design their container shipping network depending on factors like competition, cooperation, pricing and relationships with other CLS companies or other players that intervene in the supply chain. The network consists of a number of service routes forming a round trip involving a fixed sequence of port calls and each port call is served at a fixed frequency by a set of vessels. Therefore, the objective is to select ports, design routes and deploy vessels in order to satisfy the customers' demand. The whole planning of these routes covers vessel fleet deployment, schedule design, speed selection, and dynamic routing and container management. Specifically, this can be understood as determining the planned arrival and departure times on each port call for service routes, assigning the customer demands into different routes, specifying the container transit times for each pair of ports or planning the sailings speeds of the different container ships [125]. Summarizing, it can be said that the provision of liner container shipping services requires extensive investment in shipping infrastructure in terms of container ships, advanced information and communications technologies, containers, shipping agents and network development among various players in the industry [128].

### Situation

In the recent several years, containerized cargo shipments between North America and Europe have developed slower than Asian corridors. This was caused by recession in U.S. and Europe economies, and by the continued growth of Asia's role in global economy due to the North American and European companies that have outsourced their production there. However, the transatlantic corridor between USA and EU has an enormous impact on the overall shipping industry due to the size of both, the United States and EU, that together represent 60% of global GDP, 33% of world trade in goods and 42% of world trade in services [130]. This corridor can be considered as mature and stable, meaning that cargo flows are predictable with little possibility for unexpected and volatile changes. Consequently, shippers, ocean carriers, and ports can safely plan their activities, develop service patterns and prepare investment strategies. On the other hand, the situation in Asia is different for their fast economic growth whereas the east-west and Pacific markets are subjects for frequent volatile market ups and downs [131].

Table 5.1: Trade Routes. TEU shipped 2013 [132]

| Route | West | East | North | South | Total |
|---|---|---|---|---|---|
| Asia-N. America | 7,739,000 | 15,386,000 | | | 23,125,000 |
| Asia-N. Europe | 9,187,000 | 4,519,000 | | | 13,706,000 |
| Asia-Mediterranean | 4,678,000 | 2,061,000 | | | 6,739,000 |
| Asia-Middle East | 3,700,000 | 1,314,000 | | | 5,014,000 |
| N. Europe-N. America | 2,636,000 | 2,074,000 | | | 4,710,000 |
| Australia-Far East | | | 1,072,016 | 1,851,263 | 2,923,279 |
| Asia-S. America | | | 621,000 | 1,510,000 | 2,131,000 |
| Europe-S. America | | | 795,000 | 885,000 | 1,680,000 |
| N. America-S. America | | | 656,000 | 650,000 | 1,306,000 |

As it can be seen in the previous table, (*Table 5.1*) and next figure, (*Figure 5.5*), and the major traffic goes from Asia to United States and Europe through either Suez Canal or Panama Canal. These two sites are very relevant actors in the overall picture of the shipping industry because they mean a shortcut in travel time but there is also a specific capacity they can handle. Even though the Panama Canal is currently under work to expand their capacity, their negotiation power is high comparing to the carriers. Moreover, if vessels are going through the Suez Canal they should consider not to sail cross the shores of Somalia due to the high piracy activity. This happens also in the strait of Malaysia, one of the few corridors from east Asia to Europe.

Figure 5.5: Volume of Vessels in different Routes [133]

In the following table, (*Table 5.2*), it can be seen the top 10 CLS companies in the world together with their capacity in TEU and their global market share. Just to highlight that the first 5 players account for more than the 60% of the market share and the sum of all of the top 10 accounts for more than the 80% of it.

Table 5.2: Top 10 players 2018 [134]

| **Company** | **TEU Capacity** | **World Market Share** |
|---|---|---|
| APM-Maersk | 4,128,928 | 18,7% |
| Mediterranean Shg Co | 3,260,878 | 14,8% |
| CMA CGM Group | 2,535,554 | 11,5% |
| COSCO Shipping Co Ltd | 1,976,289 | 9,0% |
| Hapag-Lloyd | 1,618,114 | 7,3% |
| Ocean Network Express | 1,563,716 | 7,1% |
| Evergreen Line | 1,090,906 | 4,9% |
| OOCL | 697,123 | 3,2% |
| Yang Ming Marine Transport Corp. | 643,691 | 2,9% |
| Pacific Int. Line | 427,624 | 1,9% |

The goals of any CLS company include objectives from diverse areas [120]:

- **Financial:** profit maximization, increase the shareholder wealth, capital investment sharing and financial risk reduction.
- **Economic:** cost reduction and economies of scale.
- **Strategic:** entry in new markets, wider geographical scope and increase the purchasing power.
- **Marketing:** satisfy customer requirements better by providing higher frequency, flexibility, reliability and expanding the network through the offer of a greater

variety of routes and destinations.

- **Operational:** increase in frequency of services, vessel planning and coordination on a global scale.

They can be summarized into risk and investment sharing, exploit economies of scale, cost control and ability to adapt to the new dynamic and disruptive environment [120]. To satisfy all of them CLS companies are continuously seeking for competitive advantages to outstand their competitors. These competitive advantages may be classified into three categories: operational efficiency, service effectiveness and risk avoidance [128].

### 5.2.1 Operational Efficiency

Operational efficiency can be defined as the ratio between the output gained from a business and the input to run that operation. In other words, the business has to be profitable, emphasizing in cost reduction and asset utilization. Among the strategies to maximize the profits can be found: horizontal integration by forming strategic alliances, adopting slow steaming in vessels, implementing pricing strategies, deploying larger vessels for economies of scale, deploying more efficient vessels and sharing resources to improve utilization [125].

#### Slow steaming

CLS companies adopt this strategy in their container vessels when the freight rate is low due to overcapacity of the market, lower demand or increasing fuel prices. The fuel consumption of vessels increases approximately cubically with the speed of the vessel. Therefore, by sailing ships at a lower speed than the design one, it is achieved a lower consumption of fuel and consequently cut costs [125]. However, this has a negative side as well. As the trips will take longer, planning the routes will become more important because there may be some products that have an expiry date or maybe some customers are dissatisfied with the length of it.

#### Empty container repositioning (ERC)

The shipping industry is a two-way with the same capacity while the demand in each way can notably vary. Analyzing the trade flows around the world, (*Table 5.1*), it can be seen that there is a severe imbalance of trade demands. The production and the consumption are not in the same location or even nearby. Therefore, there are many vessels with full containers sailing in one direction whereas when coming back, a significant amount of the containers are empty. This has been an important issue and an economic burden for the industry and to tackle this problem, CLS have developed a pricing strategy know as Empty Container Repositioning (ECR).

Figure 5.6: Containers in a port [135]

This strategy aims to reduce the flow of empty containers, the trade imbalance, by pricing in two directions. Here the major costs consist of the handling and holding costs. Consequently, CLS companies have to plan how many empty containers to keep at each port and when and how many empty containers are to shipped from one port to another [125]. So, good relationships with ports are essential. They also need to consider that carrying an increasing number of empty containers to overcome this trade imbalance, is a cost. Hence, they should know how much cost is incurred in repositioning these empty containers to price accordingly and charge these costs to the services where the vessels carry full containers.

Moreover, with a low freight rate, CLS are reducing this cost of moving empty containers by increasing the demand moving low-value products as waste and scrap in those flows where the demand is low [136]. Doing this, CLS minimize their costs but also reduce their environmental and social impacts.

**Vessels**

Ships are expensive items of capital investment and CLS companies invest in them when they are optimistic about the seaborne trade volume [124]. Therefore, cost saving is an important motivation for deploying larger and efficient vessels. The bigger the vessel, the cheaper the unit cost. But only if this additional capacity is filled and the utilization level is maintained. Otherwise the advantage of scale economies will disappear and CLS companies will incur in losses [136]. Nowadays, the vessels can be categorized into three main categories: Container Ships (< 10.000 TEU), Very Large Container Ships (VLCS) (between 10.000 and 20.000 TEU) and Ultra Large Container Ships (ULCS) (> 20.000 TEU) [131].

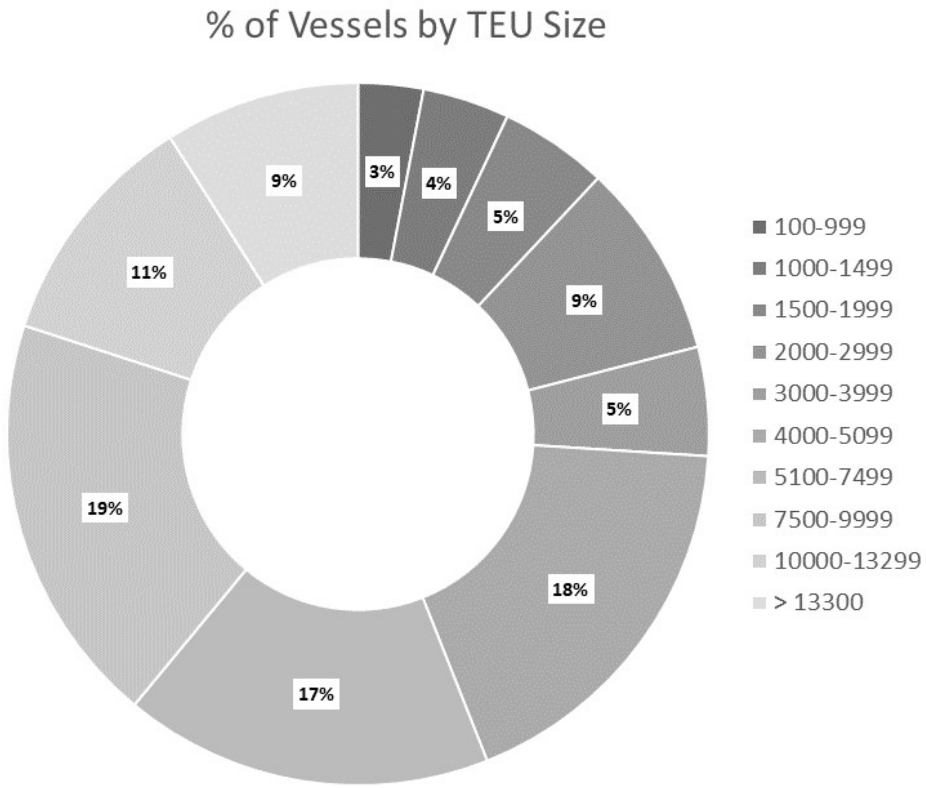


Figure 5.7: Percentage of Vessels by TEU capacity [137]

In the previous image, (*Figure 5.7*), it can be seen that the vessels under 4.000 TEU of capacity accounts for the 26%, between 4.000 and 10.000 TEU, around 54% and bigger than 10.000 TEU, the 20%. This information was released in 2015, nowadays there are more vessels deployed in the last category.

The twenty-foot equivalent unit (TEU) is an inexact unit of cargo capacity used to describe the capacity of container ships and terminals. It is based on the volume of a 20-foot-long container, meaning that one of this containers is equivalent to 1 TEU. There are different sizes and standards of containers such as 40ft but there are also containers with other sizes that are not standard.

The world container markets are currently preparing for a significant structural change which will occur when a larger number of VLCS and ULCS are deployed. The introduction of these larger vessels will significantly change shipping and operation patterns for basically all major world routes [139]. And it also will have an important


Figure 5.8: Vessel sailing [138]

impact on ports, which will require expansions to increase their capacity and upgrades to be able to dock these new ships [131] and load and unload them in a competitive period of time or risk to be skipped by CLS to other ports that have implemented these changes already [136].

Table 5.3: Fleet of the Top 10 CLS companies 2018 [134]

| **Company** | **Vessels** | **Percentage of Vessels** |
|---|---|---|
| APM-Maersk | 755 | 12,4% |
| Mediterranean Shg Co | 520 | 8,5% |
| CMA CGM Group | 498 | 8,2% |
| COSCO Shipping Co Ltd | 361 | 5,9% |
| Hapag-Lloyd | 229 | 3,7% |
| Ocean Network Express | 234 | 3,8% |
| Evergreen Line | 197 | 3,2% |
| OOCL | 100 | 1,6% |
| Yang Ming Marine Transport Corp. | 106 | 1,7% |
| Pacific Int. Line | 135 | 2,2% |

In the previous table (*Table 5.3*) it can be seen that the top 3 CLS companies by size control around the 30% of all vessels in the world.

However, major savings in the future will not come from increasing vessels' capacity but from further consolidation, from the optimization of shipping networks by creating alliances, joint logistics and intermodal operations and also from the optimization of vessels utilization [131].

### Horizontal integration

The CLS industry is among the firsts to use the concept of cooperative behavior and collaboration agreements in order to achieve business objectives [120], originally through liner conferences and more recently through alliances. CLS companies cooperate to reduce cost by enhancing the utilization of facilities, to improve the service frequency and region of coverage by expanding the capacity, to rationalize the shipping service network, to reduce risks, to take advantage of scale economies, and to share management resources [125], [127]. Historically, CLS companies have used liner conferences as a way to set tariffs, fix prices, allocate output among their members through quotas and specify terms and conditions of carriage in certain trade routes [125], [127]. However, the demolition of the conference system in the US in 1998 and the abolition of exemptions in anti-trust rules by the EU in 2008, have enhanced the competition within the industry pushing the leading companies to seek other forms of collaboration in the effort to gain advantages. These new forms of cooperation take mainly the form of alliances and they play a central role in the operational and long-term viability of CLS companies [120].

These alliances aim to jointly operate container ships over specific routes, including sailing schedules and itineraries, frequency, port selection, sequence of the ports, the use of joint terminals and also coordinate the use of containers on a global scale [120], [125]. There are other types of collaborative agreements between carriers within alliances including vessel sharing agreements and slot sharing agreements. The former enable members to work together to fulfill the demand on particular trade routes through vessel sharing and also performing joint optimization on vessel departure times and on the assignment of different orders to vessels whereas the latter requires that some of the vessels' capacity are exchanged between carriers over a period of time. This could be favorable when two members of the alliance are going to deploy vessels on the same route but with different departure time schedules. Through these practices, CLS companies share profit, operating costs and collaborate on the basis of demand information sharing [120]. However, they are still competitors, so the cooperation among the members is often limited to ship operations without involving marketing, pricing, revenue pooling, profit/loss sharing, joint sales, joint ownership of assets, or joint management and executive functions. This mutual agreement, the alliance, aims for full integration of the service capabilities of the parties into one whole [120], [125]. CLS companies must offer complex packages to their customers to differentiate from their competitors, because the main service and the price are no longer a differentiator.

The rise and diffusion of these alliances are due to primarily two factors. First, as said before, it is required huge investment in vessels and infrastructure to keep the business running and consequently, CLS companies have tended to limit the economic and financial risk by joining efforts with each other. Secondly, they could also be viewed as the response to the intensification and increasing competition within the sector derived from factors such as freight rate which is in constant decline, technology developments, exponential growth in investments, increasing deregulation, loss of power on the part of conferences, and the emergence of south-east Asian lines in the international competitive scenario [140], with the objective to reduce this pressure. Summarizing, because of the globalization of production and markets, as well as the technological developments, a growing concentration within the sector has taken place and mega CLS companies have emerged. However, these alliances are very limited. CLS companies tend to develop these relationships with a single partner or few partners, in a specific lane and during a short period of time [140]. The reasons for the instability of the alliances is mainly due to the individualistic behavior of the members, who are trying to pursue organizational objectives that may have an impact on the whole alliance, but also it is due to the nature of their role, the contribution to the alliance and the level of mutual trust between members [120].

Table 5.4: Alliances in the Shipping Industry 2018 [141]

| **Alliance** | **Members** | **Million of TEUs** | **Vessels** | **Market Share** |
|---|---|---|---|---|
| 2M | Maersk<br>MSC | 7,4 | 1275 | 33,5% |
| Ocean Alliance | CMA CGM<br>Evergreen<br>OOCL<br>COSCO | 6,3 | 1156 | 28,5% |
| THE Alliance | ONE<br>Hapag-Lloyd<br>Yang Ming | 3,8 | 569 | 17,3% |

Nowadays there are 3 major alliances [127], [141] and all of the CLS companies in the top 10 in the world are member of one of these. These 3 alliances together account for more than 17,5 million TEU, almost 80% of the global container capacity and the same percentage is for their market share. During the last decades there has been a huge process of consolidation due to mergers and acquisitions (M&A) within the CLS industry leading to the creating of huge players and now to enormous alliances.

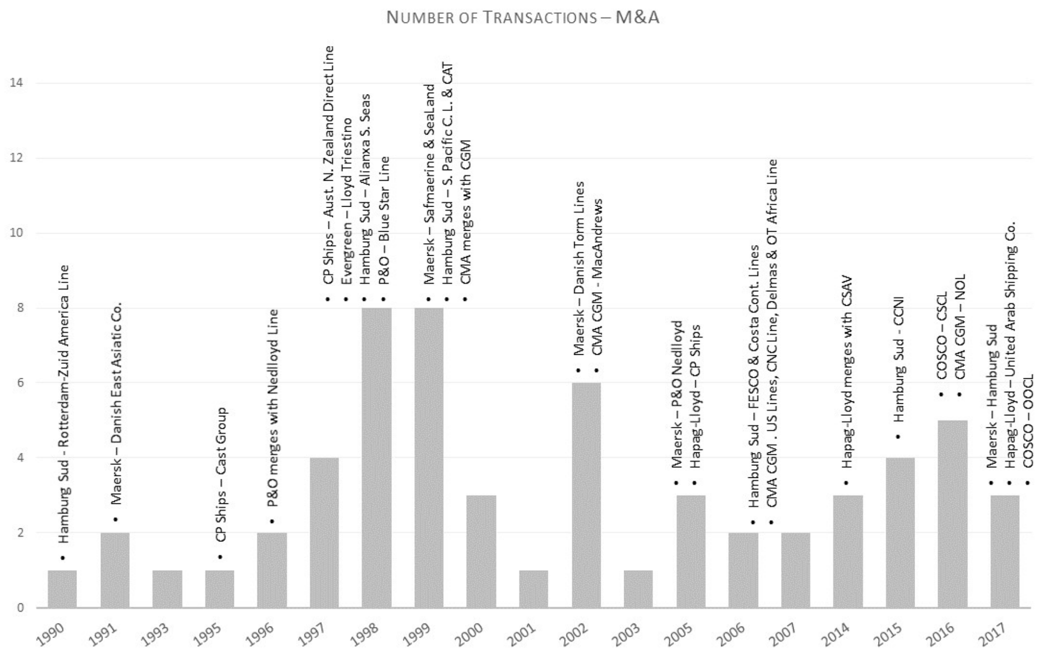


Figure 5.9: Time-line of Mergers and Acquisitions in the Shipping Industry [142], [143]

In the previous time line (*Figure 5.9*) it can be seen the number of operations M&As. The consolidation before the economic crisis of 2008 was driven by growth. This path was seen as a way to improve profitability and establish a more sustainable structure for the industry as a whole. However, after the crisis, M&A is about survival. The motivation behind is to take advantage of the potential synergies to cut costs, to exploit the economies of scale, to raise the investment required that allows operations with the appropriate quality of service guarantying a share in the market [143], [144], to provide an extended and integrated logistic service, to combine complementary geographical strengths, to increase their power of negotiation [143] and to protect their position in the market from new competitors that are rising due to the decreasing barriers of entry [139]. Nevertheless, the outcome of these mergers can differ from the expected. The market share will not be the exact sum, both companies have weaknesses and strengths, they have IT systems heavily integrated in their respective organizations and when merging there is a period where both companies have to reorganize internally to eliminate duplicates and consolidate departments [143].

Hence, some key points can be extracted from the previous lines. First, the market is turning into an oligopoly because of frequent M&As, lower market investment, and low profitability. But depending on the trade lanes size, large (>1.000.000 TEU volume) or small (<1.000.000 TEU volume), the power of each CLS differs and also their market share [129]. Second, alliances are growing in scale and scope, creating high barriers of entry and so cut-throat competition is inevitable. Third and last, service quality and reliability will be the key issues for alliances in the future [125].

### 5.2.2 Service Effectiveness

Service effectiveness, on the other hand, accentuate and focus on service differentiation and quality of service. An example could be the vertical integration with partners from the supply chain which leads to the expansion of their logistics services, shipping network and coverage. But also having a more frequent, flexible and reliable service thanks to the use of robust IT systems and new technologies as Big Data or Internet of Things.

#### Vertical integration

Not only exist both competition and cooperation between carriers, ports and terminals horizontally but also vertically [125]. This is achieved through internal growth, acquisitions of or collaboration with container management services providers, intermodal service providers and container terminal operators or ports [120], [144], [145].

The CLS industry is essentially a commodity market with little room for differentiation of service, however the areas mentioned before is where this can occur. Focusing on the management of containers, the call frequency and cargo security can increase positively the brand of the CLS company [144]. These companies are the ones in charge to develop applications and IT systems that optimize and enable a more efficient way to handle the containers all along the supply chain. Here is where the new technologies explained through the whole report can have a huge impact. This will be explained more ahead in this chapter. On the other hand, the intermodal service providers are the ones that focus on the inland transport, such as rail operators or road hauliers. The acquisition of these companies by CLS firms has allowed the latter to extend their services, control the whole journey from the manufacturer to the customer and differentiate from their competitors. It is estimated that the proportion of inland transport directly controlled by shipping lines is around 30% [125]. Furthermore, CLS companies spend a lot of effort on establishing connections with ports in order to improve their transshipment operations. Therefore, having good relationships with ports and selecting the appropriate ones is essential. In the ports, the terminal operators are the ones responsible for loading and discharging containers, container storage and gate movement operations [128]. Many CLS companies have integrated and acquired terminal operators in order to control and optimize the flow of containers in the ports making the process smoother.

Table 5.5: List of Ports 2016 [146]

| Rank | Port | Country | Volume (million TEU) |
|---|---|---|---|
| 1 | Shanghai | China | 37.1 |
| 2 | Singapore | Singapore | 30.9 |
| 3 | Shenzhen | China | 23.9 |
| 5 | Busan | South Korea | 19.8 |
| 9 | Dubai | U.A.E. | 14.7 |
| 11 | Rotterdam | Netherlands | 12.3 |
| 12 | Port Klang | Malaysia | 13.1 |
| 13 | Antwerp | Belgium | 10.4 |
| 15 | Kaohsiung | Taiwan | 10.0 |
| 17 | Los Angeles | U.S. | 8.8 |
| 18 | Hamburg | Germany | 8.9 |
| 24 | Saigon | Vietnam | 5.9 |
| 27 | Jakarta | Indonesia | 5.5 |
| 29 | Valencia | Spain | 4.7 |
| 31 | Tokyo | Japan | 4.7 |
| 33 | Mumbai | India | 4.4 |
| 36 | Felixtowe | U.K. | 4.0 |
| 38 | Piraeus | Greece | 3.7 |
| 42 | Santos | Brazil | 3.3 |

The previous table (*Table 5.5*) illustrate the importance of selecting and stay in good terms with ports, having an appropriate system of handling containers there and collaborating with or integrating inland transport companies. Depending on how CLS invest on and how much importance give to these areas will result on how competitive they are, how much market share they will have and therefore, for how long they will manage to stay on business.

### 5.2.3 Risk avoidance

The shipping industry is complex, many stakeholders have influence over it and the supply chain within and which is part of is broad. Therefore, many risks and uncertainties can arise due to geographical distances, the weather, customs in every country, social and environment impacts due to decisions taken, unstable economic cycles, empty container repositioning, seafarer shortages, escalating bunker prices, cargo space oversupply, delays in the scheduling that result in a cascade effect in the followings, fluctuating ship prices, port closures, or damages to ships due to collisions, fire, explosions, warfare, terrorist attacks and piracy [125], [147]. These risks should be taken into account and this is done through a maritime supply chain risk management. It can be defined as the process of taking decisions that will minimize the adverse effects of accidental losses, based on risk assessment methods involving cooperation and communication between all members implicated in the maritime supply chain activities [148].

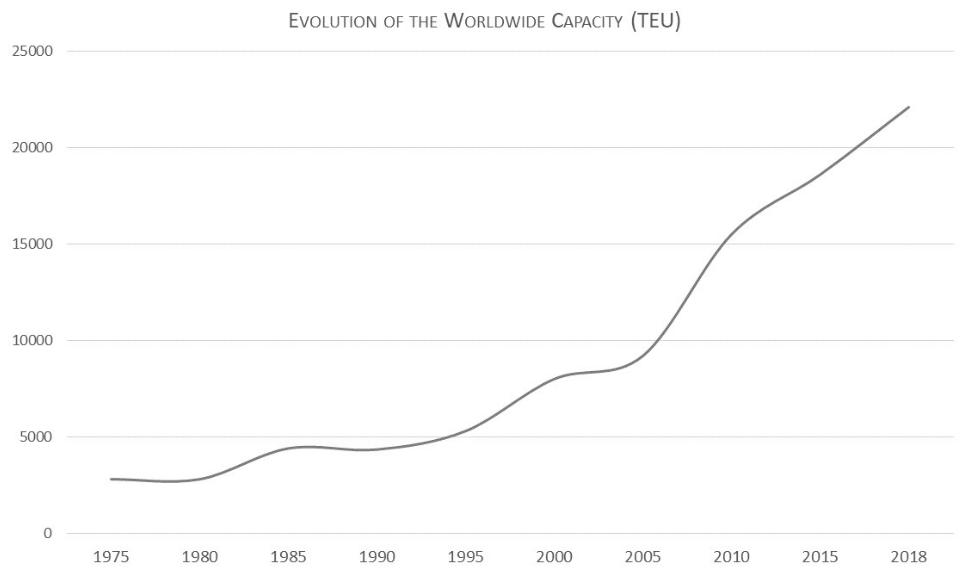


Figure 5.10: Evolution of the Worldwide Capacity (TEU) [149]

The ability of a supply chain to both resist disruptions and recover operational capability after the disruptions occur is called Supply Chain Resilience (SCR). In order to improve it, factors and measures as agility, collaboration, information sharing, sustainability, risk and revenue sharing, trust, visibility, risk management culture and adaptive capability should be developed, improved and implemented in the different organizations taking part all along the maritime supply chain [147]. By enhancing the visibility across the supply chain and sharing information and knowledge, location and statuses of containers can be known in real time and managed accordingly [148].Here, Big Data and IoT can play a key role enabling these functionalities. By improving the agility and flexibility of the supply chain, the effects of disruptions on it will have a less impact and during a less period of time. However, the most important action that CLS can take is to introduce a risk management culture in their organizations. It is the overall organizational philosophy that places risk management as a priority because it influences on both risk management performance and on the CLS company's overall performance. Having a weak one, will mean a challenge for them to respond to appropriately changes, to increase their ability to share information between organizations during times of disruption, and to allocate in advance more resources to deal with incidents related to some of the risks mentioned before. Therefore, adopting an efficient and strong risk management culture, that will allow CLS to predict changes in the SC, be prepared to react on time in the face of disruptions, and to mitigate possible negative effects and risks, is critical for CLS to maximize their performance [147].

## 5.3 Data in the Shipping Industry

Reached this point, it can be said that the shipping industry is essential to the worldwide economy but it can also be considered as a volatile industry and under a turbulent condition due to the current poor economic situation, energy price fluctuations, technological immaturity and upcoming increases in regulations [123]. The new technological developments that took place recently had and are still having a considerable influence on the maritime sector. Depending on the attitude of the companies towards them will decide if these recent changes are opportunities or threats to the achievement of their goals, having an impact on all of the three competitive advantages explained before, the risk avoidance, operational performance and service effectiveness.

Currently, there are new and fresh players with more flexibility entering the game. IT start ups [150] or even giants part of the whole supply chain like Amazon [151], are expanding their business vertically, integrating more stages into their businesses. They want their piece of the pie whereas the already established, mature and with a rigid structure are struggling with these new transformations and disruptions. Therefore, if they want to continue to stay on business, they will have to adapt and introduce these innovative technologies, such as Big Data or Internet of Things, into their organizations [152], [153]. The shipping industry digitalization has already begun and the path towards the success is through the adoption and embracement of disruptive technologies [154] and working with IT companies to implement new solutions [155].

CLS companies are starting to apply some of these new technologies mainly into two areas interrelated. The first one is the design and building of smart vessels. Some firms have already begun to invest in this new types of ships where data and connection are the key to exploit new opportunities. For example, Maersk has started to develop vessels with new propulsion systems more efficient, with more capacity (around 18.000 TEU) allowing them to carry more containers without requiring more power and lowering the emissions of $CO_2$ per container transported [156]. This same company is also investing in the creation of autonomous ships [157] that will be game changer in the sector. The second area of focus is on IoT and Big Data, including sensors, analytics, advanced communications or even technologies that are not well understood yet like Blockchain [152] but with a huge potential to become a differentiator in how companies in the sector work. Regarding Blockchain, big players like Maersk has begun to work on this with partnerships with IBM, a company not related to the shipping sector but that nowadays may have a role in the supply chain field [158], [159]. These transformations will encourage technological sophistication, operational efficiency and commercial performance in the shipping industry.

### Applications

Some of the applications derived from the used of Big Data and Internet of Things applicable to the shipping industry could be [123], [153]:


Figure 5.11: Applications of Big Data and IoT in the Shipping Industry

- **Vessel Remote Sensing.** Vessels will be monitored continuously from remote locations while data is being collected and gathered autonomously into a database. Later this information will be distributed to the different stakeholders allowing them access to up-to-date information, to take better decisions, to enable a more dynamic pricing and to be more responsive to market changes.
- **Voyage Planning Optimization.** CLS companies will be able to optimize the voyage planning after analyzing data regarding the routes, vessels performances, currents, meteorological data and other external factors. The outcome of analyzing this data will help to identify the most efficient route for the journey, estimate accurately the arrival time, allocate vessels and capacities to specific trade lanes, select particular ports and plan alternative routes to avoid delays.

- **Intelligent Traffic Management.** The transmission in real time of data such as the ship current position, cargo and personnel to the port authorities and terminal operations would allow them to monitor the congestion, coordinate the arrivals and improve the cargo handling performance.
- **Operational Performance and Condition Monitoring.** As the vessels will be full of sensors gathering and analyzing data, their operational performance can be monitored in real-time allowing to optimize the vessel and to predict future statuses of the machinery such as engines, pumps, boilers and compressors giving early warnings of the need for maintenance.
- **Predictive Maintenance System.** This system will detect the need for maintenance to avoid potential failures. It will record and analyze data from machinery, fuel consumption and other sources to indicate and measure the risk of failure. The system will reduce the cost of asset failures, minimize unscheduled downtime, dictate when and what maintenance would be required before failure occurs and reduce the time spend of the crew on maintenance and scheduling activities.
- **Energy Management.** As the shipping industry is becoming more aware of social and environmental issues, their efforts are moving towards more flexible, eco-friendly and alternative energy systems. By having an autonomous ship energy management system, based on real-time data, the power will be distributed and according to the needs and the emissions of $CO_2$ can be monitored to act accordingly.
- **Vessel Safety and Security.** The use of the IoT technology like wireless sensors and extensive satellite communication systems will increase vessel and crew safety. The real-time access and communication of information will prevent collisions to occur and will avoid happening risks and dangers in some routes like piracy, congestions or dangerous weather conditions.
- **Storage and Container Management.** Data can allow the real-time visibility of all container movements, providing full transparency on shipments, from one end of the value chain to the other and enabling the prediction of a container's availability, arrival times, and so forth. This way, the handling of containers will be optimized in the ports by speeding up the operations regarding the loading and unloading of the vessels or the trucks and reducing handovers, waiting times, and unnecessary handling. But also, during the journeys on the vessels, the containers can be monitored allowing to know what is happening inside them, like the temperature, humidity or another factor, creating additional value for the

customers too (132).

**Challenges and Risks**

As it has been seen, a vessel and what it carries can create a large amount of data in real time in different formats and from multiple sources like traffic data, cargo data, weather data or machinery data. Therefore, BDA will be required to extract and exploit all the opportunities and enjoy the benefits. However, these technologies are new to the shipping industry, so many challenges are arising now and will do in the future regarding Big Data and IoT implementation [123]. Digitalization contains a lot of promises for improvements in the future but CLS companies should not lose sight on the practical applications for today either.

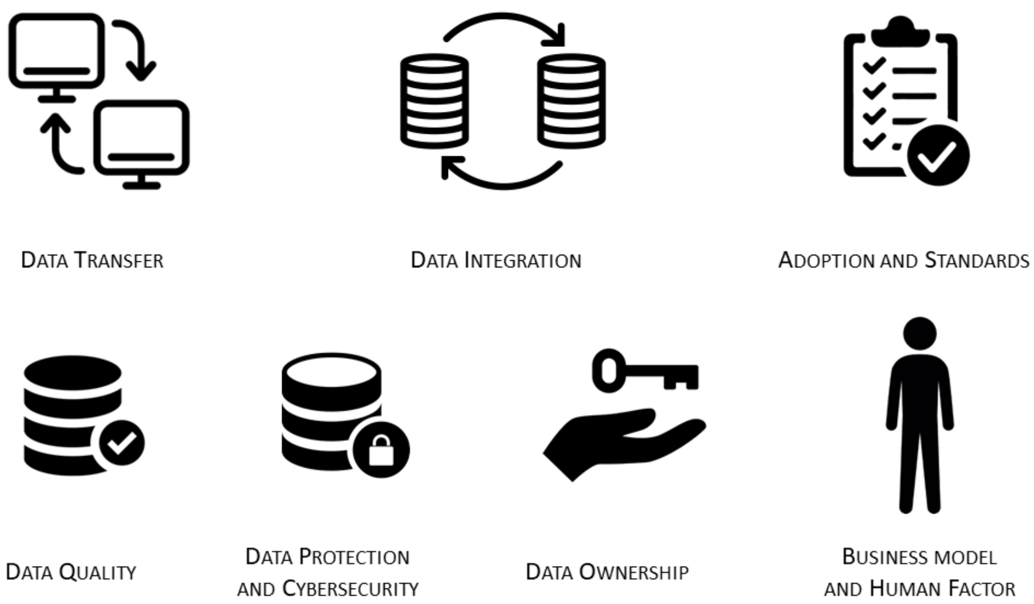


Figure 5.12: Challenges from implementing Big Data and IoT in the Shipping Industry

- **Data Transfer.** Vessels have a very large number of sensors on board and a primary cause of uncertainty comes from data transfer from those sensors. Usually every sensor requires a specific communication bandwidth, so it is important to have an appropriate and secure communication system to transmit the information to the database and to avoid interferences that could lower the quality of it.
- **Data Integration.** The data collected from the sensors is inconsistent and unreliable. It comes from diverse sources and therefore it needs to be integrated for analysis. Some of the CLS alliances have shared and integrated most of their

data on joint logistics solution systems where the process of it than happen easily and faster (126) but it may require heavy investments.

- **Data Quality.** It is a big concern because low-quality data can potentially lead to errors in interpretation and consequently take wrong decisions that end up worsen the performance or put in danger assets and more important, people.
- **Data Protection and Cybersecurity.** The safety and security of the data network and data management is becoming vital for shipping companies in order to prevent any disruption. Data needs to be protected from external interventions such as piracy, viruses or terrorist attacks, because a cyber-attack on the network would interrupt the overall system and could mean significant losses for the business. Moreover, data will move all along the supply chain to different parties, therefore, sensitive data will need special attention regarding security and privacy.
- **Data Ownership.** The supply chain of the shipping industry is very complex and with many parties involved. The ownership of the data allows access to read, create, update and delete entries in databases as well as traceability through the data lifecycle. Thus, the ownership of data as well as the level of authority to access to it is crucial in order to maintain the appropriate level of quality and security.
- **Adoption and Standards.** The industry will need to create specific conditions and spread a mindset across the stakeholders to adopt the new technologies, tools, processes and also to encourage the use of standards. Moreover, the different parties from the maritime supply chain like terminals, carriers, freight forwards or transport companies, are using different IT systems complicating the share of data and limiting the final outcome of the chain. Therefore, a uniform system and same norms should be used and implemented all along the supply chain in order to take advantage of Big Data and IoT, to remove duplicate management and support structures and to provide visibility.
- **Business Model and Human Factor.** The industry is facing important technological changes. Consequently, this will force them to make changes in the business model so as to stay in the market. It will allow the development of a transparent supply chain, where the share of knowledge happens and where the data plays a key role with the help in the decision making. Moreover, the connectivity between the crew on the vessels and the personnel in shore, in the terminals or in the offices will be crucial to increase the operational efficiency and safety. The employees will require to take additional training to gain the skills needed and also a robust and friendly user system to support all the processes.

CHAPTER 6

# Conclusion

The *current global situation* is driven primarily by two phenomena: globalization and digitalization. The world is becoming a united and connected marketplace where every person, company or government can communicate and make business with people from the other side of the globe. The competition is fierce and companies are constantly moving their production sites from one place to another looking for lowering their costs in order to be profitable and stay in business. This has significant impacts on the supply chains of many companies. They will need to adapt to new environments, face new challenges and solve the upcoming problems. Furthermore, with the grow of the use of computers, internet, telecommunications, data and so on, the way of doing business, of communicating or even entertaining has changed dramatically. But focusing on the business side and specially in the supply chains, many companies have started to digitalized and virtualized many of their processes that some time ago, they required physical documentation or meetings in person. However, this is not an easy transformation. There are many challenges to be solved, some regarding to companies like behaviour, trust, knowledge sharing, new skills and others regarding having a proper and robust IT system that allows to collect, store analyze and protect the data. This second family of challenges are trying to be solved with the appearance of new methods, approaches and technologies.

These *new technologies emerged* under the umbrella of a new concept, Industry 4.0. It is meant to be the $4^{th}$ industrial revolution, the one where virtual and physical processes merge. It is driven by the massive use of data, the rise of the Internet and the increase number of connected devices that allow to monitor, communicate between them and take autonomous decisions. The causes of this new industrial paradigm is the lower costs regarding the transfer and storage of data, the decrease in the price of sensors and devices, the growth of data and also the increase of computer power. All these factors led to the development of new methods and innovative technologies to use and share this huge amount of data on real time. Among them, Big Data and Internet of Things stand out as the innovations with more potential due to the wide range of applications on which they can be used.

These novelties, once *applied to supply chains*, give rise to a brand-new concept, Supply Chain 4.0. Any supply chain has as objective the movement of goods and information from producers to consumers. But this new approach connects all the stakeholders on real time allowing data to be always flowing along the chain, to be shared and encouraging collaboration practices among all the parties. Moreover, it enables a better analysis, provides a better big picture of the situation and ensures that every member of the supply chain take decisions based on the same information. Supply chains will become more efficient, effective, flexible, fast and agile but they will also reduce the costs due to this optimization and due to possible disruptions in the supply or demand of products and services.

Supply chains can be very wide, long and complex, and the introduction of these innovations have to start somewhere within. Thus, the focus of the report is which are the *challenges faced by the shipping industry* and how they are doing. This sector can be considered as an oligopoly, where few players control most of the market share. It is running an old fashion way of and now is trying to adapt to the new environment in which events like the stagnation of prices, the increase of the oil price, the disruption due to new technologies, the appearance of new IT players, the world economic crisis, the overcapacity, risks such as weather, piracy, delays and accidents, the decrease of barriers of entry or the increasing concentration of players, among others, drive the actions to be taken in the future.

However, through the implementation of these technologies, these challenges can be *overcome or be even exploited*. Applications where Big Data and Internet of Things are the founding layer. Among them it can be found the remote control and monitoring of vessels, increase the vessel performance by monitoring it, by having predictive maintenance and an optimized energy management.Also the vessel safety will increase and a better vessel traffic and container management at ports can take place, reducing the time of handling and avoiding unnecessary risks. Moreover, the voyage planning will be optimized with the proper selection of ports and routes, reducing possible delays and dangers.

Summarizing, the *new technologies are reshaping the shipping industry*. All the parties involved and specially the Container Liner Shipping companies, are rethinking their way of doing business and their place within the supply chain. The shift in which they place data as a key strategic asset means the beginning of the digitalization of the industry. Apart from collaborations with IT companies, huge investments are being made in the sector, and will continue in the future, on having a robust, flexible and proper IT system to handle and use these considerable amounts of data.

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