European Master in Business Studies

The perception of industry 4.0 technologies in supply chain and the identification of the barriers to their integration

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Abstract

Title: The perception of industry 4.0 technologies in supply chain and the identification of the barriers to their integration

Background: Industry 4.0 refers to the application of the latest ICT technologies in industrial manufacturing, with the aim of increasing productivity and the overall business performance. Due to the latest changes in the global market, companies who want to maintain or increase their competitiveness need to implement these technologies, particularly in supply chain's departments. The deployment of these technologies revolutionizes supply chain operations, increasing their efficiency and responsiveness. Nevertheless, the process of implementation and especially the process of integration of these technologies into the supply chain are complex and still running.

Aim: The thesis aims to investigate the perception of industry 4.0 technologies in the light of supply chain managers. The qualitative study will highlight whether they consider these technologies as disruptive or sustaining, and as an opportunity or threat in the context of supply chain. Moreover, it will identify the barriers to the internal integration of these technologies into the supply chain, in order to derive an integration framework.

Methodology: Semi-structured in-depth interviews, based on the qualitative designed proposed by Gioia (2012), will be implemented to address the aim of the research. The results of the interviews will be analyzed through the software Maxqda.

Contributions: This research aims to fill the gaps present in the previous literature along two main directions. The classification of industry 4.0 technologies in the context of supply chain will be provided on the basis of the Disruptive Innovation Theory. Thus, this study provides a further application of the DIT theory in the new context of industry 4.0. Moreover, the barriers to internal integration will be defined, filling the lacuna present in the literature and preparing the ground for further investigations on the external integration. The identification of the barriers is also fruitful for the companies, since they will know the challenging and problematic variables to implement for a successful supply chain 4.0. Moreover, companies will also be benefited by having a clearer view on the managers' knowledge-base and perception of the technologies. In fact, they will know whether there are problems to be solved, such as a problem of technology acceptance or lack of knowledge. Lastly, the definition of the maturity level of the technologies as well as the level of awareness of SC managers will suggest policymakers the direction of future legislation and guidelines; for instance, whether training programs or courses should be implemented to train the workforce.

Keywords: supply chain 4.0, industry 4.0, smart manufactories, supply chain integration

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List of abbreviations

AI = Artificial intelligence
BDBA = big data business analytics
BI = Business intelligence
CPS = Cyber Physical Systems
C2C = Humans to humans
C2M = Humans to machine
DIT = Disruptive innovation theory
ERP = Enterprise Resource Planning
ICT = Information and communication technology
IoT = Internet of things
IT = Information technology
M2M = Machine to machine
R&D = Research and development
RFID = Radio frequency identification
SC = Supply chain
SCI = Supply chain integration
SS = Semi-structured interviews
SCM = Supply chain management

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1. Introduction

This first chapter aims to give an introduction of the thesis content. The importance of industry 4.0 technologies is highlighted in relation to the latest changes in the global market, particularly considering their impact on supply chain. The integration of these technologies into the supply chain process is preliminary to a higher performance, but companies are still challenging this complex process. Thus, this chapter describes the problem statement and the research questions, which aim to provide companies a deeper understanding of industry 4.0 technologies in relation to supply chain. Lastly, the contributions of the research are described.

1.1 Context

In 2015, the 72% of industrial companies were forecasted to adopt industry 4.0 technologies by 2020 (PwC, 2015). But the reality exceeds the expectations: 91% of manufacturing companies are financing major investments in disruptive technologies and factories 4.0 (PwC, 2020). Moreover, this trend is foreseen to exponentially increase in the near future thanks to governmental funds and international policy projects (Koh et al., 2019).

Over the last decades, many new manufacturing companies entered the global market causing an exponential increase in the level of competition. These firms offer new products and services, which contribute to enlarge the variety of choices available to the final customers (Dombrowski et al., 2017). As a direct consequence, to remain competitive a company needs to be fast in delivering fully customized and individualized products, becoming even more customer oriented (Dombrowski et al., 2017; PwC, 2020).

In order to cope this trend of "mass customization", firms require a more flexible and integrated supply chain (SC). Thus, companies decide to adopt the framework of the Fourth Industrial Revolution introduced at the Hannover Messe in 2011 with the scope of delivering "fundamental improvements to the industrial processes involved in manufacturing, engineering, material usage and supply chain (SC) and life cycle management" (Kagermann et al., 2013). These technological advances will drastically transform how the firms operate and compete, transforming the companies' production processes into a decentralized framework. As a consequence, by including these disruptive technologies, the companies aim to develop a supply chain which will become instrumented, interconnected, intelligent, automated, integrated and innovative, so ultimately more agile (Wu et al., 2016; Burtner, 2010).

These benefits could be even more amplified, in case of an effective integration of the new technological advances into the SC (Wu et al., 2016). In fact, integration "is claimed as being synonymous with supply chain management excellence" (Childerhouse & Towill, 2011). Indeed, many benefits are associated with integration in terms of costs, economies of scale, product assortment (Bowersox et al., 2002), inventory reduction (Stevens, 1989), productivity (Fawcett & Magnan 2002), operational efficiency (Lee, 2000), material flow (Childrhouse & Towill, 2003) and other variables, which boost the overall performance (Leuschner & Rogers, 2013; Kamble et al., 2018). Nevertheless, integration is also considered as a SC utopia (Childerhouse & Towill, 2011). In fact, it requires complicated, valuable and unwarranted capabilities and resources (Leuschner & Rogers, 2013).

Hence, companies are still struggling with implementing an effective integration, which became even more complex when new technologies are considered. This assumption is also confirmed by the data. Despite the increasing number of firms investing in digital factories, only 6% of the firms have "fully digitalized" factories (PwC, 2020); moreover, the 41% of companies use these technologies for stand-alone solutions, while 44% for partially integrated solutions (PwC, 2020). Thus, these data suggest that companies are currently challenging to fully exploit the capacities of these technological advances and are struggling to integrate them into the SC process. Hence, the first step towards this direction consists of implementing internal integration, which means functional coordination among departments within a company (Braunscheidel & Suresh, 2009). In fact, as suggested by Rummler & Brache (1995) and tested empirically by Childerhouse (2002), internal integration is propaedeutic and preliminary to external integration: the company needs to "put one's own house in order" before implementing its integration with the entities along the SC.

1.2 Problem statement, gaps and research questions

The deployment of industry 4.0 technologies revolutionizes the SC process and guarantees higher performance to the companies (Frohlich & Westbrook, 2001: Kumar, 2001). Despite this, there is no common agreement on the perception of these technologies in the eye of SC managers as well as no consistency in the classification of these technologies, as disruptive or sustaining. Moreover, companies have not yet identified the factors that lead to an effective and linear integration process. Hence, firms lack a deeper clarification on the barriers to internal integration, in order to successfully implement these technologies and obtain a higher performance.

In fact, although previous studies have been conducted on the topic of industry 4.0, two main deficiencies can be identified. Firstly, there is no specific agreement on the classification of industry 4.0 technologies in relation to supply chain. Neither academics nor practitioners agree on the classification of these technologies as disruptive or sustaining (Koh et al., 2019). Secondly, even though SC integration was largely studied, there is still a significant misalignment between theory and practice on its implementation (Childerhouse & Towill, 2011). This gap becomes even more significant when considering industry 4.0 technologies, because internal integration is a very long process and many barriers can occur (Gimenez & Ventura, 2005). Considering that the literature about industry 4.0 is in its infancy (Büyüközkan & Göçer, 2018; Picarozzi et al., 2018; Veile et al., 2020), only the barriers to the industry have been identified (Kumar et al., 2014; Kumar et Asjad, 2020; Ghadge et al., 2020). Thus, the literature lacks further studies on the barriers to the internal integration of these technological advances (Frederico et al., 2019; Hermann et al., 2016; Kumar, 2020; Oztemel & Tekez, 2019; Rojko, 2017).

Considering the lacunae of the previous literature, this research aims to further investigate the perception of these technologies and the barriers to their integration, which ultimately give insights to the company on their implementation. This purpose statement is divided into two core parts and is structured as follows.

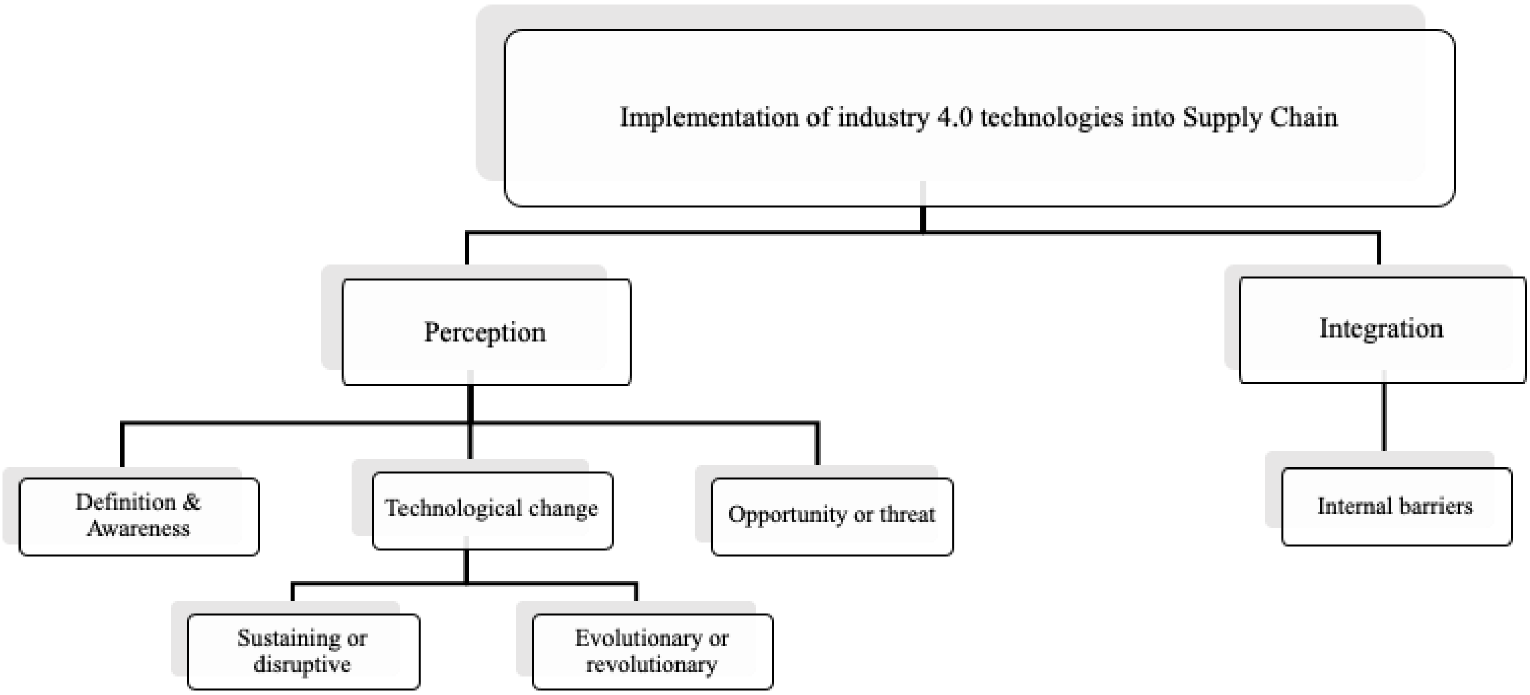


Figure 1. Purpose statement. *Own source*

The first part regards the perception of 4.0 technologies in the eyes of supply chain managers. The main aim is to understand the knowledge base and the level of awareness that SC managers have towards the latest technological advances. Moreover, it wants to investigate how they consider these technologies: sustaining or disruptive (Christen, 1997), evolutionary (Abernathy & Clark, 1984) or revolutionary (Kondratieff, 1979)? In addition, the last section wants to explore their opinion about the technologies: do supply chain managers consider these technologies an opportunity to exploit or a threat to escape? Do they have other opinions rather than the belief embedded in this dyadic view?

Do they expect more benefits than costs? In fact, many academics and practitioners believe that industry 4.0 technologies will drastically redesign supply chain and business operations. But previous literature also highlights how some managers saw the deployment of these technologies as contrived. Thus, this first part wants to clarify the opinion of supply chain managers about these technologies, to see whether a problem of technology acceptance may be present and may need further investigations in future studies.

Whereas, the second section focuses on the integration of the technologies into the supply chain. It will identify which are the barriers, that companies need to overcome to fully integrate the technologies. Particularly, the study will analyze internal barriers considering both horizontal and vertical scenarios.

The analysis will be conducted from short-term and long-term run, to verify the current situation and to forecast the future influence of the technologies on the supply chain. Moreover, the qualitative study will not only investigate the beliefs of SC managers, but also of IT specialists. Thus, the findings will compare two different points of view, by highlighting the similarities and stressing the main differences, in order to provide a further theoretical development.

Moreover, the theoretical framework will review the applications of the main industry 4.0 technologies, named Internet of Things (IoT), cyber-security blockchain, big data analytics, automation (including both robotics and digitalization), artificial intelligence (AI), cloud technologies and radio-frequency identification (RFID) (Frederico et al., 2019). It aims to address the following sub-questions: which is the current status of industry 4.0 technologies? Which are their main applications? Which are the main challenges? In fact, both the theoretical framework and the findings of the empirical study will lead to design the integration framework, which links all the technologies together, clarifying the barriers to overcome and the applications of the technologies at the different stages of the supply chain.

1.3 Significance of the study

On the basis of the abovementioned problem statement, this thesis aims to investigate the perception of supply chain 4.0 technologies and the barriers to their internal integration, in order to allow companies to go one step further in the process of integration and implementation, as explained by Figure 1. By addressing these research questions, this dissertation aims to give threefold contributions.

It will contribute to the current theoretical framework by defining whether industry 4.0 technologies are considered disruptive or sustaining technologies by supply chain managers giving an implementation of the Disruptive Innovation Theory; it will also provide insights by delineating managers' perceptions and awareness. Moreover, it will fill the gap present in the literature regarding the internal integration by identifying the main barriers to the interoperability of the technologies. As stated by Rummler & Brache (1995) and Childerhouse (2002), having a clear picture on internal integration is fundamental and preliminary for further studies regarding external integration.

By identifying the barriers to the integration of the technologies, also companies will benefit from the study. In fact, the companies will have a better level of understanding of the barriers and of the challenges that they still need to face, in order to enhance their internal integration. Additionally, the framework, proposing how to integrate these technologies at the different steps of the supply chain while including the related barriers, gives fruitful insights to the company on how to implement them. Moreover, by defining the knowledge-base and the perception that SC managers have in relation to industry 4.0 technologies, companies will know whether problems of technology acceptance or lack of know-how need to be solved.

Lastly, the dissertation will also define the maturity level of the technologies and the level of awareness among the supply chain managers, giving suggestions to policy makers about their future protocols, legislations, decisions and investments; particularly considering that some regions and government actively support the implementation of industry 4.0 factories and organize training program to develop the necessary skills (Erro-Garcés, 2019; Faller & Feldmüller, 2015).

To conclude the study will not focus on a specific country or industry, to provide insights which can be generalized and applied to different industry's fields. Nevertheless, all the limitations of the study will be addressed in the following sections.

1.4 Thesis overview

In order to address the research questions explained above, the structure of the thesis is as follows. Firstly, the theoretical framework is described, particularly focusing on the concept of supply chain and supply chain integration; while the following part introduce the concept of industry 4.0 and supply chain 4.0. The theoretical framework is completed by the description of the six disruptive technologies, which will be considered in the qualitative research. Then, the research methodology is explained, and it is followed by the results of the study and the framework for the integration of the technologies. Finally, the last section will compare the results with previous studies, discuss the limitations of the research and define possible further investigations.

2. Theoretical Framework

This section aims to define the concepts of supply chain, industry 4.0 and supply chain 4.0 with the scope of describing the three key pillars of this study. Moreover, it explains the concept of integration and its different definition, while describing the major frameworks. Lastly, the section concludes with the analysis of the barriers to the industry, a starting point for the qualitative research. This section is fundamental, as it suggests the gaps and the deficiencies present in the literature, which need further investigations. In the end, the propositions will be drawn on the basis of the theoretical framework.

2.1 Supply Chain Management

The concept of supply chain management (SCM) was introduced only lately and evolved drastically over the years, leading to different definitions. The steps towards SCM can be explained, as follows.

Before 1960s, there was a fragmentation of activities and tasks among the departments of a company, leading to sub-optimal situation in terms of cost, cash and customer service (see Figure 2). For instance, the possibility of offsetting and balancing the cost of warehousing and transportation was unlikely to be considered, at that time. Then, the concept of logistics was introduced and explained mainly in a military context. Logistics concerned the "procurement, maintenance and transportation of military facilities, materiel and personnel" (Ballou, 2007). This definition was implemented in 1964, when Heskett et al. introduced the term "business logistics", which included all the activities related to the physical supply and material management. By that time, the costs of logistics and physical distribution could reach even the 32% of sales at the company's level (LaLonde & Zinzer, 1976). Hence, both researchers and companies realized that there were unexploited possibilities of reducing the overall costs, by better managing these two main departments. Particularly, academics analysed two specific variables: the coordination of activities carried on within the company (Ballou, 2007; Heskett et al., 1964) and the relationship with other external companies and stakeholders (Stevens, 1998; Beamon, 1999; Lambert & Cooper, 2000). Hence, different steps and years led companies to move from logistics to supply chain management: from the fragmentation of the activities to their consolidation and functional integration, to obtain logistics; consequently logistics, information services, marketing and strategic planning merged to obtain SCM in the early 2000s (Ballou, 2007).

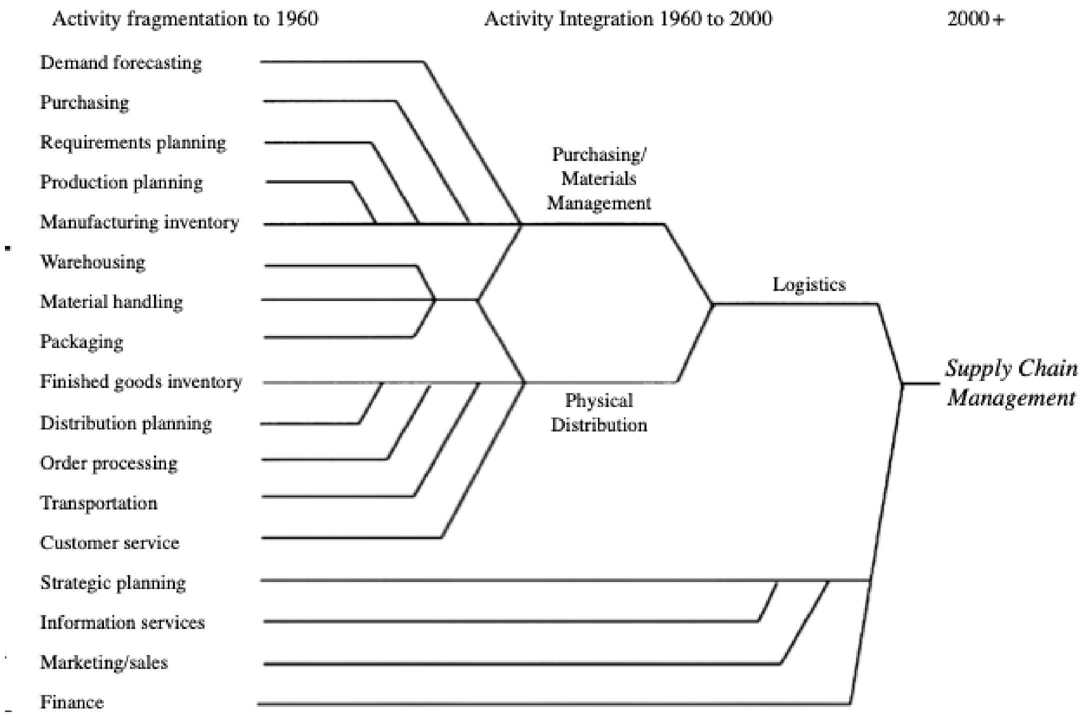


Figure 2. Evolution of SCM. Source: *Ballou, 2007*

Previous studies defined SCM differently, according to the philosophy and view considered (Mentzer, 2001). Whereas, the Council of SCM Professionals (CSCMP) conceptualized SCM, as follows:

> Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all Logistics Management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, Supply Chain Management integrates supply and demand management within and across companies.

As by this definition, three dimensions characterized SCM: activity and process administration, which overlaps and includes all the logistics' activities; inter-functional coordination among different departments within the same company; interorganizational coordination among different companies along the supply chain (Ballou, 2007). Hence, different entities are involved in SC, leading to the concept of ultimate supply chain (Beamon, 1999; Mentzer et al., 2001), as shown by Figure 3. Moreover, an integrated behavior and shared information between the SC members are fundamental elements for being successful in the competitive global market (Bowersox & Closs, 1996; Cristopher & Peck, 2004; Prajogo & Sohal, 2010) and for establishing a long-term cooperation – necessary to share risks and rewards (Mentzer et al., 2001; Thomas & Griffin, 1995).

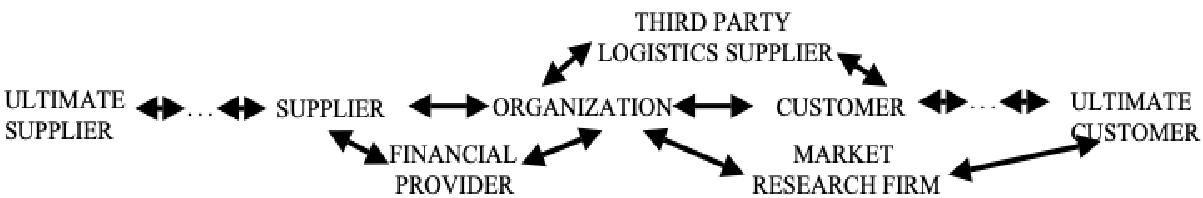


Figure 3. Ultimate supply chain. Source: *Mentzer et al., 2001*

Meanwhile, according to the Global Supply Chain Forum (GSCF), SCM is "the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders". This definition stresses two fundamental aspects of SCM. Firstly, it highlights the importance of the material and information flow through the company, which follow two opposite directions: material flows from suppliers to customers; while, information from customers to suppliers (Stevens, 1989; Lambert & Cooper, 2000; Mentzer et al., 2001). Secondly, the definition focuses on the concept of added value. In fact, the scope of the SCM is to gain competitive advantage in respect to three specific factors: cost, cash and customer service. For instance, the SCM goal may be reducing costs while keeping the customer service constant (Houlihan, 1988). Thus, a tradeoff among these three factors is necessary every time the company tries to enhance its efficiency (Drucker, 1962) or effectiveness (Mentzer, 2001), in order to gain profitability (Ballou, 2006; Cristopher & Peck; Mentzer et al., 2001).

Nevertheless, given the complexity of the SCM, it is complicated to measure the SCM performance (Beamon, 1999; Chow et al., 1994). Different frameworks were developed in the literature, different according to the measurement systems and the variables considered. For instance, Camp (1989) introduced benchmarking to measure the performance, rather than only the effectiveness of the variables. In addition, previous studies present two polarized performance measurement systems: either cost (Cohen & Lee, 1998; Lee & Feitzinger; Tzafestas & Kapsiotis, 1994) or cost and customer responsiveness (Altiok & Ranjan, 1995; Ishii et al., 1988; Lee & Billington), which share the same challenge: translating qualitative measures into quantitative models (Beamon, 1999). Moreover, performance measurement has been tightened by two elements: the evolution of global SC models (Meixwell, 2005) and the introduction of new technologies, as enhancing benefits (Handfield, 1994) Thus, in 2003 the Supply-Chain Council defined five variables (reliability, responsiveness, flexibility, costs and assets) to measure performance appropriately.

To conclude, the concept of SCM evolved rapidly over the years and it is still changing quickly due to factors, such as the increase of competition in the global market or latest technological advances, as explained in the following section.

2.1.1 Supply Chain integration

Supply chain integration (SCI) refers to "linking major business functions and business processes within and across companies into a cohesive and high-performing business model" (CSCMP Glossary of Terms, 2009). The concept of integration is strictly linked to higher performance, thanks to the optimization of the whole SC rather than individual entities (Parnaby, 1979). Integration can be analysed at different perspectives (internal or external integration) and dimensions (concerning organization, information and resources) (Childerhouse & Towill, 2011).

Considering the first classification, integration can be internal or external.

Internal integration or functional integration (Rummler & Branche, 1995) refers to the interaction between different departments within a company (Chen, 2009), such as logistics, marketing and production (Gimenez & Ventura, 2005; Ellinger et al., 2000), which generates a unified and continuous operational flow. Internal integration can be vertical when there is collaboration among different hierarchical sub-systems along the same production line, or horizontal when there is inter-corporation collaboration and end-to-end engineering integration when the process or service is designed and completed from the first to the last stage (see Figure 4).

Supply chain 4.0 technologies can enhance SC integration in all the three perspectives. Firstly, the introduction of these new technologies leads to the integration of the different hierarchical levels within smart factory (Wang et al., 2016). Moreover, the relationship and interaction between the levels are monitored improving plant operations. Horizontal integration is improved because industry 4.0 technologies simplify the communication among different departments; in fact, information sharing is facilitated. Lastly, end-to-end integration is benefited, because the product life-cycle management is linearized; for instance, thanks to 3D real-time simulations (Posada et al., 2015). Thus, product customization and operational costs are benefitted.

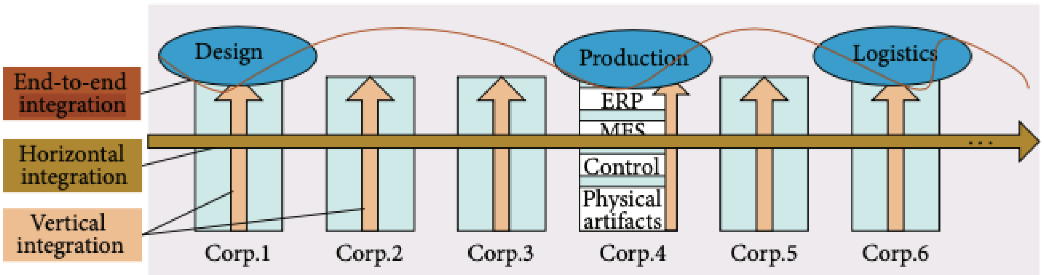


Figure 4. Three kinds of integration. Source: *Wang, 2015*

According to Stevens (1989) and Rummler & Branche (1995), internal integration is preliminary to external integration, which deepen upstream and downstream relationships. On the other hand, external integration can be considered an incentive to the internal one, because companies need a seamless organizational flow to implement external collaboration (Gimenez & Ventura, 2005). Thus, internal and external integration need to be distinguished, but managed simultaneously (Chen et al., 2009).

External integration refers to the coordination, cooperation and/or collaboration with other organizations along the SC (Chen et al., 2009): upstream integration with suppliers and downstream integration with customers (Childerhouse & Towill, 2011). According to the integration with the other entities along the supply chain, arcs of different breadth can be delineated (see Figure 5). Two different extremes can be identified: a company completely not integrated is defined as inward; while, a company strictly connected to both its suppliers and customers is outward-facing (Childerhouse & Towill, 2011). The integration with other entities along the SC can imply many drawbacks, nevertheless many other benefits can be outlined. For instance, a positive relationship has been identified between the breadth of the arc and profitability (Frohlich & Westbrook, 2001). Other gains associated with a wider arc are a more streamlined information flow, shorter planning period and material flow lead time (Childerhouse & Towill, 2011). When companies are integrated along the SC, production costs are reduced thanks to economies of scale, improved asset utilization, inventory savings and lead time reductions (Chen et al., 2009). On the same idea, the study of Bowersox et al. (2002) states that integration creates three types of values: economies of scale are exploited, minimizing costs and waste; a wider variety of products is offered to the customers (market value), who also receive highly customized products (relevancy value). In fact, the integration with customers leads to collect information, which can be exploited to offer new innovative services and creative products (Lii & Kuo, 2016).

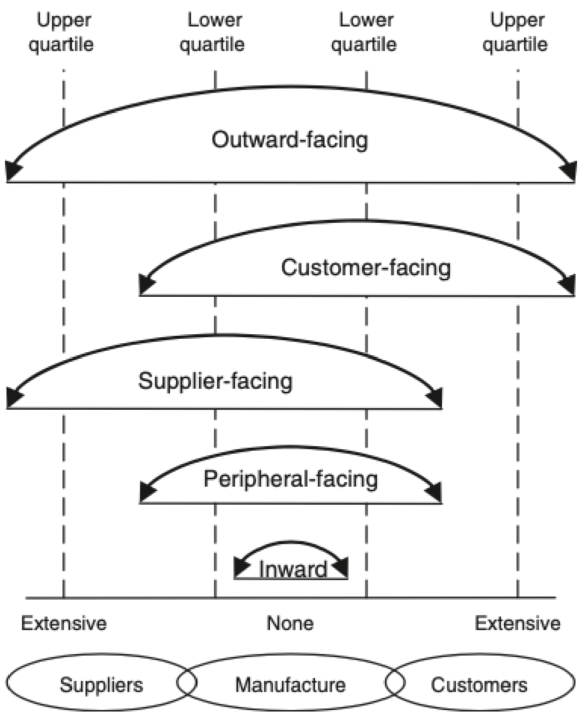


Figure 5. Arcs of SC integration. Source: *Childerhouse & Towill, 2011*

The second classification regards the dimensions of integration. Childerhouse & Towill (2011) and Leuschner et al. (2013) report three dimensions: information integration; co-ordination and resource sharing (which could also be split into flows of good and planning and control);

organizational relationship linkages. The former refers to knowledge and data sharing (for instance, demand forecast, warehouse capacity etc.). Secondly, coordination and resource sharing imply alignment of decision-making process, operational process and activities. Lastly, organizational and relational integration refers to a strategic long-term collaboration among the organization based on trust.

The last classification regards the intentions for implementing integration: operational, tactical and strategic levels (Childerhouse & Towill, 2011). The first operational level refers to integration of daily operation for a seamless organization flow; it provides operational benefits through information sharing or process alignment, as an example (Flynn et al., 2009). The second level regards tactical integration, when different entities share information and align their processes. For instance, it is possible thanks to collaborative planning and forecasting and integrated information systems. Finally, the strategic level implies sharing risks and rewards thanks to a long-term partnership. This strategy implies join investments, R&D, open book, know-how sharing etc. Therefore, strategic integration provides both organizational and strategic benefits, since the parties are committed to achieve reciprocally advantageous goals.

To conclude, integration is a costly process, very complicated to implement due to the different entities involves and due to sudden changes. The current debate among academics and practitioners does not regard whether companies should implement integration or not, but the question regards the depth of integration: how much? under which conditions? (Childerhouse & Towill, 2011). For instance, Cox (2011) states that upstream and downstream relationships may change according to the other organization, but they should not always be fully integrated to be effective.

2.1.2 The role of supply chain managers

Due to the latest changes in the global market, the companies need to reshape their SC into global network. A fundamental role is played by the managers, who are fundamental for succeeding in strategic and operational goals (van Hoek et al., 2002). In fact, SC managers face continuous challenges and need to develop their skills to face frequent changes, especially when considering the implementation of the latest technologies.

Considering the case of innovation adoption, which distinguishes the phases of initiation and implementation, SC managers play a key role in both steps. Leading SC managers, who are innovation-oriented, will support the innovation process, which can only succeed in case of an effective adoption. Empirical analysis show that the managers plays a greater role on innovation adoption, rather than the environmental and organizational factors (Damanpour & Schneider, 2008). Particularly, the results highlight that the variables of “pro-innovation attitude” as well as “liberal ideology" have a positive impact on the innovation adoption. The educational background of managers plays also a key role as well as their managerial experience until the point when the willingness to change decreases due to change to their routine (Damanpour & Schneider, 2008). The characteristics of operational team is also related to the innovation adoption rate. Particularly, relevant factors having a positive influence are the size and the heterogenous composition of the team, where heterogeneity increases innovation but also the turnover rate (Bantel & Jackson, 1989).

To conclude, the opinion and beliefs of key SC managers could be crucial to an effective implementation of the technologies, thus they should be always considered by the companies.

2.2 Industry 4.0

Since the first industrial revolution in the late XVIII century, many innovations drastically changed the manufacturing production over the decades. The implementation of information and communication technology in the 1960s (Posada et al., 2015) and the creation of the term ubiquitous technology by Mark Weiser in 1991 have attracted the attention on the latest technologies, facilitating the launch of the Fourth Industrial Revolution. As the only revolution predicted a priori, industry 4.0 was introduced at the Hannover Messe in 2011, supported by a €200 million fund from the German government and integrated into the "High-Tech Strategy 2020 for Germany" (Hermann, 2016; Dombrowski et al., 2017). In USA the Industrial Internet has been introduced by General Electric in 2012, leading to the creation of the Industrial Internet Consortium, which forecasted that Industry 4.0 will have a positive impact of 46% on the international economy (Rojko, 2017; Ghobakhloo, 2018). Whereas, the Industrie 4.0 Platform is the association that was created at the European level in 2013, to develop long-term strategies, also included in the H2020 program (Posada et al., 2015). The international landscape also includes the Chinese initiative of "Internet+" and "Made in China 2025" created in 2015, with the scope of transforming Chinese manufacturing industry in a leading country until 2049 (Keqiang, 2016). Not only international institutions, government agencies, regional organizations and researchers focused their attention on the disruptive technologies introduced by industry 4.0, but also private companies. In fact, not only prototypes of smart factories are created and studied by academics (as the Factory 2050 at the University of Sheffield in the UK, the SmartFactoryKL in Kaisrslautern, Germany etc.), but some companies already implemented some technologies. According to the Roland Berger Strategy Consultants the following firms are laying the foundations of these technologies: Siemens and Bosch in Germany, Rolls-Royce in the UK, Dassault in France (Posada, 2015; Koh et al., 2019).

Even if industry 4.0 drew the attention of numerous representatives from different contexts (academic, economic and politic world), a broad consensus on the definition of Industry 4.0 and its technologies still lacks. As a consequence, different interpretations are proposed in the literature. Industry 4.0 refers to the application of the latest ICT disruptive technologies in industrial manufacturing, with the aim of delivering "fundamental improvements to the industrial processes involved in manufacturing, engineering, material usage and supply chain and life cycle management" (Kagermann et al., 2013). Initially, only Cyber Physical Systems (CPS), IoT and Cloud technology were identified as disruptive technologies (Bunse et al., 2014; Vaidya et al., 2018). Nevertheless, the literature also lacks alignment in the classification of disruptive technologies. In fact, more technological advances are considered by different authors in the context of the Fourth Industrial revolution, such as industrial automation, robotics, digitalization, cybersecurity blockchain, big data analytics, AI, RFID, business intelligence (BI), enterprise resource planning (ERP) etc. (Frederico et al., 2019) (see Figure 6). Thanks to these technologies, there is a continuous communication and flow of information between the machines themselves (M2M), rather than only between humans (C2C) or humans and machines (C2M) (Roblek et al., 2016; Zhou et al., 2015).

Companies need to develop new business models and strategy based on industry 4.0 technologies, since they recently faced new challenges due to the high volatility of the international market and the increasing level of competition. In fact, as a consequence of the numerous competitors, the consumers can choose between a wide range of products, which may be even more customizable. This current trend of "mass customization" challenges the companies to be flexible in terms of time and costs, while guaranteeing high-quality products to their customers (Dombrowski et al., 2017). Thus, in order to remain competitive in the market, the companies need to develop a new business model based on industry 4.0 technologies, implementing even more the principles of the Lean Production Systems which have already been adopted by the 90% of the companies (Glass et al., 2016).

Hence, this new smart factories' business framework may lead to several benefits, starting from a drop of the technologies' prices and from an increase of their performance level – as suggest by the Moore's Law[1]. Moreover, Rojko (2017) states that this new framework lowers the production, logistic and quality management costs, while increasing mass production and customer responsiveness. Additionally, as other advantages, the development phase is reduced, while high flexibility in production is enhanced due to the increased level of customization. So, in order to reach a very

[1] The concept of the Moore's Law has been introduced by Gordon E. Moore in 1965, who states that the performance of the processors and the number of the transistors available for it in an integrated circuit, doubles every 18 months. So, its limit will only consist in reaching the physical limits imposed by the reduction of the size of the transistors, expecting an insurmountable limit equal to the size of 2 nanometers. Furthermore, the Moore's Law has been used to forecast the growth rate of the entire semiconductor industry. Whereas, the second Moore's law states that the investment in creating a new microprocessor technology grows exponentially over time, leading to an industry with high entry barriers and oligopoly (Schaller, 1997).

flexible and efficient manufacturing production line, a decentralization of the decision-making process is fundamental. Lastly, this new value chain organization has a positive impact on sustainability, since it leads to a more conscious use of resources, and on circular economy (Lasi et al., 2014; Erro-Garcés, 2019). Despites all these benefits, the companies face daily challenges to implement these technologies, in terms of operational, technical and managerial issues.

To conclude, the Fourth Industrial Revolution leads the companies to design a new manufacturing model, based on integration, interoperability and decentralization. Thus, these disruptive technologies revolutionize the business process of a company in terms of production and manufacturing systems, in order to become even more competitive in the international market (Koh et al., 2019).

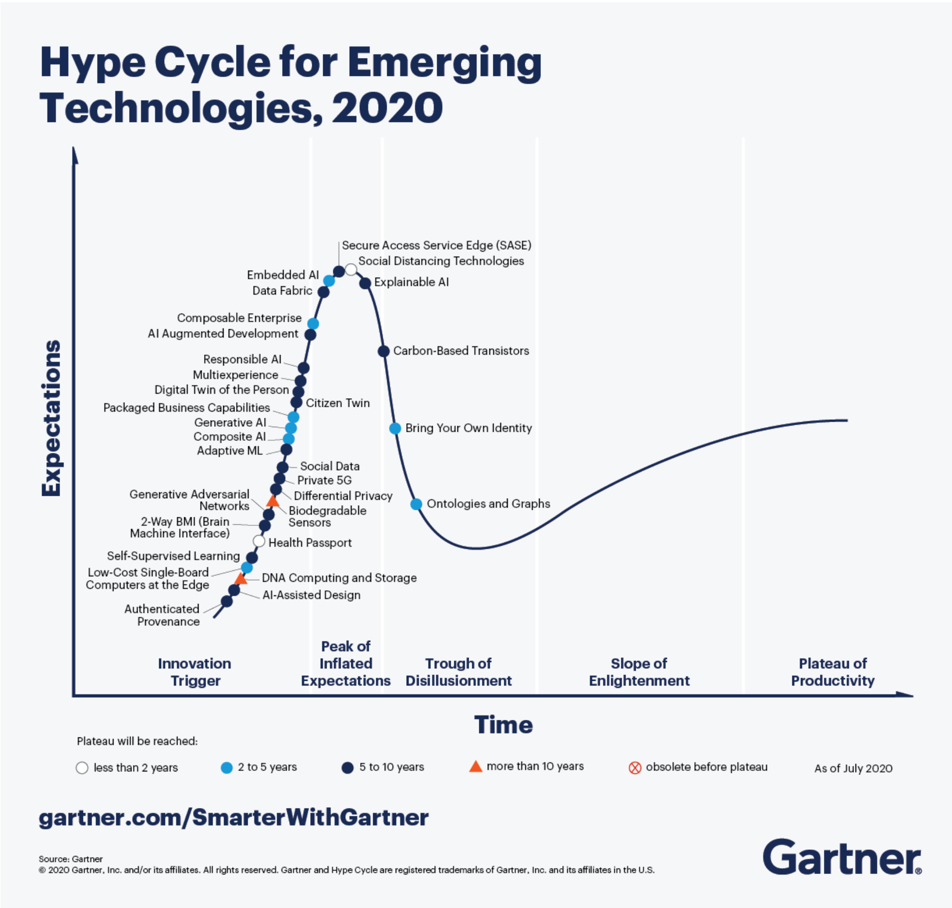


Figure 6. Hype Cycle for Emerging Technologies, 2020. Source: *Gartner, 2020*

2.2.1 Barriers to industry 4.0

The deployment of industry 4.0 technologies changed radically business models and supply chain management, which is the new focus of competition. Despite of all the gains associated to these technologies, the implementation process is particularly complex. Thus, this section will explain the barriers to industry 4.0.

On the basis of previous studies barriers to industry 4.0 are divided into 7 macro dimensions, as reported in Table 1.

The first category of organizational barriers is split into financial and managerial barriers. The former includes all the economic barriers, which may hinder the adoption of industry 4.0 technologies. Financial constraints due to the huge investments required to implement the technologies as well as an unclear cost-benefits tradeoff constitute a barrier to the industry. It also includes uncertainty of the recovery, which is the risk associate to the investment. As tested empirically by Kumar et al., (2020), a clear cost-benefits analysis as well as reliable return on investment's forecasts will motivate companies to innovate (Ghadge et al., 2020; Kiel et al., 2017; Kumar et al., 2014). In fact, it is proven that economic variables play a major role in the plan of expansion of a company. Secondly, managers have also a huge impact on the potential deployment of the technologies. The first managerial variable is knowledge-base, meant in terms of skills and hard knowledge regarding industry 4.0, is considered. Companies struggle in finding skilled and qualified manpower, especially at low cost (Luthra & Mangla, 2018). In fact, the world changes rapidly, but the academia does not follow the same path and so workers lack of hard skills. This is the reason behind new training courses and new curricula created by universities, government bodies and company: preparing a skilled and qualified workforce. The attitude of the managers towards the adoption of new technologies is also fundamental and it is classified as support or resistance to the change. In fact, management support and dedication are fundamental for the revolution of business models and operational processes for two reasons. Firstly, managers have crucial positions in the decision-making process, thus they have huge influence. Then, an optimistic approach leads to an encouraging attitude towards the process of technologies' adoption. The last managerial variable is timeframe; considering that the implementation of these technologies is a very long process, managers should define a priori the length of the process, in order not to interrupt the process before gaining actual benefits (Ghadge et al., 2020; Glass et al., 2018; Luthra & Mangla, 2018).

Even if companies are aware of the relevance of industry 4.0, they still do not realize the crucial implications and consequences for their business, mainly due to a scarcity of knowledge. Thus, this unfamiliarity with the industry as well as the ignorance of the associated gains give rise to strategic barriers. They are also increased by a lack of R&D in solving technological issues. The sum of these factors hinders the transformation of companies' idealistic plans into practice (Kumar & Asjad, 2020; Kumar et al., 2014).

The third group of variables is composed by legal and ethical issues. The implementation of industry 4.0 technologies means that several computers, machines and sensors share data among themselves and share information on the internet (Ghadge et al., 2020; Luthra & Mangla, 2018). So, companies are more vulnerable to privacy, security and cybersecurity attacks as well as spying crimes. Moreover, there are not clear regulations, laws, directives implemented by the government or regional bodies, which can be applied to manage these legal disputes. Lastly, from an ethical point of view, Kumar et Asjad (2020) consider the risk of increasing unemployment as well as the need of re-training as a possible barrier to industry 4.0; nevertheless, it can be overcome by training the workforce through course and classes.

Political barriers form the fourth group of barriers to industry 4.0. Firstly, government and regional bodies did not support the development of this new industry under different aspects: guidelines and regulations, funds and tax-benefits, education and training (Glass et al., 2018; Kumar & Asjad, 2020) The government lacks a close collaboration with other institutions in order to boost this new industrialization process; moreover, policymakers lack a clear roadmap for changing the current business world. Regional conflicts as well as political instability may constitute a barrier to industry 4.0, especially when considering developing countries. Thus, companies want to be certain that a country is politically stable during the time frame planned to implement the technology. Lastly, the lack of national or international guidelines also imply the absence of "global standards and data sharing protocols" (Luthra & Manga, 2018).

Then, the lack of socio-cultural support may be considered as an obstacle to the implementation of the technologies. In fact, technology implementation should consider the purchase behaviors and intentions of the customers, because companies cannot offer totally new products to their consumers; but the transaction process to the new conception of products should be smooth. Thus, different factors play an important role in this process, such as culture, social systems, education and base-knowledge etc. Nevertheless, there are insufficient data to analyze the behaviors and purchase intensions of consumers when considering these new technological applications (Kumar et al., 2014).

Technological barriers are composed of different factors. Firstly, an imperative barrier is the lack of IT infrastructure in terms of connectivity, capacity, computation facilities etc; hence, these technological infrastructures are preliminary to further technological developments. Moreover, as stated above, the absence of technical standards hinders the process because companies do not have a clear guideline when implementing technologies and business plans (Ghadge et al., 2020; Kumar et al., 2020). As a technological barrier, there are matured data analytics technics to analyze business and manufacturing data. Moreover, the current devices, computers and sensors are not compatible with the new standards and the new technological development. Thus, integration among heterogenous components become even more complex, leading to a negative influence on performance and effective communication (Luthra & Mangla, 201; Glass et al., 2018). Therefore, companies may hesitate to implement new technologies due to the high complexity of the process in terms of legal, financial, technical and marketing issues.

The last category regards SC issues, which may arise among the entities along the SC causing barriers to the implementation of the technologies. Firstly, as already stated for the socio-cultural barriers, customers may not welcome positively the launch of new products or services on the market, proposing new technological features, when there are other products already meeting their needs. In addition, the size of the customers willing to accept and purchase these new products in the market may be so little that it will not be convenient for the companies to implement these technologies. Lastly, all the organizations along the SC may be benefit from a technological change, by moving toward a technological improvement. Thus, the case of a supplier which lacks technical competences may turn out into a positive gain for the company, which can work closely to the supplier and create a valuable SC (Kumar et al., 2014; Kiel et al., 2017).

To conclude, many different factors and variables can be detected as barriers to industry 4.0. The degree of importance of these barriers change according to the specific situation of the company as well as its geographical location and industry. In general, all these variables may be classified as internal or external. The former is perceived as weaknesses which can be potentiated efficiently to become strengths; whereas, the latter is considered as a threat or challenge, which can be managed to seize opportunities.

Business dimensions	Barriers	Level	Ghadge et al., 2020	Kumar & Asjad, 2020	Kumar et al., 2014	Luthra & Mangla, 2018	Glass et al., 2018	Kiel et al., 2017
Organisational								
Financial	Huge investments	Internal	X	X		X	X	X
	Unclear benefits tradeoff	Internal	X			X		X
	Uncertainty of recovery	Internal			X			
Managerial	Lack of properly skilled/trained/qualified manpower	Internal		X	X	X	X	X
	Lack of expertise	Internal	X		X	X	X	
	Management support	Internal	X	X	X	X	X	X
	Resistance to change	Internal	X					
	Lack of timeframe	Internal			X			
Legal and ethical	Data insecurity	Internal	X	X		X		X
	Privacy insecurity	Internal	X			X		X
	Lack of regulatory mechanism	External		X			X	X
	Unwarranted strain to manpower	External		X				
Strategic	Lack of R&D	Internal			X	X		
	Lack of digital vision and strategy	Internal	X			X	X	
Political barriers	Missing government support	External	X	X	X		X	
	Missing standards	External					X	
	Missing partners and funding support	External		X			X	
	Political instability	External			X		X	
Socio-cultural	Insufficient data	Internal			X		X	
	Difficulty in transfer and diffusion				X			
	Inefficient cultural judement	External			X			X
Technological	IT infrastructure	Internal	X	X		X		
	Matured data analytics techniques	Internal	X	X				
	Missing standards	External		X		X		
	Low maturity level and integration of required technologies	External		X			X	
	Very high complexity	Internal		X	X	X	X	
	Poor compatibility of current solutions	Internal		X		X		
Supply chain	Current products meeting the needs	Internal			X		X	X
	Inactive role & resistance to change of SC members	Internal			X			X
	Size of targeted group	Internal			X			

Table 1. Classification of barriers. *Own source*

2.2.2 Industry 4.0 technologies

When the concept of Industry 4.0 was launched in 2011, only few technologies were considered part of this revolution, particularly named Cyber Physical Systems (CPS), IoT and Cloud technology. Afterwards, other technologies were implemented as shown by the Figure 7 (Frederico et al., 2019), which lists the technology and the respective number of articles. Thus, considering previous studies and the importance of the technologies for practitioners, this section aims to describe the features of the following technologies: IoT, blockchain, big data analytics, automation (including also robotics and digitalization), cloud technologies, AI and RFID.

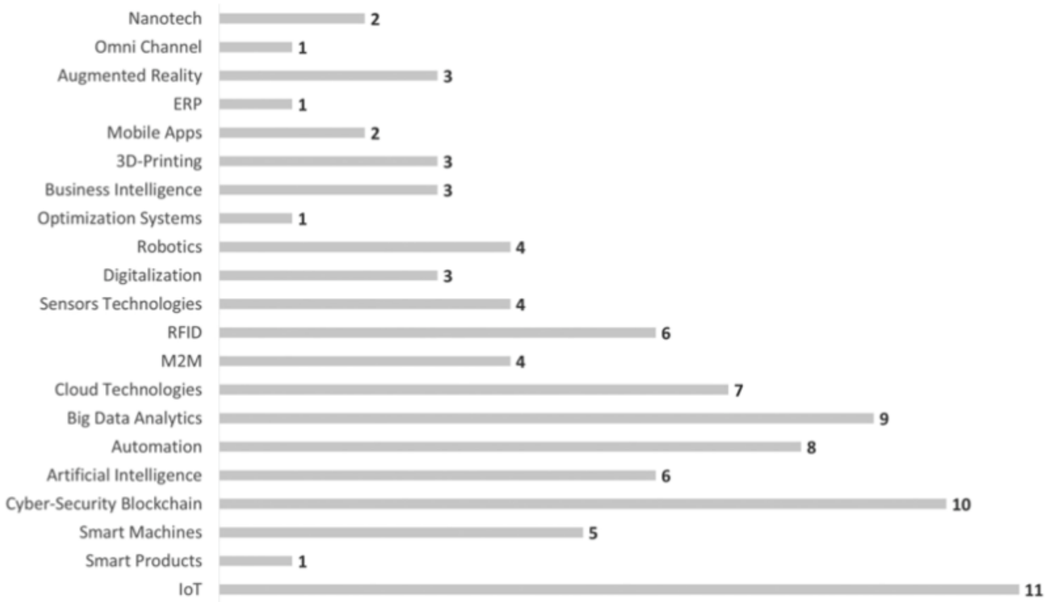


Figure 7. Number of articles considering each technology. Source: *Frederico, 2019.*

i. Internet of Things

After the introduction of the concept of IoT in 1999, different definitions were proposed mainly due to the presence of two different terms, internet and things. Thus, definitions polarized in two different visions: on one side, there is a focus on the "internet" components; on the other side, the "things" components (Ben-Daya et al., 2017). Ben-Daya et al. (2017) proposed a definition of IoT in relation to SCM as

> a network of physical objects that are digitally connected to sense, monitor and interact within a company and between the company and its supply chain enabling agility, visibility, tracking and information sharing to facilitate timely planning, control and coordination of the supply chain processes,

where the "things" could be smart machines, products or services.

The term IoT includes five technologies: RFID, wireless sensor network (WSN), middleware, cloud computing and IoT applications, which allow M2M and C2M communications (Lee & Lee, 2015).

On the basis of the Supply Chain Operations Reference (SCOR) model, which divides SC in six phases (plan, source, make, deliver, return and enable), the most relevant benefits associated with the main phases are listed below.

IoT implement purchasing and sourcing, because these technologies allow virtual and real time track of the materials as well as advances quality control and planning (Ben-Daya et al., 2017). Moreover, the deployment of IoT technology leads the company to collect data from its supplier and then better the flexibility of the SC. The following gains can be listed: “lower lead time, higher visibility and flexibility, better quality and product differentiation at lower cost” (Ben-Daya et al., 2017). IoT also implements manufacturing in terms of quality, maintenance, sustainability, production planning and scheduling, by reducing lead time and costs and increasing product life cycle and revenues. Moreover, IoT has a positive influence on one of the most important phases of SC, meaning delivery, which includes warehouse, order and inventory management and transportation. There is an implementation in terms of safety, security, information sharing, theft reduction, quality monitoring. Thus, there are overall gains in terms of time, space, money and waste (Ben-Daya et al., 2017). Nevertheless, company still face some challenges, such as the incompatibility of software among buyer and suppliers which causes the loss of data and information (Bowman et al., 2009). Finally, IoT fosters the Kanban model as well as the lean production. Thus, reverse logistics as well as waste collection are facilitated (Ben-Daya et al., 2017).

To conclude, many different benefits can be associated with the implementation of IoT technologies, even though companies face daily challenges in their implementation and integration both inter and intra-company, especially in terms of data management and mining, privacy and security (Bowman et al., 2009; Lee & Lee, 2015).

ii. Blockchain

The blockchain is a “distributed digital ledger of transactions”, which is decentralized, verified and immutable (Hackius & Petersen, 2017). The former feature is provided by the lack of a central authority, so all the peers in the network have a local copy of the ledger. Blockchain is also verified since every member has its own private-public-key cryptography, which is used to sign every transaction and it is not associated with the corresponding name of the company guaranteeing anonymity. It is also immutable because there is interdependency among the blocks. When a transaction is approved, it is added to a block, which also adds the hash of other blocks. Thus, it can be changed ex post (Hackius & Petersen, 2017).

In the context of SC, blockchain can provide multiple benefits to the companies, especially when integrated with other technologies (Ghobakhloo, 2018), in terms of immutability, transparency and decentralization (Dobrovnik et al., 2018). Three main areas of interest were identified in relation with the deployment of blockchain. Firstly, blockchain can implement shipping and transportation, especially considering international transports where the cost of paperwork is between 15 to 50 percent of the total transportation cost (Dobrovnik et al., 2018). Blockchain can digitalized these records, so that every partner can always analyze the status of the products saving money and time (Hackius & Petersen, 2017). Moreover, blockchain facilitates the identification of counterfeit products. In fact, by replacing paper certificates with blockchain, the digital ledger shows all the previous owners of a product guaranteeing authenticity and legitimacy. Blockchain also guarantees transparency, since products can be tracked along the SC (Hackius & Petersen, 2017). As a consequence, companies can show to their customers the journey of the product, from the raw materials' stage to the finished goods' phase, increasing loyalty and also profitability (Dobrovnik et al., 2018).

Finally, blockchain reduces risks and costs, increases knowledge and information sharing, facilitate origin tracking, ease paperwork etc. (Dobrovnik et al., 2018). Despite all these gains, companies still face daily challenges associated with scalability, interoperability, security and privacy, lack of standards and regulations.

iii. Big data business analytics

The definition of big data business analytics (BDBA) is controversial, because there are two aspects to consider. On one side, big data refers to data that are available in large amount and that are produced by different sources extremely fast. On the other side, business analytics refer to the constant analysis of the company's situation to obtain insights in order to better its strategy, organization, operations (Wang et al., 2016). Thanks to BDBA, companies can analyze huge amount of data, which can benefit different fields of the companies, strategic management as well as SCM.

Wang et al. (2016) distinguish two different scopes of applications of BDBA in the context of SCM.

BDBA can be applied to improve sourcing, SC network and product design. Firstly, the analysis of big data facilitates the forecast of future demands as well as market trends. Moreover, companies can simplify purchasing strategies thanks to tools for cost and risk estimation (Wang et al., 2016); thus, the contract terms can be defined more precisely (Apte et al., 2011). Moreover, BDBA can be used to settle metrics and benchmarks, so that suppliers can be evaluated and then selected more consciously. In fact, it is crucial for the performance of the company, that raw materials are delivered in the correct quantity and quality, and at the correct time (Wang et al., 2016). Furthermore, BDBA can be used to outline the most successful SC design in terms of number and location of the plants,

of machinery, warehouses as well as shipping points. BDBA can also be used to identify bottleneck points as well as the distribution of work along the SC, to optimize the triple trade-off between cost, quality and product's differentiation (Wang et al., 2016).
BDBA can also be used to better develop the strategic and tactical side of SCM, particularly applying them to demand planning, procurement, production and inventory. For instance, they provide a deeper understanding of the production cost as well as the production time, so that it is less complicated to match demand and supply and to manage the inventory (Wang et al., 2016).

In conclusion, BDBA are fundamental for current companies, because they provide decisive insights about the organization, the strategy, the operations of the whole organization, and particularly of the field of SCM.

iv. Automation

The history of automation goes back to Ford's factories at the beginning of the XX century. Nevertheless, robotics and digitalization boosted automation in the last year, with the scope of automating all the stages of the SC from procurement of raw materials to the final delivery. Thus, automation is not applied only to manufacturing anymore, but to material flow, information, relationship between suppliers and companies as well as companies and customers, and control (Viswanadham, 2002). Nevertheless, huge investments are required to the companies to implement and then integrate these technologies.

In the context of SC, automation is expected to provide benefits mainly in terms of capacity, cost and service (Baker & Halim 2007). Moreover, the goal of the companies is to become more agile and flexible reaching a lean production, in order to successfully deal changes in the market trends. Many different applications of robotics and digitalization can be applied to reach this result. For instance, loading and unloading activities can be fully automated to create a seamless process. Moreover, inventory and delay time can be reduced by creating direct connections between different entities along the SC, for instance through cross-docking or vendor-management inventories (Viswanadham, 2002). Simulations can also be conducted to find the potential bottleneck in the warehouse automation (Baker & Halim 2007). Additionally, relationship can also be automatized, for instance through continuous interactions or data mining.

Automation can provide many gains to the companies, even if it is very costly for the companies since many projects are developed in parallel and may not have users-friendly interfaces.

v. Cloud technologies

The National Institute of Standards and Technology defines cloud computing as

> a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (Giannakis et al., 2019).

Three main types of services can be provided by the Cloud Service Provider to the Cloud Service Customer: software as a service, platform as a service and infrastructure as a service. In the former case, all the applications are run by a third party and are delivered via internet. In the second option, a platform for the creation of the software is delivered through the web. A third party manages all the features of the software beside of networking, applications and data storage. In the latter case, the company can access the whole infrastructure, having the benefit that a third party manages and checks its status (Giannakis et al., 2019).

Even if companies can decide to implement among the three different types of services, the following benefits can be generally highlighted in the context of SC. Thus, these gains are presented according the five main features of cloud technologies. The first characteristic is on-demand self-service which leads to a reduction of costs along two different directions: costs aligned with profits and no requirement of technical staffs to monitor the software (Giannakis et al., 2019). Secondly, broad-network access which allows companies to share and integrate information coming from different sources with different platforms and with partners located anywhere. Then, thanks to resource pooling, different subsidiaries can align their strategies in light of the latest changes, as suggested by the huge amount of information shared. Rapid elasticity increases SCM responsiveness as well as computing scalability. Lastly, a measured service means that any change is immediately available to all the parties, so that the maintenance time and costs are minimized (Giannakis et al., 2019).

In general, cloud technologies increase the flexibility, efficiency and responsiveness of the SC while reducing costs and lead time (Babiceanu and Seker, 2016; Giannakis et al., 2019). On the other hand, companies face challenges in terms of legal and ethical concerns as well as technical and administrative problems.

vi. Artificial intelligence

AI is characterized by two main features, as described by Legg & Hutter (2007). Firstly, the actions should be chosen by the AI tool according to the most likely positive outcome, on the basis of the scope previously defined. Secondly, AI does not usually have all the information needed, but many different possibilities are involved; thus, these tools have to learn and adapt over time.

In the context of SCM, these tools are able to autonomously and successfully decide the development of an action in certain and usually unknown circumstances (Baryannis et al, 2018). Supply chain managers implemented AI mainly to assess risk with regard to production costs and losses. In fact, AI tools are able to define costs according to the different possible production scenarios, considering time and capacity in respect to the final product. Moreover, these tools can be used to select suppliers according to different scenario, since risk can be measured considering variables related to environment, society etc. (Baryannis et al, 2018).

SC managers implement these technologies to have a better understanding of the all possible scenarios when making a decision. These tools help managers during the decision-making process, but they do not take decision solely. Nevertheless, a lack of knowledge regarding AI tools leads managers to prefer other mathematical programming software. Thus, many benefits of AI in relation to uncertainty and risk are not completely clear to the managers. The other main challenge that companies are facing regards the amount of data necessary for an effective outcome. In fact, the more the information available and accurate is, the more precise the result is; but, problems regarding security and safety may arise.

vii. Radio Frequency Identification

RFID is a technology that allows the identification of objects thanks to radio waves (Angeles, 2012); they may be seen as an upgraded version of traditional barcodes, which need to be scanned by a reader in its eyeline. These tags are composed by two main elements, which are a microchip to store data and an antenna which is the bridge to the reader. Moreover, RFID tags can be classified according to two main variables: the presence of a battery and the feature of the chip. In the former classification tags can be active when they have a battery to activate the microchip, passive when the reader powers the tags through the antenna and semi-passive tags when they use both possibilities. In the latter classification, read-write tags are used for very valuable items, while read-only for low-value products (Angeles, 2013).

Different applications of RFID tags in the field of SC can be listed, providing many gains to the companies. Firstly, the tags can be installed on the pallets, so that it is possible to track them in the warehouse only by walking through them. As a consequence, the company can have reliable information about the numbers of pallet and their characteristics – in terms of weight, height, number of items etc. (Angeles, 2012). These tags can also be used to track raw materials along the chain, which is crucial especially in the food industry. As a benefit, the manufacturing process becomes smoother, information more precise and the frequency of errors lower.

Besides all the benefits in different stages of the SC, companies still need to develop RFID technologies and, particularly, need to improve integration with back-end applications and with other companies (Angeles, 2012).

2.3 Supply Chain 4.0

Over the last decades, the international market has undergone impressive changes: an increase of competition, which had the dual effect of creating even more complex products and of raising the price pressure (Rauch et al., 2016). So, at the same time, customers increase their expectations in terms of customization, transparency, quality, service level and ease of access (Alicke et al., 2017). But traditional SC are too complex, pricey and vulnerable (Wu et al., 2016) to guarantee competitiveness in a demand-drive market. So, companies do not only have to challenge more sophisticated consumers' demands, but also the latest technological advances to reshape business organizations (Barreto et al., 2017). In fact, in order to cope these challenges and remain competitive in the market, companies needed to rethink their SC by including industry 4.0 technologies and so creating supply chain 4.0.

SC 4.0 is defined as automated; instrumented because information is generated by machines and sensors; interconnected because all the entities are connected along the smart SC; intelligence because ideal decisions are taken to improve the performance; integrated because all the entities collaborate; innovative because new solutions are created to solve new problems (Butner, 2010; Wu et al., 2016). Hence, the implementation of these technologies into SC operations (as design, planning, production, distribution etc.) leads multiple benefits. For instance, SC 4.0 will become faster by reducing the length of the supply chain and improving forecasting tools, more flexible thanks to real-time decisions, more granular, more accurate thanks to the integration of data from different stakeholders and more efficient thanks to smart factory (Alicke, 2017). Thus, there will be improvements in terms of costs, service and capital – the three pillars of SC, which turn out to increase the agility and flexibility of the SC. For instance, according to McKinsey, inventory costs are expected to decrease by 50 to 80 percent (Alicke, 2017). Moreover, demand planning will be fully automated and implemented, so that safety stock will become unnecessary; but also lead time and transportation time will be decreased. So, there will be benefits not only in terms of costs, but also in terms of customer service, because more orders will be fulfilled and a better interaction with the consumers will be developed. Moreover, supply chain 4.0 has a huge positive impact also on other stakeholders, such as workers who saw an increase of the employment rate or customers who increased their expectations. In fact, international companies are using the technological advances to redesign consumers' value propositions (Berman, 2012). SC 4.0 also changes the relationship among the different entities along the SC, such as buyer-supplier (Veile et al., 2020). In fact, integration and collaboration is propaedeutic to value creation, but it also implies sharing information, sensitive data etc. Thus, full integration is not immediately implemented, and a complex assessment is required. Moreover, an effective horizontal and vertical internal integration is propaedeutic to external integration.

To conclude the implementation of industry 4.0 technologies into SC brought several benefits to the companies in terms of costs, cash and customer service, which can be even more amplified by further improvements.

2.4 Innovation

The concept of innovation evolved during the centuries, from the definition by Aristotle in *Plato* to the classification proposed by Schumpeter (1942), to the contemporaneous connotation of the world. This chapter aims to provide the Schumpeterian definition of innovation and summarize the main visions and theories on the topic. By clearly defining the concept of disruptive, revolutionary and evolutionary innovations, this section aims to prepare the ground for the classification of supply chain 4.0 technologies in light of the results of the qualitative research.

2.4.1 Definition of innovation

Among the pillars of innovation theories, Schumpeter grouped innovations into two patters: Schumpeter Mark 1 or widening pattern and Schumpeter Mark 2 or deepening pattern (Malerba & Orsenigo, 1995). In the former, new innovators continuously enter the market enhancing innovative developments and challenging incumbent firms. Thus, it is characterized by “creative destruction”, enhanced by low entry barriers and a multitude of small firms. (Malerba & Orsenigo, 1995). Whereas, in the latter innovation is promoted and sustained only by large established firms, which accumulate new inventions over time in a nearly oligopolistic market. Hence, it is characterized by “creative accumulation”, where R&D investments and high barriers to entry play a key role.

Schumpeter state that these patterns arise in consequence of two opposite technological regimes, based on four dimensions: technological opportunities, appropriability of innovations, cumulativeness of technical advances and properties of the knowledge base. The former represents the chance of success of innovation in relation to its investment: high opportunities characterized both patterns. The likelihood to protect an innovation from imitations as well as its profitability represents the second key factor: low appropriability conditions are present in a market with a multitude of small firms as Schumpeter Mark 1, while the vice versa occurs in Schumpeter Mark 2. Widening patters are also characterized by low cumulativeness conditions, third key dimension. It represents the likelihood that an innovation is followed by other subsequent inventions, as improvement of the initial model. Certainly, the two patterns are characterised by opposite values for this dimension. The last variable refers to the degree of technical knowledge sustaining the technological advances that companies have (Orsenigo & Malerba, 1995).

2.4.1 Classification of innovations

Abernathy et Clark. (1984) proposed a classification of innovations on the basis of two dimensions: the market transilience scale and the technology resilience scale. Thus, this classification is known as “transilience map”. In fact, the combination of these two variables is fundamental to define the competitive impact of the innovation on the market. As shown in Table 2, the classification leads to four different types of innovations.

Architectural innovations are improvements and ameliorations of well-established technological advances. Thus, they consist in the implementation of already existing technologies in new industries or in the revolution of previous sectors. They were labelled “architectural”, since they lay down the structure of the sector, changing cooperative and competitive dynamics. Not science-based, they are designed to be implemented for a long time (Abernathy et Clark, 1984).

The second group is innovation in the market niche, when previous technologies are exploited to create new niche market with the aim of maintaining previous designs. The implementation of these technological in niche market may lead to a change in the technology itself, but these changes are essentially based on previous knowledge and competences. Certainly, in order to be successful they need to meet the consumers’ desires and requests (Abernathy et Clark, 1984).

Regular innovations bring changes that are based on previous technological advances and are applied to large stablished markets and devoted consumers. Thus, they develop imperceptible variations, which have a huge increasing consequence on productivity, outcomes and costs. Hence, these innovations implement the features of existing products, which enhance productive skills and benefit consumers. These innovations have both visible and direct effects as well as indirect consequences; nevertheless, they do not have a huge effect of competition (Abernathy et Clark, 1984).

Finally, revolutionary inventions disrupt the previous technological advances and scientific knowledge. They are related to the idea that the capitalistic economy is not linear, but it is characterized by cycles, also known as long waves (Kondratieff, 1979). These long waves are caused by factors embedded in the economy itself and, at the same time, influence the main social and economic sectors. In fact, the idea behind these long waves is that after a certain period of time technologies are matured and not so fruitful anymore, since they do not foster new innovations and investments. Thus, their implementation rate decreases, until novel technologies are created and introduced in the market. This new wave of technologies is composed of revolutionary innovations, because they revolutionize the market and render previous technologies obsolete (Abernathy et Clark, 1984). In line with the Schumpeterian view, these technologies are fully effective only when successfully related to consumers' needs. Moreover, these long waves are considered endogenous to the technological changes, while exogenous to the economic environment.

<table>
<tr><td></td><td colspan="2">Disrupt existing/Create new linkages</td><td></td></tr>
<tr><td rowspan="2">Conserve/Entrench existing competence</td><td>Niche creation</td><td>Architectural</td><td rowspan="2">Disrupt/Obsolete existing competence</td></tr>
<tr><td>Regular</td><td>Revolutionary</td></tr>
<tr><td></td><td colspan="2">Conserve/Entrench existing linkages</td><td></td></tr>
</table>

Table 2. Transilience Map. Source: *Abernathy & Clark, 1985*

2.4.2 Disruptive innovation theory

Industry 4.0 technologies have the potentialities to revolutionize the manufacturing industry, by creating smart factories which can enhance competitiveness and boost profitability. Despite the growing importance of these technological advances in the global market – especially in the SC -, the implementation process is long and is still running. Thus, the first step is to define innovation and then quantify how much innovation these technologies bring to the economic world, in the light of the Disruptive Innovation Theory (DIT) (Christensen, 2013).

Firstly, Christensen states that "innovation refers to all changes of processes by which an organization transforms labour, capital, materials and information into products or services of greater value" (Christensen, 2013). Given the definition, the DIT classifies innovations into two categories: sustaining or disruptive innovations.

The former are discontinuous or radical innovations, which better the performance of the products already in the market without its total revolution. They are usually implemented by incumbent companies, which are unlikely to implement disruptive technologies (Christensen, 2013).

The latter are incremental innovations, which revolutionize the previous business models and propositions. At first, the products offered have a lower performance than conventional proposals (in the usual terms of size, speed and functionality); so that, only few customers appreciate these new characteristics. In fact, these technologies "overshoot" their customers by offering a product above their needs or above their reference price. But underperforming technologies are likely to succeed in the future in the same market conditions, due to a change in the consumers' demand. This dynamic is clearly represented by Figure 7. In fact, incumbents invest in technologies that satisfy the needs of the most valuable customers, locating in the highest market segment. On the other hand, they do not satisfy the requests of the least profitable market segments, which leave an opening for new entrants to propose innovative products. As shown by the upward line, new entrants will expand their market by increasing its target customers and by reaching more profitable market segment; thus, they challenge mainstream companies (Christensen, 2013).

Disruptive technologies are usually implemented by new entrants in the market; and well-established firms hesitate to invest because of three main reasons. Disruptive technologies offer lower profit margin at the first step of their implementation rather than sustaining technologies (Christensen, 2013). Secondly, the vast majority of customers as well as the most valuable consumers do not welcome positively the launch of these new products in the market; thus, they are confined in small niche and emerging markets, leading to low profitability.

To conclude, this theory explains the definition of sustaining and disruptive technologies as well as their associated characterizing factors. Thus, it seems appropriate to use this theory as a basis for the classification of industry 4.0 technologies, since academics and managers still do not agree on their definition; especially, considering that disruption is a relative term. In fact, an innovation can be disruptive only in one industry but not in the all market (Christensen, 2013), which may be the case of industry 4.0 technology and the specific sector of supply chain.

Figure 8. Disruptive innovation model. Source: *Christensen et al., 2015*

2.4.3 Innovation-orientation and supply chain integration

There is no general consensus on the definition of *innovation orientation.* The first definition was proposed by Manu in 1992, mainly considering the launches of new products and the amount of R&D investments. Thus, this definition did not consider some aspects, such as the company's beliefs, the impact of technologies, the knowledge base, the role of employees and the willingness of the company to innovate (Siguaw et al., 2006). In general, all the definitions agree that innovation orientation deeply characterizes the philosophy of the company, which is based on learning and increasing knowledge in every department. Thus, this learning philosophy shapes a corporate culture, based on openness to innovation, risk and creativity (Siguaw et al., 2006). Among previous studies, Siguaw et al. (2006) defines innovation orientation as

> a multidimensional knowledge structure composed of a learning philosophy, strategic direction, and trans-functional beliefs that, in turn, guide and direct all organizational strategies and actions, including those embedded in the formal and informal systems, behaviors, competencies, and processes of the firm to promote innovative thinking and facilitate successful development, evolution, and execution of innovations.

This definition refers to the learning philosophy of a company without defining its propaedeutic elements. In fact, different firms may decide to stress and implement different elements, in order to create their successful formula (Siguaw et al., 2006). Moreover, previous studies suggested a positive relationship between innovation orientation and firm performance, since these companies may react quickly to market changes, may satisfy consumers' needs straightaway and gain advantages (Siguaw et al., 2006). Hence, persistent innovation is the only guarantee to high competitiveness (Zhou et al., 2005).

Furthermore, innovation-orientation enhance supply chain integration under different aspects. Firstly, companies adopting this strategy are more likely to create value for all the entities along the SC. Thus, suppliers are more willing to integrate their operations, as shown empirically by Lii & Quo (2016): the more developed the innovation orientation is, the greater the SCI is. In fact, by following this process of integration, the whole SC can gain competitive advantage by forecasting the customers' demand more easily and by reacting more quickly to new needs (Li & Quo, 2016). On the other hand, also integration with customers is boosted by innovation orientation. Thanks to continuous contacts with the customers, the company may have more information about their preferences, needs, requirements and also may know all the reasons behind this final decision. Thus, not only they positively strengthen their relationships with customers, but they also reinforce the image of the firm (Swink et al., 2006).

To conclude, innovation orientation has a positive influence on integration, both internal and external. Moreover, this SCI enhances competitive capabilities and boost the company's performance. Hence, the relationship between the innovation implemented by industry 4.0 technologies and SCI should be analyzed, to implement the current literature.

2.5 Propositions

As presented in the previous sections, many benefits are associated with the implementation of industry 4.0 technologies at the SC level. Nevertheless, companies still struggle to fully integrate these technologies into the SC processes, thus there are unexploited gains. Hence, the barriers to internal integration as well as the perception of industry 4.0 technologies in the eyes of SC managers are still unclear. In line with the research questions highlighted in Figure 1, this section outlines the propositions of this research, mainly grounded on the theoretical framework (Kleining, 1982).

The first set of propositions regards how SC managers perceive industry 4.0 technologies.

P1: SC managers' awareness of 4.0 technologies plays a role in the implementation of the technologies.

P2: SC managers consider industry 4.0 technologies as disruptive in the field of SC.

P3: SC managers perceive 4.0 technologies in a multifaceted way.

The research aims to investigate whether supply chain managers are completely aware of the potentialities associated with the implementation of these technologies. Moreover, it wants to analyze whether a problem of technology acceptance may exist, giving meaningful insights to the companies which need to work towards that objective and to academics suggesting further studies on the topic. The aim of the second proposition is to understand the opinions of SC managers on these latest innovations. It is still not clear whether these technologies are considered as disruptive or sustaining. Moreover, as suggested by the Disruptive Innovation Theory (DIT), some technologies may be disruptive in one industry and sustained in another field. Thus, this proposition wants to investigate the disruption of these technologies in the field of SC. Moreover, it wants to further investigate whether they are considered revolutionary or evolutionary. After having defined the knowledge base and the opinion of the SC managers, the last proposition wants to investigate how they perceive these technologies. Assuming that these technologies cannot be strictly classified only as an opportunity to enhance the performance of the company or as a threat to escape, this proposition wants to explore their beliefs.

The second set of propositions regards the integration of the technologies into the SC.

P4: Different factors play the role of barriers to internal integration of 4.0 technologies into SC.

The analysis of previous literature leads to categorize the factors, as follows.

P4a. Financial reasons hinder the development of the technologies.

P4b. The lack of management skills in industry 4.0 restrain the adoption of the technologies.

P4c. Legal issues discourage the adoption process of the technologies.

P4d. Technical issues slow down the deployment process.

On the basis of previous studies investigating the barriers to industry 4.0 technologies, this study aims to identify the factors which limit the internal integration of these technologies at the company level. In fact, the identification of internal barriers will simplify the process of integration. Thus, companies will benefit since they will know the variables to improve.

2.6 Literature review

Topic	Title	Author(s)	Year	Contributions
SCM	Integrating the supply chain	Stevens, G.	1998	SCM involves both materials and information flows, following two opposite directions: the former from suppliers to customers, the latter from customers to suppliers. Integration of both variables with external entities enhances the performance. To faciliate the integration, the material flow is considered under strategic, tactical and operational perspectives.
	Business Logistics: Management of Physical Supply and Distribution	Heskett, J.L., Ivie, R.M. and Glaskowsky, N.A. Jr	1971	The concept of business logistics has been introduced, including all the activities related to physical supply and material management.
	The evolution and future of logistics and supply chain management	Ballou	2017	The evolution of logistics and SCM is delineated. The concept of of SCM evolved drastically over the years, becoming always more comple and incorporating other departments. SCM is also fragmented in 8 sub-processes, in order to simplify its clarify.
	Defining supply chain	Mentzer, J. T., DeWitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D., & Zacharia, Z. G.	2001	SC is defined as a group of at least three companies which trade materials, information, services etc. This definition is given as preliminary to the definition of SCM, which is presented under different philosophies. Lastly, the concept of supply chain orientation is described as the recognition to implement SC and the relationship with the organizations along the SC, given its associated benefits.
SCM integration	Supply chain process integration: a theoretical framework	Chen, H., Daugherty, P. J., & Landry, T. D.	2009	Internal integration is defined as the cooperation among different departments to reach a seamless flow of activities. Whereas, external integration refers to the collaboration with upstream and downstream organizations along the SC. The theoretical model proposed shows that internal and external integration are two distinguished process, which should be implemented simultaneously.
	Defining and operationalizing supply chain process integration	Chen, H., Daugherty, P. J., & Roath, A. S.	2009	Connectivity and simplification (in terms of business process) are defined as the two key components of integration. The importance of the implementation of these two variables is testested empirically through a qualitative study.
	A meta-analysis of supply chain integration and firm performance	Leuschner, R., Rogers, D. S., & Charvet, F. F.	2013	SCI includes both the concept of collaboration and coordination with external entities. The relationship between SCI and performance is analysed according to three different theories: resource-based view, resource-advantage and relational view theories. SCI is divided into three dimensions: information, resource sharing ando organizational integration.
	Arcs of supply chain integration	Childerhouse, P., & Towill, D. R.	2011	A framework showing five alternative arcs of SC integration is proposed. Each arc represent the level of integration of the company in relation to its suppliers, customers or the company itself. An empirical analysis shows a positive relationship between performance, productivity, outcomes and the breadth of the arc.

Topic	Title	Author(s)	Year	Contributions
Industry 4.0	Design principles for industrie 4.0 scenarios	Hermann, M., Pentek, T., & Otto, B.	2016	The design principles of smart factories are delineated as interconnection, information trasparency, decentralized decisions and technical assistance. In the ideal scenario, all these principles should be implemented, but interconnection is tested to be the crucial variable.
	The future of manufacturing industry: a strategic roadmap toward Industry 4.0	Ghobakhloo, M.	2018	A six-stage approach literature review identifies 12 design principles and 14 technological trends. A strategic roadmap for each key department of a company designs the steps to follow, in order to implement industry 4.0 technologies.
	Supply Chain 4.0: concepts, maturity and research agenda	Frederico, G. F., Garza-Reyes, J. A., Anosike, A., & Kumar, V.	2019	The systematic literature review identifies 21 dimentions, which are important when considering industry 4.0 and supply chain. A 4-steps framework for identifying the maturity of the technologies is also proposed in theory, but not actually implemented in practice.
Supply chain 4.0	Supply Chain 4.0 in consumer goods.	Alicke, K., Rexhausen, D., & Seyfert, A.	2017	Supply chain 4.0 is defined as faster, more accurate, more flexible, more granular, more efficient. The implementation of new technologies benefits several activities, such as planning, physical flow, performance management, order management, collaboration. So, there are positive gains in terms of costs (especially warehouse costs), service and cash - leading to higher flexibility and agility
	The smarter supply chain of the future	Butner, K.	2010	SC face the current 5 challenges: cost-containment, visibility, risk (especially risk management), customer intimacy (rather than supplier intimacy), globalization. Thus, the three core characteristics are instrumented, interconnected and intelligent.

Table 3. Literature review. *Own Source.*

3. Methodology

This section describes the appropriate methodology to address the research questions and to have a deeper understanding on the research topic. Firstly, the justifications for choosing a qualitative study to address the problem statement are clearly described. Then, research design, data collection methods and the sampling decisions as well as the final sample of respondents are presented. This chapter ends with three sections regarding data analysis, data presentation and the limitations of the study.

3.1 Research approach

Industry 4.0 captured the attention of academics, practitioners and also politicians, as evidenced by the growing number of articles published every year on the topic. Particularly, the application of these technological advances to the supply chain became even more relevant, thanks to all the benefits and gains associated. Nevertheless, as the topic has been introduced very recently, there are lacunae and deficiencies in the previous literature. For instance, the literature lacks further studies on internal integration, which is preliminary to a successful implementation of these technologies. Hence, this study aims to fill this gap by identifying the barriers to the integration of these technologies into the supply chain.

A qualitative research approach seems to be the most suitable method (see Figure 8), due to the exploratory nature of the research, which aims to further investigate the topics explained in the research questions. Previous studies are analyzed as preliminary to further investigation through a qualitative approach, without following the concept of *tabula rasa* proposed by (Glaser & Strauss, 1967). Hence, in-depth semi-structured interviews will guide the research for two main reasons. Firstly, investigating the internal integration of technological advances into the SC is a very complex and broad topic, which includes several factors and variables. Thus, semi-structured interviews are chosen since they allow the identification of a wider spectrum of variables and a deeper understanding of the complex dynamics and processes within a company. Secondly, semi-structured interviews guarantee flexibility, since the questions can be changed, adapted, postponed according to the respondents, in order to deepen certain aspects of particular interest. The flexibility is also guaranteed by the research process, which is not linear but composed of interlinked stages. This process also stresses the principle of *verstehen*, which leads to a deeper and more open understanding of the topic considering the respondents' point of view (Wundt, 1982). Moreover, as shown in the figure, the interviews are the center of the process and the comparison of qualitative data leads to the theoretical development.

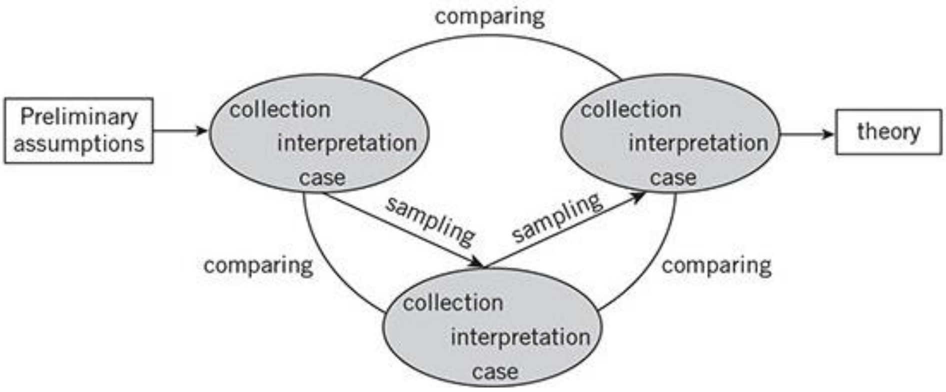


Figure 9.Circular model of the research process. Source: *Glaser & Strauss, 1967.*

3.2 Research Design

The aim of the study is to investigate how companies can implement supply chain 4.0 technologies, by delineating the perception of SC managers and by identifying the barriers to the internal integration of the technologies.

The interviews will follow the same structure of the research question. Firstly, the perception of SC managers is investigated, in order to identify their level of awareness and their general opinions on the new technological advances. The aim is to understand whether they believe these technologies are disruptive and an opportunity to reshape the SC system. Then, the barriers to the internal integration into SC are investigated.

The interviews will follow two steps. Firstly, SC managers will be interviewed to have a deeper understanding on supply chain 4.0 technologies and on the process of their integration. In fact, delineating their beliefs and opinions as well as identifying the barriers is crucial for the research. Then, IT experts will be interviewed to highlight the points of views of specialists in the sectors. The aim is to identify whether there is a mismatch between SC managers' and IT experts' opinions; it is even more crucial to detect the mismatch between the variables considered as barriers to the internal integration. In fact, according to (Bogner & Menz, 2002), collecting knowledge about a specific issue by interviewing different experts will lead to discover further theoretical insights. Thus, expert interview is used as a complementary method to SC managers' interviews. In fact, the comparison with SC managers' answers will identify the areas to deeper investigate in the literature and the challenges to overcome in the companies.

The interviews will consider both a short-term and long-term perspectives, in order to investigate the current situation and to forecast future changes as well as challenges.

To conclude, both set of interviews will be combined in order to identify fruitful insights, which will answer to the research questions.

3.3 Interview Design

To answer the research questions beforementioned, a qualitative research approach is chosen, particularly in form of in-depth semi-structured (SS) interviews (Groeben, 1990).

The interviews will be in-depth, meaning that intensive individual interviews will be conducted. This research technique will allow the respondents to express their opinions, thoughts, perspectives on the topic, leading to broader insights (Boyce & Neale, 2006). Additionally, more detailed information and specific references may be provided. The interviews will also be semi-structured, allowing open-ended questions to investigate the respondents' opinions on the topic and to provide the actual explanations of the topic on the basis of previous knowledge (Flick, 2018). Theory-driven and hypothesis-directed questions may also be asked, in the light of researcher's theoretical presuppositions. These questions aim to make the respondent's knowledge more explicit. Lastly, confrontational questions may be asked: on the basis of the notions and theories mentioned by the respondent, the researcher proposes a competing alternative. Thus, the participant needs to re-examine his/her belief on the basis of the new information available. In order to avoid the possibility that the respondent includes this alternative in his/her theory, the alternatives should have a completely opposite direction. Thus, the research may have a different spectrum of theories to propose as alternatives, according to the interview.

Moreover, a set of questions is previously designed to guide the conversation, but the questions can be changed during the interviews. The primary set of questions are derived from the theory and then adapted to guarantee flexibility during the interview, in order to face any possible context-specific issues (Kvale, 1996). For instance, if a respondent does not understand a question, this interview format leads the research to go further in the explanation (Saunders et al., 2016). Moreover, new questions can be raised according to the respondent's answers (Newcomer, Hatry, & Wholey, 2015), in order to delve deeper into relevant aspects. Additionally, questions about real-life examples, past and current experiences will be delineated, in order to make comparison among different industry's field and to gain practical explanations (Saunders et al., 2009).

The qualitative design will follow the framework proposed by Gioia (2012), but it will be adapted considering the specific interview technique chosen. Hence, the framework of Newcome et. al, (2015) and Boyce & Neale (2006) will be also integrated when designing the interview.

In order to address the research questions, the interview will be divided into three-parts: introduction, main body and conclusion. At the beginning of the interview, the researcher will present herself and the scope of the research; then the respondents will introduce themselves defining their profile, particularly nationality, the role in the company, the field of the company, the years of work in the field etc. These briefing questions have to main scopes: delineating the characteristics of the sample and making the respondent more comfortable with the overall situation and interview technique. Then, the main body is divided in two sub-area: perception of the technologies and integration of the technologies. Both SC managers and IT specialists will be interviewed to understand their level of awareness, consideration on the basis of the DIT theory and opinion on the technologies. The second part of the interview will focus on the variables that are considered barriers to the internal integration of the technologies into the supply chain. At the end of the interview, respondents will have time for adding any detail, consideration or concern.

A pilot interview will be conducted both with a SC manager and IT specialist in order to understand the feasibility, the clarity and the length of the interview. As a consequence, further changes may be implemented in the following interviews.

Confidentiality will be guaranteed as well as the anonymity of the answers. In fact, a Consent Form (see Appendix) will be sent via e-mail or LinkedIn messages before the interview and will be signed by both parties. It will inform the participants about the scope of the study, the characteristics of the interview and the data collection, to meet ethical standards (Northway, 2002). For the same reason, the consent will be given voluntarily by a person who is competent and fully informed (Allmark, 2002). The Consent Form has a threefold aim. Firstly, confidentiality enhance trustworthiness with the participants (Saunders et al., 2016); thanks to anonymity, the respondents will be more willing to discuss about sensitive topics and past experiences. Lastly, it allows the researcher to tape record the interviews. The recording helps the researcher to focus on listening, formulating questions and have unbiased records (Saunders et al., 2019); nevertheless, respondents may be intimidated (Saunders et al., 2016). Thus, respondents are completely free to choose. In case recordings are allowed, a complete transcription and a summary of the answers will be available in the Appendix; but the recording tape will not be disclosed to guarantee confidentiality (Lüders, 2004). Otherwise, notes will be taken by the researcher during the all interview and review immediately afterwards.

3.4 Choice of respondents

In order to address the research questions, SC managers and IT specialists will be interviewed. The respondents are selected according to their relevance with the object of the research, not for representing a statistically perfect sample of the overall population – according to the grounded theory approach (Glaser & Strauss, 1967).

The selection of SC managers (including demand planners, procurement managers, project managers etc.) has been done considering four elements: the size and internationality of the company, its industry, its geographical location and the role of the SC managers in the company. Firstly, SC managers are selected among the companies that have already implemented smart factories and industry 4.0 technologies in their SC in accordance to the IoT Analytics (January, 2019) (see Figure 9 in Appendix). In order to study the same phenomenon considering different perspective, SC managers working in international multinational companies are also selected (Denzin, 1989). Moreover, the geographical location as well as the industry of the company is also important, since this study does not focus on any target industry or country. Thus, respondents working in different fields and states are selected. Lastly, the position of the SC managers in the company is also crucial, since it is assumed that a higher position is directly correlated to sufficient knowledge and experience within the topic of the study. Hence, only supply chain managers, head supply chain managers and CEO are interviewed.

The selection of IT specialists has been done only considering their position in the company. As for SC managers, it is assumed that the role in the company reflects the knowledge and experience in the field.

According to Glaser and Strauss (1987) and Guest et al. (2006), the sample size can be determined by the concept of theoretical saturation, which occurs when no additional data emerge from the interviews. Thus, when a sample reaches its theoretical saturation, sampling and interviewing procedure are completed; as a consequence, the number of interviews cannot be determined a priori.

The respondents were reached via e-mail, LinkedIn and a personal contact of the researcher, working in an international company perfectly in the target of the study. The interviewer does not have any previous relationship with the respondents, which may bias the conversation.

The respondents are reached on LinkedIn as follow. A first introductory message has been sent to possible candidates in September (see Appendix). Then, a follow up message explaining the scope of the research and asking for the availability to participate to the study has been sent. It follows a brief conversation to set up the online interview in October. This methodology has been adapted from Dillman (2011).

The interviews will be conducted via Zoom, Skype or online platforms due to the worldwide location of the respondents and due to the Covid-19 restrictions. They can be conducted either in English or in Italian, according to the preference of the participant. Thus, the consequences of these current conditions and of language barriers will be addressed in the section about the limitations of the study.

3.5 Sample

The respondents, chosen following the concept of theoretical saturation (Glaser & Strauss, 1987), are listed in the table 4. In order to guarantee confidentiality and the anonymity of the participants, a code name has been assigned to every respondent. The table gives further information about the respondent and the characteristics of the interview.

Respondent	Position	Location	Platform	Structure	Length	Date
R1				SS		
R2				SS		
R3				SS		
…				SS		

Table 4. Description of the sample. *Own source.*

3.6 Limitations of the study

Despite the rigor of the interview design and the sampling procedures, some limitations may be identified.

Due to the worldwide location of the respondents and due to the Covid-19 restrictions, the interviews will be conducted online (Mann & Stewart, 2000). Thus, respondents may find more difficult to familiarize with the environment of the interview, because the online format may create a barrier: spontaneity and paralanguage are difficultly maintained online. Hence, it will be challenging for the researcher to make them comfortable with the interview format, which is a crucial aspect. In fact, when respondents are comfortable, they are more open and willing to share their opinions, beliefs and past experiences.

The early phase of some industry 4.0 technologies may constitute a limitation. Even if the research regards technologies at different development stages, as shown by the theoretical framework, some technologies may still not be implemented in some companies. Thus, SC managers may not be so familiar with some technologies to properly identify the barriers, and they may do not have past experiences as benchmarks.

The last limitation may regard the language. The interviews may be conducted either in Italian or in English, as the respondents prefer. So, two limitations may arise. Communication barriers may occur when interviews are conducted in English, since it is not the mother tongue of either the respondent or the researcher, or both parties. Secondly, when the interviews are conducted in Italian, no communication barriers will occur, but the translation may constitute a limitation.

To conclude, these limitations should be taken into consideration when analyzing the data and particularly when generalizing the findings.

3.7 Data analysis

The software Maxqda will be used to conduct the data analysis. Thus, the data obtained from the interviews will be inserted into Maxqda. Then, they will be coded and analyzed in order to provide the pillars for a theoretical development and for the integration framework.

4. Expected contributions

This study will provide fruitful insights to companies as well as academics about industry 4.0 technologies in relation to supply chain, particularly considering the perception of the technologies and the barriers to their internal integration.

Companies will realize the elements and factors which must be enhanced in order to successfully implement smart factories and remain competitive in the global market. In fact, the study will highlight the perception, the knowledge-base and the awareness that SC managers have on industry 4.0 technologies. Since the research will evidence whether a problem of technology acceptance as well as a lack of hard knowledge or soft skills exist, the companies will know the next steps and the next moves. For instance, they will know whether they have to invest in training or re-training programs rather than technical implementations. Moreover, the study will highlight which elements and factors hinder the internal integration process. Thus, companies will also know the barriers and challenge that need to be overcome for a successful integration of the technologies, fundamental for the improvement of the performance.

From an academic point of view, the study will fill the deficiencies present in the previous literature, still at an embryonic stage. The study will classify industry 4.0 technologies as disruptive or sustaining, as an implementation of the DIT theory. Moreover, the identification of the internal barriers will allow academics to go one step further in the analysis of external integration. In fact, internal integration has been proved to be preliminary to external integration (Rummler & Brache, 1995).

5. Thesis chapter overview

Abstract: brief summary of the research topic and its scope

List of abbreviations

List of figures

List of tables

1. Introduction: overview of the background – industry 4.0 technology and supply chain – and summary of the research topic – perception of the technologies and barriers to the integration. This chapter includes the problem statement, the deficiencies of the literature, the research questions and the contributions.
2. Theoretical framework: overview of the most important notions used to build a solid theoretical background and the proposition of the study. A summary of the most relevant academic papers is also presented in the literature review table.
3. Methodology: justification of the qualitative approach as well as explanation of the following interviewing process. The choice of the respondents as well as their description is presented. The section also includes the interview design and its main limitations, which need further improvements once the study will be completed.
4. Results: analysis of the results of the semi-structured interviews through the software Maxqda. The main findings will be outlined in order to further the theoretical development.
5. Conclusions: final conclusions, paths for further researches and main limitations will be described.
6. Appendix: addition of tables and figures not included in the main body.
7. References

6. Plan of work

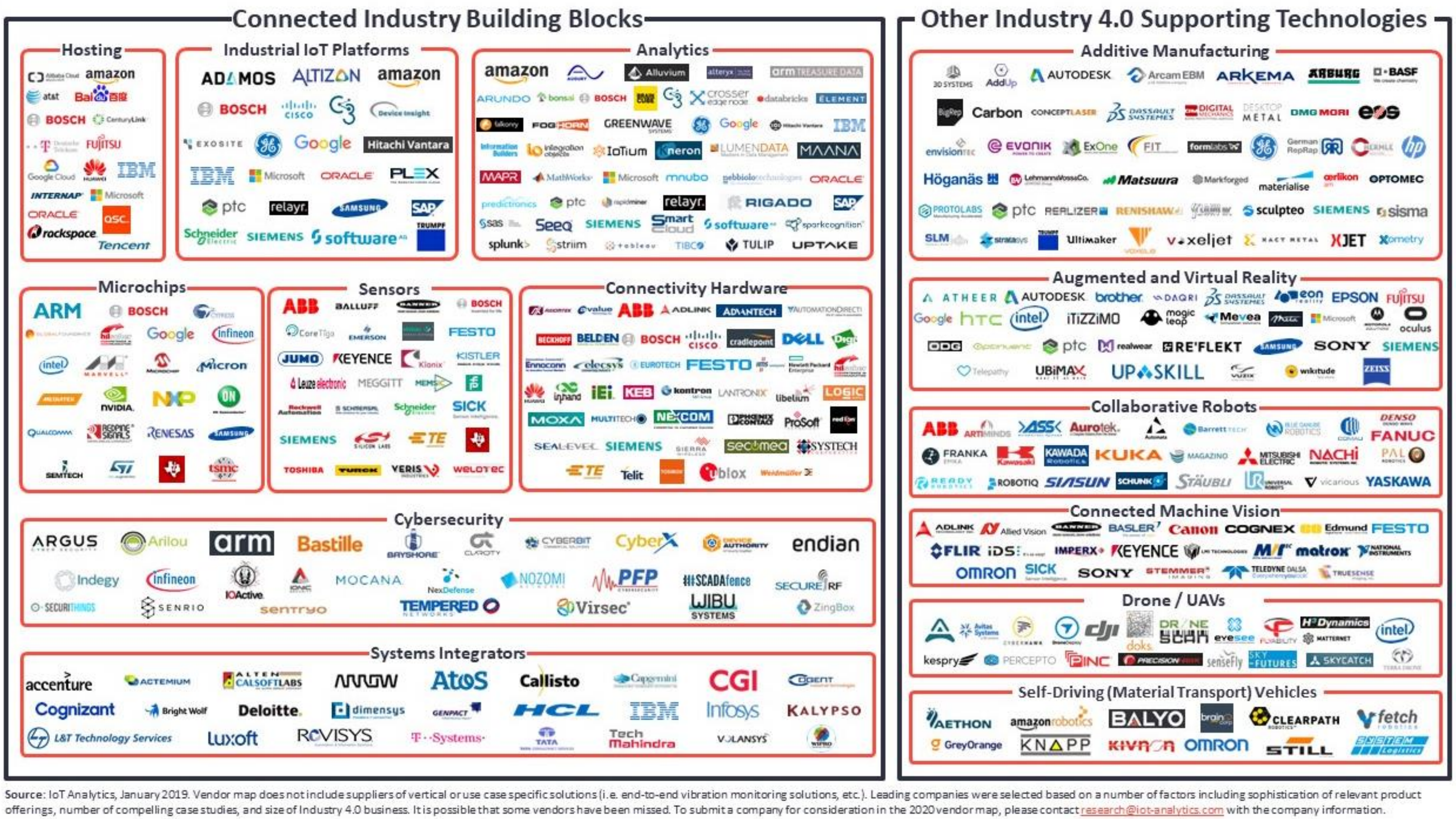
The plan of work represented in Table 5 summarize the activities to do in order to complete the thesis. They are divided into four macro-categories to simplify the organization of the work. Following the table will facilitate the tasks and will guarantee that deadlines will be met.

Plan of work - EMBS Master Thesis																						
ACTIVITES		September					October				November				December					January		
		36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	1	2	3
Reading	Theoretical Framework																					
	Industry 4.0 technologies																					
Methodology	Interview design																					
	Gathering contacts																					
	Interviews																					
Writing	Coding																					
	Analysis of the results																					
	Integration framework																					
	Conclusion																					
	Review																					
Presentation	Speech																					
	PPT																					
	Dissertation preparation																					
Deadlines						30.09															13.01	19.01

Table 5. Plan of work. *Own Source.*

7. Appendix

Figure 10. Leading Industry 4.0 Vendors 2019. Source: *IoT Analytics*, *2019*.



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