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Information sharing as the sustainability enabling mechanism in supply chains in the Industry 4.0 era.

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ABSTRACT

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This thesis examines the relationship between two megatrends, Digitalization and Sustainability. Moreover, the purpose is to find the element through which the sustainability efforts are conceptualized in digital supply chain context. The research is twofold: firstly, a systematic literature review is conducted, during which the published literature between 2000 and 2020 is examined thoroughly. Based on that, the research question and hypothesis are formulated. Secondly, a survey that resulted 147 answers from Finnish companies operating in various industries, was conducted. The results were analyzed using a PLS SEM-path model. The insights from the model validated the proposed hypothesis and showed that 1) Industry 4.0 has a positive effect on the practices how companies handle and share information within their supply network, and 2) the enhanced information sharing processes then further improve the sustainability practices in companies and help achieving the set sustainability goals throughout the supply chains. The previous research on the topic is scarce and this thesis provides pioneering results and practical implications on how the various digital technologies can be used in order to effectively obtain sustainability benefits in companies.

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Tämä Pro Gradu-tutkielma tutkii kahden megatrendin, digitalisaation ja vastuullisuuden välistä suhdetta. Tarkoitus on löytää elementti, jonka välityksellä vastuullisuustavoitteet voidaan saavuttaa digitaalisten hankintaketjujen kontekstissa. Tutkimus on kaksijakoinen: ensinnä suoritettiin systemaattinen kirjallisuuskatsaus ja vuosien 2000 ja 2020 välillä julkaistuja artikkeleita analysoitiin tarkemmin. Sen perusteella muodostettiin tutkimuskysymys sekä hypoteesit. Toiseksi, suomalaisyrityksille kohdennettiin kyselytutkimus joka tuotti 147 vastausta, joita analysoitiin käyttäen PLS SEM-polku mallia. Mallin tarjoamat tulokset validoivat esitetyt hypoteesit ja todistivat, että 1) Teollisuus 4.0 konsepti edistää tiedon jakamista yrityksissä, sekä 2) parantuneet keinot ja käytänteet tiedon jakamiseen edelleen edistävät yritysten vastuullisuuspyrkimyksiä ja auttavat saavuttamaan asetettuja tavoitteita koko hankintaketjun matkalla. Aikaisemman tutkimuksen määrä tästä aiheesta on varsin vähäinen, joten tämä tutkielma tarjoaa edistyksellisiä tuloksia ja käytännön ehdotelmia siitä, miten yritysten tulisi hyödyntää tarjolla olevia erilaisia digitaalisia teknologioita sekä kyetäkseen parantamaan informaation jakamista ja siten vastuullisuutta läpi niiden hankintaketjujen.

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Fortunately, this is not the end of my studies.

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
BC	Blockchain
BD	Big Data
BDA	Big Data Analytics
DC	Dynamic Capability
DCV	Dynamic Capability View
IIoT	Industrial Internet of Things
RBV	Resource Based View
SC	Supply Chain
SCM	Supply Chain Management
SSCM	Sustainable Supply Chain Management
SLR	Systematic Literature Review
TBL	Triple Bottom Line

INTRODUCTION

The recent Covid-19 pandemic forced people and companies to take a leap into more digital world. As face-to-face meetings became an unnecessary risk, companies had to, among other things, develop substitutive ways to organize their mandatory business meetings, and to find new methods for their employees to work from home. This resulted in a massive advancement in the level of digitalization in the companies. In addition to new ways of conducting business, Covid-19 also caused a decrease in the global CO2-emissions. During the times when the restrictions to normal life were at their strictest point, the average emissions were 26% lower compared to the 2019 numbers (Le Quéré et al., 2020). This is the scale we need to achieve and maintain if the ongoing contamination and warming of our planet is to be stopped. However, this change will probably be temporary as humanity is most likely able to overcome this crisis, after which the consumption will return to the pre-pandemic level. More long-term solution is imperative to stop the global-warming and to ensure the sustainable use of the scarce natural resources. By doing that we can ensure healthy and equal living conditions for the future generations as well. Digitalization could offer a variety of tools to help achieving this ambitious goal, but more knowledge about how it can help is needed.

1.1 Background

Since majority of the economic, social, and environmental interactions are organized through supply chains, businesses around the globe, and especially the supply chains formed by them, have a massive impact on the applied solutions, and thus on the overall sustainability (Linton, Klassen & Jayaraman, 2007). For that reason, new ways to improve the business processes are needed in order to obtain a more permanent change. In the emerging digital technologies lie a great potential to improve the overall performance of a firm (Dubey, Gunasekaran, Childe, Papadopoulos, Luo, Wamba & Roubaud, 2019). In addition, Ghobakhloo (2020) pointed out that it is often economic sustainability, which is the direct result of digitalization in firms, what then leads the way for implementation of more socio-environmental projects of digitalization. Thus, digitalization could be a major enabler of more sustainable supply chains and ensure the sufficient use of natural resources in the future. According to Melander and Pazirandeh (2019), digitalization contributes to

sustainability by enabling radical innovations and by helping firms to gather and organize information in order to make better decisions. They also found that companies are, however, struggling with the implementation of digitalization and they are not able to reap all the possible benefits associated with it. Nevertheless, some of the most progressive companies have begun to take the first steps to actually integrate digitalization initiatives with sustainability. For example, KONE (KONE, 2019) uses digital technologies in order to develop elevators with socioenvironmental impacts in mind, DHL (DHL, 2020), with their customer, used digitalization to gain transparency and helped them to aim for smaller carbon footprint, and Philips (Philips, 2020) utilizes algorithms and predictive analytics to offer highly personalized healthcare for their patients. And even countries, such as Finland (Ministry of Transport and Communications, 2020), have begun to formulate digital strategies that pursue for more sustainable tomorrow. These are just a few examples about companies and public sector recognizing the possibilities of digitalization when enhancing sustainability. There are, and also will be many more such companies and other entities in the upcoming years as the practices become more obtainable and as the current challenges are overcame.

1.2 Objectives of the thesis

This study aims to shed some light on how these two concepts, digitalization and sustainability, are linked together. And as this connection is vague, the aim is to provide managers with information on how, by adapting digitalization initiatives, a company can achieve improved sustainability and extend the effects throughout its whole supply network. Even though currently in its infancy, the use of digitalization as a way to improve sustainability will become a standard during the upcoming years and decades. The integration between digitalization and sustainability has started to gain attention amongst the researchers and, for example, Govindan, Cheng, Mishra and Shukla (2018) have noted the great opportunities that emerging digitalization technologies offer for promoting sustainability in supply chains. Papadonikolaki (2019) sees digital technologies as information-driven means that help to structure and regulate the various information flows in supply chains and if paired with supply chain management philosophy, it can solve many profound and complex problems in the supply chains. This research gives answers on how

these two megatrends can be combined, and what else is required in order to successfully implement them into organizations.

Traditionally quite heavily towards the focal firm leaning supply chains must reshape themselves and their supply chain philosophy needs to adapt to the emergence of digital technologies. Especially, this would mean the increased importance of cooperation with partners, i.e. to digitally linking the companies in the same supply chain together, in order to achieve the sustainability goals (Bag, Telukdarie, Pretorius & Gupta, 2018). If a supply chain reaches a digitally integrated, and truly cooperating state, within and along the whole network, it becomes easier to, for example, observe and optimize the use of resources (Neligan, 2018). Probably the most key element of the successful integration are the procedures of how companies share data between them. Beier, Niehoff, and Xue (2018) emphasize the influence of transparency along the entire supply chain, the efficient digital connection process and data exchange between companies to support more sustainable practices. Thus, firms need to learn how to combine their processes and software in a way that would help them to share information, knowledge and innovations between them. Only together can the greatest benefits be achieved. However, it is easier said than done, since many companies appear to have preconceptions about the transparent integration and information sharing. This research tries to help managers to see the opportunities of digitalization in improving sustainability. The goal is to create a model that connects sustainability and digitalization, which then offers people in managerial positions a concrete framework that can be used to truly obtain sustainability benefits via digitalization and information sharing.

1.3 Research gap

This thesis utilizes systematic literature review, which revealed that there seems to be a lack of studies in the field of digital sustainable supply chain. Also, the knowledge inside the companies about the concepts, but also willingness to invest in them appears to be scarce. Melander and Pazirandeh (2019) noted that firms often struggle with finding the optimal solution to implement digitalization into their processes. One possible reason for this is presented by Beier et al. (2018) who in their study found out that approximately only a fifth of the companies asked, were willing to digitally involve their suppliers into the supply

chain. For example Kamble, Gunasekaran, and Gawankar (2020) concluded that there is a demand to form a better understanding on how a digitally driven environment can help firms to perform more sustainably. However, some studies investigating sustainability and digitalization together, have begun to emerge.

Liu, Chen and Liu (2020) conducted a literature review about the relationship between big data analytics, which is one key technologies of digitalization, and sustainability and found out that over 80% of the papers were published within the past three years. They also summarized that the field is in its infancy and it lacks comprehensive knowledge about how digitalization could enable sustainability. This argument is shared also, for example, by Esmaeilian, Sarkis, Lewis, and Behdad (2020) who pointed out that researchers have mostly focused on how digitalization can solve needs related to sustainability instead of focusing on the ways how digitalization actually influences sustainability in the companies. Also, of the previous studies only few show the connection between digitalization and sustainability (Bai, Dallasega, Orzes & Sarkis, 2020), or what is the actual digitalization mechanism that leads to supply chain sustainability (Bag et al., 2018). So, in line with Liu et al. (2020); Esmaeilian et al. (2020); Bai et al. (2020); and Bag et al. (2018), but also based on the findings from the conducted systematic literature review, this research aims to provide information on to this gap. More specifically, the research gap to which this thesis aims to add, is: *How the digitalization leads to sustainability and what is the actual element through which the impact is realized?* So, the purpose is to identify the components through which digitalization has most effect on sustainability in companies and supply chains. The Figure *1* visualizes the gap this study aims to contribute on.

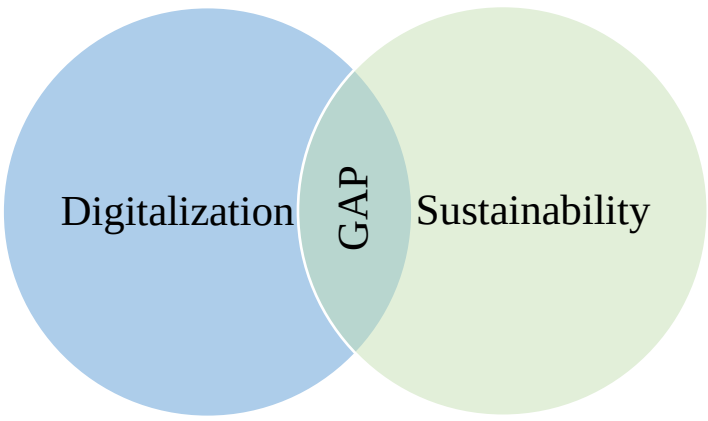

Figure 1. The research gap of the thesis

1.4 Research method

This research was conducted by utilizing quantitative method. First a systematic literature review (SLR) was done in order to get an overview on the current situation of the research field in question. The results from SLR helped to formulate the research gap and objectives and served as a starting point for data collection. The data was gathered with a survey instrument from Finnish companies and it resulted 147 answers from variety of industries. These results were then analyzed using a smartPLS software and PLS-SEM path model.

1.5 Conceptual framework

The theoretical foundation of this thesis is threefold: Firstly, it draws from the sustainable supply chain management (SSCM) literature. The competition doesn't occur anymore between single companies but between groups of companies. Simultaneously, the increased public pressure forces them to pay more attention to the sustainability of their actions. In essence, SSCM is the integration of environmental, social and economic pillars of sustainability, allowing firms to achieve long-term economic benefits in the whole network without compromising the nature or the people (Tseng, Wu, Lin & Liao, 2008). Secondly, this research draws from dynamic capability view (DCV) which argues that in order to obtain long-lasting competitive edge, organizations must acquire or create capabilities that are dynamic in nature, i.e. they can be used to create, modify and extend existing resources in order to fulfil the objectives and purpose of the organization (Ambrosini, Bowman & Collier, 2009). And thirdly, this study relies on the existing literature about the digitalization and the digital technologies, and their connection with sustainability. This research field is scarce, but some initial papers have emerged that have studied the relationship.

1.6 Structure

Next, the theoretical concepts, briefly mentioned in previous section, are described more thoroughly. After that, the SLR-process is presented, and then the research gap and questions are formulated. Chapter five describes the methodology used and describes the achieved results. In the following chapter, the results are discussed and mirrored to the existing literature. Finally, the last chapter concludes the study and provides the final remarks as well as pathways for future researchers. Figure *2* visualizes the research structure.

Figure 2. Structure of the thesis

2 THEORETICAL BACKGROUND

This thesis aims to show the connection from various information technologies to sustainability of supply chains. This happens via big data analytics and information sharing, which are seen as organizational capabilities. Thus, the main theoretical foundation of this study is dynamic capability view (DCV) in sustainable supply chain management (SSCM) context. Next, the earlier research is reviewed broadly on the mentioned topics.

2.1 Sustainable supply chain

This chapter has two themes. First it describes and defines supply chain management and sustainability separately, after which the combination of these two is discussed. The constantly increasing media presence and tightening legal restrictions have made companies' processes more transparent, thus allowing customers to evaluate the standards which organizations use when holding suppliers and their suppliers accountable (Ehrgott, Reimann, Kaufmann, & Carter, 2011). In order to monitor the supplier network, which is often complex and global, they have, for example, begun to conduct regular auditing (Ferreira, Silva & Azevedo, 2016). In recent years, more and more companies have adopted sustainability measures into their supply chains.

2.1.1 Supply chain management

It is no longer the case that the same company mines metals and sells the car to the customer. Increasingly, companies are specializing in one section of the product's life cycle. This change calls for cooperation between the companies, i.e. in the supply chain. Supply chain (SC) includes the activities and processes related to the flow and transformation of products from raw materials to the consumption, as well as the related information flows (Handfield & Nichols, 1999). More specifically, SC consists of sourcing the raw materials, refining those into semi-finished and finished goods, and then storing, tracking and delivering those products for the end customers (Hervani, Helms & Sarkis, 2005). Supply chains can be interpreted from different perspectives. New (1997) posited that the two most commonly used view-points are to look the SC from the perspective of a certain company or a certain product. The structure of a supply chain includes external suppliers, internal processes and functions and external distributors and customers, and there is no limit on how many SCs a

company can simultaneously belong to (Hervani et al., 2005). However, the name supply chain may be slightly misleading as the companies cooperate with more companies than with just the next link in the chain (Lambert & Cooper, 2000).

The competitive landscape has changed and now it is not single companies that are competing but larger supply chains (Min & Zhou, 2002). The Figure 3 presents a simplified supply chain structure. The suppliers include all tiers from the point of origin to the manufacturer, who in this case is the focal company actually assembling the final product. The internal processes related to this phase of the process are, for example, purchasing, logistics and production. Then, the finished products are given to external distributors and retailers who deliver them for the paying customers. The arrows represent the flows in SC. As different products move from the supplier to the customer, cash flows the other way. Information flow, on the other hand, is omnipresent as all the members in the network share knowledge with each other. The coordination and management of this complex network is called Supply Chain Management (SCM) (Hervani et al., 2005).

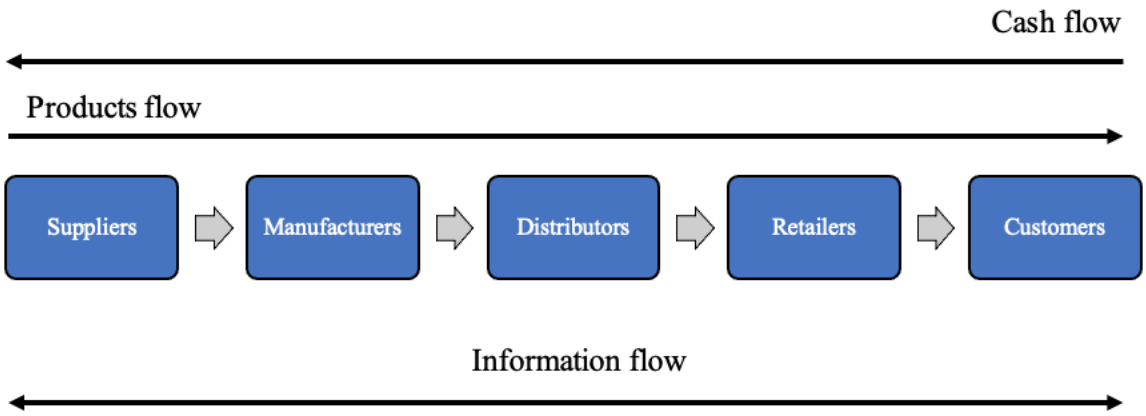

Figure 3. Supply chain process. (Adapted from Min & Zhou, 2002)

Nowadays, supply chains form naturally to connect the customers' need with the resources but SCM don't necessarily exist in the SCs (Diniz & Fabbe-Costes, 2007). The difference between these two is that in SCM, in order to create joint value, the members cooperate to integrate the processes, flows and systems (Fabbe-Costes & Jahre, 2006). Seuring and Müller (2007) discussed about the phenomenon and named it as integrated chain management, which is comprised of two dimensions: flow of materials and information and strategy and partnership of the organizations in the supply chain. They continue and define

supply chain management (SCM) as an philosophy that, by integrating the beforementioned SC elements and with improved relationships throughout the whole SC, aims to achieve competitive advantage for everyone involved in the supply network. So, as the success of a company is no longer solely based on their own actions and decisions but on the whole supply chain's, the company's ability to manage, integrate and coordinate its common processes (Lambert & Cooper, 2000). The supply chain must be managed as an entity rather than multiple separate units. This includes integrating processes across other companies in the SC.

In 2000 Lambert and Cooper designed a SCM framework that presented eight macro-business processes which need to be integrated and managed in a centralized way by cross-functional teams. Later, the developed model was updated (Lambert, 2014) after which these eight business processes reached their current names (Figure 4): Customer relationship management, Supplier relationship management, Customer service management, Demand management, Order fulfillment, Manufacturing flow management, Product development and commercialization and, lastly, Returns management. All these dimensions must be managed throughout the SCM process in order to obtain the possible benefits. However, it is often not possible to integrate or manage these processes end-to-end (Lambert & Cooper, 2000). Organizations must allocate their resources, which are often limited, in a way that they produce the maximal benefits. To conclude, SCM is the process of controlling, implementing, integrating, planning and managing operations in the supply chain in an effective way (Melo, Nickel & Saldanha da Gama, 2009) that have a chance to result in competitive advantages by adding value to the customers or by reducing costs throughout the SC (Cooper, Ellram, Gardner & Hanks, 1997).

As mentioned in previous chapter, the sustainability is not only issue for the focal company, even though it often takes the fall for possible wrongdoings. It must take care of its suppliers and the whole supply chain in a holistic way. By managing the whole network as a whole, it is easier to achieve the set goals and objectives. The globalizing world requires firms to work together in order to reach their objectives. This applies to everything but is increasingly true when it comes to sustainability. If the designated sustainability goals are desired to be reached, the companies along the same SC must implement ways and processes to reach higher level of cooperation and integration between them (Seuring & Müller, 2008). If the

cooperation is not working as flawlessly as intended and a lower-tier supplier conducts a sustainability violation, the biggest impact is often directed to buying companies, the ones being closest to the customer (Darnall & Edwards, 2006).

The cooperation between members in supply chain is one of the main focus areas in sustainability (Kamble, Gunasekaran & Gawankar, 2020). To mitigate the possibility of bad publicity, organizations should pay close attention to the procedures which they use when, for example, selecting suppliers (Rezaei, Nispeling, Sarkis, & Tavasszy, 2016). The suppliers are the core of the supply chain and therefore it is not reasonable to treat them disrespectfully. Sustainability being a core for businesses today, the extension for SCM is called Sustainable Supply Chain Management (SSCM).

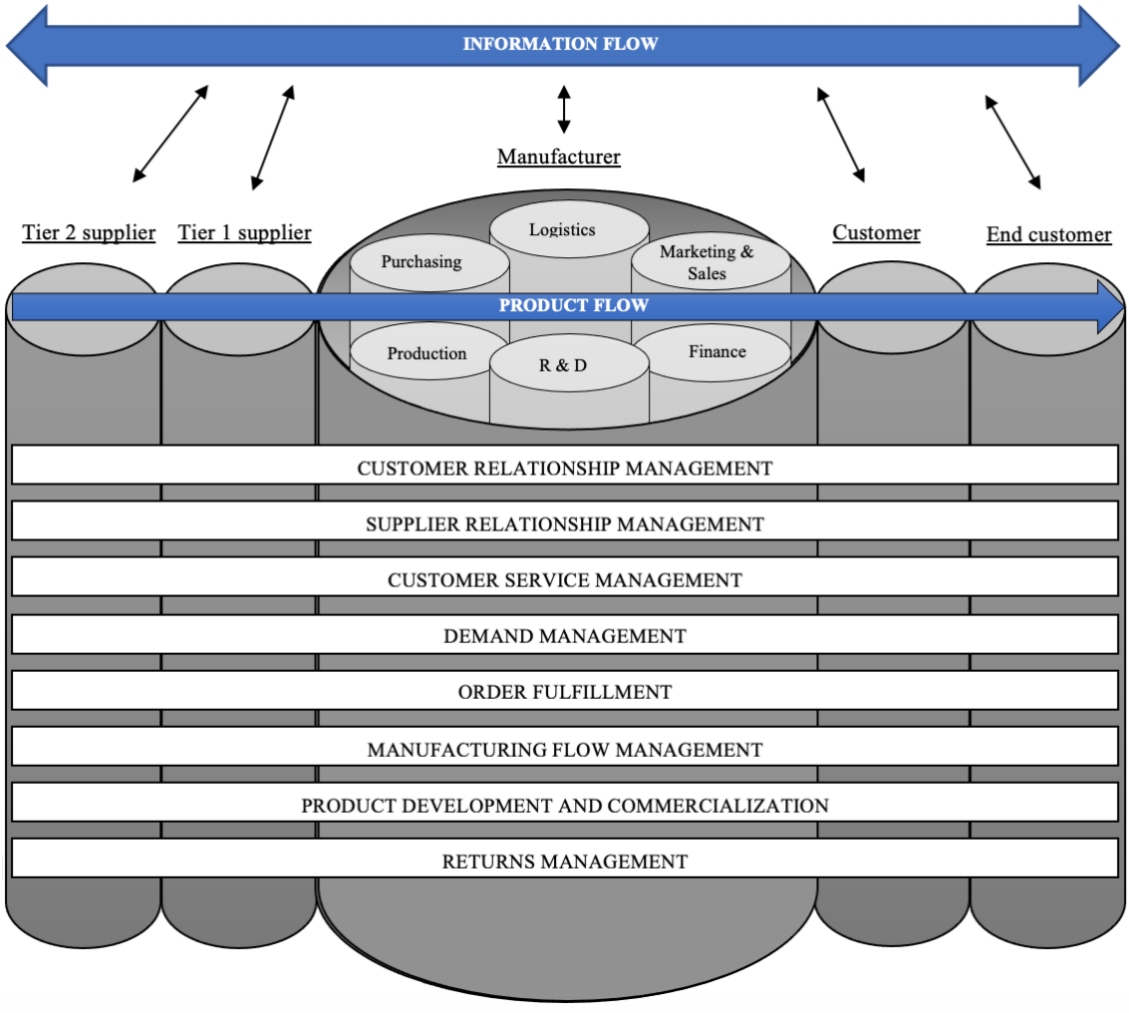

Figure 4. Supply Chain Management Framework. (Lambert, 2014).

2.1.2 Sustainability

Sustainability has become one of the hot topics of the 21st century. Even though being a familiar word for almost everyone, the meaning of the term sustainability is not straightforward. The first definition was presented in 1987 by WCED who introduced sustainability as a concept that ensures the needs of today in a way that won't endanger the tomorrow's generations ability to do the same (WCED, 1987). Traditionally, the financial aspect has been the most important for companies' and for their stakeholders. The competition between businesses is fiercer than ever before but aiming solely for higher profits may cause problems in the long run, which is why companies have started to pay attention into other aspects than only economical (Jeble, Dubey, Childe, Papadopoulos, Roubaud & Prakash, 2018). This thinking has its grounds in the Triple Bottom Line (TBL) developed by Elkington in 1998 who argued that in addition to maximizing profits, it is as equally important to include social and environmental sustainability goals into business strategies. Tseng, Lim and Wong (2015) noted that the interpretations for sustainability have been varying from inter-generational philosophical position (e.g. WCED, 1987) to a multi-dimensional term for business management (e.g. TBL).

The TBL-model consists of three main dimensions of sustainability: economic, social and environmental. The Figure *5* illustrates this sustainability framework. After the introduction by WCED and the groundbreaking work by Elkington, sustainability has since become a trend amongst many organizations and companies world-wide, as it makes it possible for them to tightly integrate environmental and social issues with their already existing corporate strategies (Srivastava, 2007). The reason for this change stems from many sources. Some companies have started to worry about the more common occurrence of extreme weather events, such as heat waves, floods or wildfires, which pose a serious threat for our environment (Winston, 2014). The increased use of social media and other technologies that accelerate and ease the communication have improved the overall awareness about social issues, resulting in some companies starting to gather and publish social responsibility reports (Wu & Pagell, 2011). The external pressure from the stakeholders towards the companies has also increased, forcing the organizations to react and address sustainability issues with a broader approach (Bai & Sarkis, 2010). This would mean adding social and environmental measures and not relying only on financial measures.

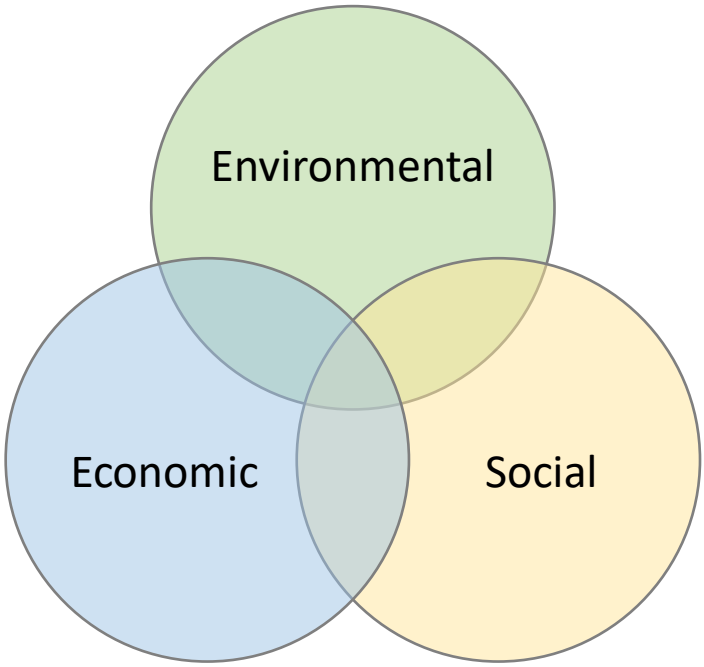

Figure 5. TBL-model. Elkington (1998)

In the Elkington's (1998) model, social sustainability is named as People, which refers to the fact that the issues in this section consider the well-being of the people. More common social matters are salaries, benefits, child and forced labor, harassment in work, working hours and overall conditions (Huq, Stevenson & Zorzini, 2014). On a general level, it contains the management of human and societal capital (Sarkis, Helms & Hervani, 2010). Sloan (2010) adds to that and describes social sustainability as actions which aim to form and maintain fair and healthy relationship with labor and surrounding communities or regions. Labuschagne, Brent, and Claasen (2005) categorized the social sustainability issues into four class: 1) Internal Human Resources, which refers to the company's own employees, 2) External population, which refers to the surrounding community, 3) Stakeholder Participation, which refers to effective communication for various stakeholder groups, and 4) Macro Social Performance Issues, which refers to greater infrastructural innovations. Aspects that reach beyond traditional issues such as cost, quality or financial performance, have started to gain attraction from regulators, customers, investors, and the public (Klassen & Vereecke, 2012). In addition, companies are not only interested in their reputation or brand image but are aiming for bigger benefits (McKenzie, 2004). On a company level, social sustainability indicates that organizations add value to the environments and communities in which they operate by growing the human capital of their employees and the societal capital of the surrounding communities (Dyllick & Hockerts, 2002).

According to Huq et al. (2014) social sustainability is not separable from the other TBL dimensions, deals with topics considering both internal and external stakeholders and attempts to create long-lasting benefits for all. Their first point is agreed by Longoni and Cagliano (2015) who noted than when implemented together with traditional strategies, social goals have possibility to expand and enrich them. According to McKenzie (2004), social sustainability actions aim to actively create and preserve skills and capabilities for current and future generations, promote health an supporting equality which enables for good life conditions both inside and outside of the organizational environment. These actions must reach the firm's suppliers, downstream distributors, end users, in-house operations and customers (Klassen & Vereecke, 2012). Social sustainability actions can be implemented with, for example, company's own practices or code of conduct, audits or supplier development programs (Huq, et al., 2014).

The most traditional dimension of sustainability is the environmental dimension (Pimenta & Ball, 2015). Customers globally are becoming more and more environmentally aware and have begun to demand for products with better environmental sustainability (Kremer, Haapala, Murat, Chinnam, Kim, Monplaisir, & Lei, 2016). At the same time, governments, environmental regulators and other policy makers are increasingly implementing new rules and laws that reshape the way of doing business (Gutowski, Murphy, Allen, Bauer, Bras, Piwonka, Sheng, Sutherland, Thurston, & Wolff, 2005). Companies have been forced to react in order to satisfy the customers and obey the laws. Thus, since many decades, companies have aimed to assess the environmental impact of any new project (Khosravi, Jha-Thakur, & Fischer, 2019). One of the more commonly used measures for environmental sustainability is the carbon footprint. Even though being rather simplified method and having its limitations, it is and important metric and can offer valuable information about the sustainability of assessed object (Kremer et al., 2016). In response to the increased awareness and pressure to reduce the environmental impacts at local and global scale, companies have started to adopt programs aiming at implementing ways to manage waste and pollution (Eltayeb, Zailani, & Ramayah, 2011).

Environmental sustainability is not a separate construct, but it must work together with other elements of the business. The primary objective of environmental sustainability enhancing initiatives is to, of course, improve the environmental performance, but in a way that won't

compromise the productivity or other fundamental aspects of a successful business (Bocken. Morgan & Evans, 2013; Parajuli, Thom & Matlock, 2019). There are multiple ways to try to achieve this. Good results can be accomplished by changing materials from unrenewable to renewable sources and using these materials efficiently (Goodland & Daly, 1996). In addition, by reducing various wastes, emissions, unnecessary use of resources or consumption of toxic and hazardous materials the harms can be mitigated (Geyer & Jackson, 2004; Zhu & Sarkis, 2004). For example Govindan, Kannan, Mathiyazhagan, Jabbour and Jabbour (2013) showed that environmental damage can be limited with the use of renewable energy sources such as wind, solar, geothermal or biomass.

Even though social and environmental issues gather the most publicity when it comes to sustainability, one cannot forget the economic pillar of the model. The financial continuity is the fundament for any sustainable company. Only after having stable economic grounds, can an organization begin to think about the other aspects of sustainability as well. In essence, economic sustainability is used to measure the profitability of a firm (Niu, Mu, Chen, & Lee, 2019). As financial performance is the key for every business and its success, it has gained a lot of attention. Over the years, some of the most used and established measures for financial performance of supply chains have been return on assets, assets turnover, return on investment, profit margin, market share, economic value added and inventory turnover (Galankashi & Rafiei, 2021). Traditionally, the measuring has focused on cost (Lawton & Solomko, 2005) but the importance to move away from basic monetary measures to nonfinancial measures has been acknowledged as well (Hernaus, Bach, & Vuksic, 2012).

As mentioned, the dimensions of the TBL-model are not separate but work together. For example, implementation of an initiative aiming at improving environmental dimension may at the same time result in upgrades in social and economic areas as well (e.g. Kusi-Sarpong, Gupta & Sarkis, 2019; Ansari & Kant, 2017). However, the dimensions may also have opposite results with each other. The most common conflict is between the economic and the other two. There often is a need to balance with the trade-off between financial and environmental aspects in a company, as the cheaper solutions tend to be less environmentally or socially friendly (Lin & Tseng, 2016). So, the sustainability is a complex problem with multiple sides to consider. There is no consensus on what the optimal solution is or how to

best mitigate the negative impacts. Furthermore, the sustainability effects won't be limited just to the company that is closest to the customer. However, Seuring and Müller (2008) pointed out that it is often the focal company that is held responsible for the environmental or social wrongdoings of the suppliers. Organizations must pay increasingly more attention to the whole supplier network that is required to manufacture the products they sell. That is required in order to prevent the negative consequences stemming from the actions of lower level suppliers. Focal company must be up to date on what is happening with their suppliers.

2.1.3 Sustainability in supply chain management

The literature on sustainable supply chain management (SSCM) is abundant, and many comprehensive reviews have been conducted (e.g. Seuring, Sarkis, Muller & Rao, 2008; Gupta and Palsule-Desai, 2011). Instead of concentrating only on economic matters like SCM, SSCM assesses and considers environmental and social topics as well (Badiezadeh, Saen & Samavati, 2018). Seuring and Müller (2007) defined SSCM as: "*the management of material, information and capital flows, as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e. economic, environmental and social aspects, into account which are derived from customer and stakeholder requirements"*. In essence, SSCM is the integration of environmental, social and economic pillars of sustainability, allowing firms to achieve long-term economic benefits in the whole network without compromising the nature or the people (Tseng, Wu, Lin & Liao, 2008). Additionally, according to Brandenburg, Govindan, Sarkis and Seuring (2014), SSCM also contains the transportation and storing of sustainable raw materials and finished goods from the source to a point of consumption.

Traditionally, the preliminary initiatives to focus on sustainability in supply chains tended to focus mainly on environmental issues, but as time has passed, companies have increasingly begun adopting approaches that take the other dimensions into account as well (Tseng, Lim & Wong, 2015). The economic dimension remains central and the other two, environmental and social, extend the sustainability considerations further (Tseng, 2013). During the 2000s, SSCM has formed to be the most feasible way for organizations to reduce the pollution and wastes from their production processes (Bojarski, Laínez, Espuña & Puigjaner, 2009). In addition to integrating systems vertically, companies are establishing

cross-industry networks that enable them to set up interconnected supply chains in which resources are used recycling and reusing in mind (Tseng, Tan, Chiu, Chien & Kuo, 2018).

Even though the objective is great and if successful, it offers remarkable sustainability benefits, the design and implementation of SSCM is often more difficult than what it sounds. For example, (Pagell & Shevchenko, 2014) argued that implementing SSCM may causes considerable pressure for the organizations in SC to change their behavior, resulting in not as great or even negative outcome. Despite the three-way beneficial link between economic, environmental and social sustainability being well researched, some companies are still hesitant to implement SSCM practices as they believe that would weaken their financial position (Ahmed & Najmi, 2018). Besides the right attitude, successful implementation of SSCM requires suitable guidelines (Zhang, Yu & Zhang, 2020), appropriate SC design (Del Giudice, Chierici, Mazzucchelli & Fiano, 2020), and use, acquiring and elaboration of adequate knowledge and information (Gupta, Chen, Hazen, Kaur & Santibañez Gonzalez, 2019).

Companies must be able to recognize the challenges and required tools to overcome them. SSCM has a potential to ultimately result in win-win situation between economic and environmental elements (Kumar & Chandrakar, 2012). So, sustainability is achievable only when managed in a right way. Also, the cooperation between various member in the supply chain is in key role when aiming for better sustainability performance. As companies are competing in groups, against other groups, i.e. supply chains versus supply chains, it is no longer sufficient to focus exclusively on own actions. A more comprehensive perspective is needed in order to succeed. In addition, the changing business environment complicates processes and brings new requirements. The currently ongoing industrial revolution and rapid shift towards total digitalization of the business processes poses challenges for the supply chains, as the traditional SC and sustainability practices cannot be adapted anymore (Bocken, Boons & Baldassarre, 2019). Companies must seek new skills and capabilities if they want to obtain sustainability benefits throughout their complete supply chains.

2.2 Dynamic capabilities view

Barney (1991) argued that the source of a firm's competitive advantage lies in its possessed resources and capabilities. He further added that these resources could be seen as bundles of tangible and intangible assets that should be valuable, rare, hard to copy and not substitutable, in order for them to provide advantage over competitors. This is shared by Grant (1991) who posited that by combining the various strategic resources, organizations may be able to create capabilities that are difficult to imitate. This perspective is called as Resource based view (RBV) that sees organizations as a set of unique tangible and intangible resources and tries to explain why one company outperforms another one (Barney, 1991). This theory is, however, often criticized as too simple and static. To counter this, Teece and Pisano (1994) presented Dynamic capabilities (DC), which, *"allow the firm to create new products and processes and respond to changing market circumstances"*. This ability is getting more and more important for the companies as the world is becoming increasingly complex and constantly changing.

Furthermore, the definition of DCs was later extended to the organization's ability to build, integrate and reconfigure both internal and external resources to prepare for the rapidly altering business environment (Teece, Pisano & Shuen, 1997). Dynamic capabilities are not valuable as such. The significance stems from their ability to create second tier capabilities and thus being the actual channel for organizations to systematically pursue for improved efficiency and long-lasting competitive advantage (Zollo & Winter, 2002). Afterwards, DCs are defined as an organizational capability to create, modify and extend existing resources in order to fulfil the objectives and purpose (Ambrosini, Bowman & Collier, 2009). The DCs are not abundantly available nor are they easy to manage once successfully created.

Focus of the managers is required to generate appropriate strategy and to allocate existing resources if building dynamic capabilities and when aiming to address the changing customer preferences in dynamic environment (Teece, 2014). That active involvement is also needed when further developing and integrating existing resources with other resources, which is made possible by the dynamic capabilities (Bag, Wood, Xu, Dhamija & Kayikci, 2020). This creates a loop, in which dynamic capabilities help in creating more dynamic capabilities, thus ensuring the competitive advantage. However, this situation does not maintain itself but requires the constant attention, as mentioned. The Dynamic capabilities

view (DCV) suggests that organizations handle change in their environment by proactively planning and deploying various capabilities and resources (Mandal, 2008). Additionally, DCs assist in realigning resources and capabilities in order to positively respond to the environmental changes and to sustain performance (Braganza, Brooks, Nepelski, Ali & Moro, 2017). Also, dynamic capabilities are in critical position when companies are balancing between exploitation and exploration (Villar, Alegre & Pla-Barber, 2014). Exploitation means efficiency, productivity increases, control, certainty and reducing variance in existing processes, whereas exploration indicates searching, discovering, embracing variation and innovating new business opportunities (O'Reilly & Tushman, 2008). So, firms need to acquire dynamic capabilities which enable simultaneous exploitation and exploration and, thus a sustainable competitive advantage.

DCs come in various shapes and there is no single right way or the best capability available. This thesis applies the DCV and explains how Big data analytics and Information sharing practices can be seen as dynamic capabilities in supply chains. These DCs are helping supply chains becoming more sustainable. The Big data analytics capability (section 2.3.4) and Information sharing capability (2.4) are discussed in later sections.

2.3 Industry 4.0

The term Industry 4.0 was first introduced to public via a project by German government in which they aimed for more computerized manufacturing (Sung, 2018). Industry 4.0 combines traditional manufacturing and physical factories with the emerging communication, information and intelligence technologies (Wang, Ma, Yang & Wang, 2017). These emerging novel technologies possess a potential to shape our world and businesses that is so enormous it has been referred as the fourth industrial revolution (e.g. Morrar, Arman & Mousa, 2017 and Bai et al., 2020). In the same way as steam power, electricity and the emergence of information technology before, digitalization is causing radical changes in multiple areas while also enabling unparalleled possibilities for value creation. Many companies and even countries have recently adopted new strategies relying on digitalization (Bag, Telukdarie, Pretorius & Gupta, 2018). According to Wang, Wan, Zhang, Li, and Zhang (2016), industry 4.0's roots lie in smart manufacturing, which refers to manufacturing systems that are able to flexible adapt their production processes based on

changing conditions. This then leads to, for example, improved quality, productivity or sustainability (Dalenogare, Benitez, Ayala & Frank, 2018). Other key aspects of industry 4.0 are, for example, information sharing, supply chain integration and production synchronization with suppliers (Ivanov, Dolgui, Sokolov, Werner & Ivanova, (2016).

Among others, Esmaeilian et al. (2020) see industry 4.0 as an umbrella term that includes all the various digital technologies as well as their connections with already used technologies and with each other. Industry 4.0 can be a confusing concept as it is often used in different contexts. Some see it as an umbrella term, whereas other see it as a part of something else. As already mentioned in 1.2, the definitions of industry 4.0 and digitalization are not completely established. Despite the varying definitions and characteristics that are assigned to industry 4.0, Kagermann (2015) found some similarities in them; the aim is not solely to integrate existing manufacturing systems with improved data gathering technologies, but also to with solutions that lead to value creation and service innovation. In order to actually concretize, industry 4.0 needs tools through which the implementation takes place. These digital technologies must be managed with strategy and clear vision in order to achieve the benefits of industry 4.0.

2.3.1 Digital technologies

The digitalization of business practices happens through digital technologies and such tools have started to emerge and evolve during the recent years. By nature, "digital technologies are a ubiquitous phenomenon" which are challenging the current world-order and changing our existing habits and routines of how we live and consume (Parida & Wincent, 2019). According to Liao, Deschamps, Loures and Ramos (2017) digital technologies mainly mean modern innovations that are designed to ease information exchange and communication between entities. The various digital technologies have a common goal: to find solutions for existing business challenges, i.e., fierce competition, volatile demand, increased necessity for customization or demand for more sustainable consumption (Kiel, Müller, Arnold & Voigt, 2017). Digital technologies include, but are not limited to, industrial internet of Things (IIoT), cloud platforms and technologies, blockchain, big data analytics, and artificial intelligence (AI) (Bai et al., 2020). These technologies are defined shortly in Table *1* and are discussed more a bit later.

Table 1. Definitions for digital technologies. (Bai et al., 2020)

Technology	Definition
Artificial intelligence	is an area of computer science that emphasizes the creation of intelligent machines that work and react like humans.
Big data analytics	refers to the strategy of analyzing large volumes of data that are used when traditional data mining and handling techniques cannot uncover the insights and meaning of the underlying data.
Blockchain	is a distributed database that maintains a completely, distributed and non-tampering continuously growing list of records using new encryption and authentication technology and network-wide consensus mechanism.
Industrial internet of things	is the various sets of hardware pieces that work together through internet of things connectivity to help enhance manufacturing and industrial processes.

In addition, Frank, Dalenogare and Ayala (2019) divided digital technologies into two: base technologies and front-end technologies. In their framework base technologies (i.e. cloud and big data etc.) provide the basis and intelligence for the front-end technologies which are smart manufacturing, smart supply chain, smart working and smart product, the first being the central dimension. This study focuses on smart supply chain. This refers to the technologies which aim to integrate external suppliers with the focal company i.e. supply chain platforms (more in section 2.3.3). Figure *6* visualizes this setting.

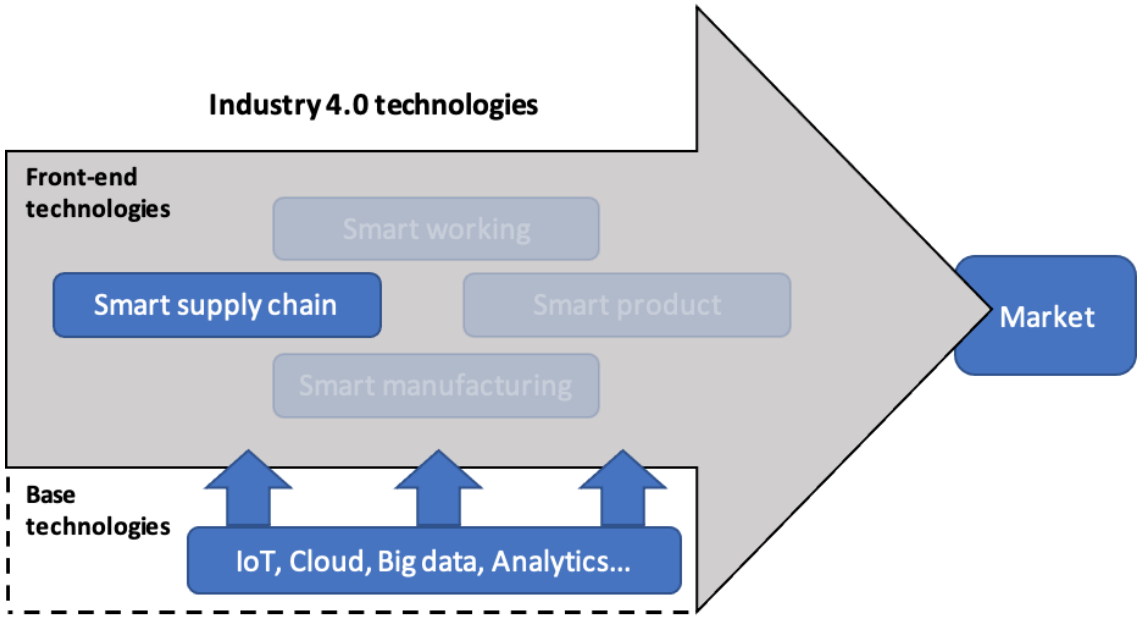

Figure 6. Industry 4.0 technologies categorization. Adapted from Frank et al., (2019).

Gobbo et al. (2018) noted the possibility of digital technologies to be a major contributor in information gathering. Papadonikolaki (2019) added to this and argued that digital technologies are information driven instruments for regulating and structuring the complex supply chain information. Digital technologies are offering constantly higher production efficiencies, while at the same time having a potential to improve social and environmental sustainability through, for example, green product design which leads to minimize the consumption of natural resources in the whole supply chain (Li et al., 2020). For social aspect of sustainability, digital technologies may help by removing monotonous and repetitive tasks, thus resulting in better motivation and satisfaction (Müller, Kiel & Voigt, 2018). Next, the impact of the mentioned technologies on 1) sustainability and 2) supply chain is briefly discussed.

2.3.2 Impact of digital technologies

Artificial intelligence (AI) is not a new technique nor a new discipline. People have been able to use it, in some ways, already for over 50 years but it has alternately been in and out of fashion (Jarek & Mazurek, 2019). However, only recently the technological developments have made it possible to truly capitalize the benefits of AI (Min, 2010). Commonly, AI is defined as the machine's capability to imitate the human actions and then communicate them

with the humans (Schutzer, 1990). In addition to the increasing enthusiasm in companies about the AI, also scholars have growing interest into the topic and one of the most prominent one seems to be supply chain management (Toorajipour, Sohrabpour, Nazarpour, Oghazi, & Fischl, 2021). Artificial intelligence is not just one single method. It includes various different techniques for solving the problems. Some of the most used techniques are artificial neural networks, which are usually based on mathematical regression, mimic human brain and are good in pattern recognition (Yang & Chen, 2015) and genetic algorithms which tries to mirror the natural selection (Kraft, Petry, Buckles, & Sadasivan, 1997). In their literature review Toorajipour et al. (2021) identified some supply chain areas in which AI has shown potential for applications; sales and demand forecasting, pricing, customer segmentation, supplier selection, etc. Whereas those are generally connected with the economic aspect of the sustainability, AI can enhance the other dimensions as well. AI presents a significant chance to leverage software and hardware for new ways of structuring supply chains to reduce the use of raw material and emissions, or it can be used to conduct dangerous or boring tasks, thus improving the social aspect and leading to a more environmentally friendly future (Nishant, Kennedy & Corbett, 2020). In addition, AI has been used in supply chain context, for example, in supplier sustainability (Jabbarzadeh, Fahimnia, & Sabouhi, 2018) or in sustainable supply chain management system (Dumitrascu, Dumitrascu & Dobrota, 2020).

Blockchain first showed up as a tool for cryptocurrency management. Recently it has started to find foothold in other areas as well, such as in healthcare, real estate or energy markets (Athey, Parashkevov, Sarukkai, & Xia, 2016). Blockchain is a "distributed data structure", i.e. ledger, in which the information is transferred in a peer-to-peer network, which consists of blocks (e.g. transaction or file of data) embedded with identification hash that links is to a previous block (Esmaeilian et al., 2020). In order to be added as a new member of the chain, each block must be verified by the earlier blocks of the chain (Casado-Vara, Prieto, De la Prieta & Corchado, 2018). Also, this hash, or tag, as Abeyratne and Monfared (2016) call it, links the products physical and virtual identity together. Costa, Antonucci, Pallottino, Aguzzi, Sarriá, & Menesatti (2013) argued that traceability is one of the bigger needs for future supply chains. Saberi, Kouhizadeh, Sarkis and Shen (2019) add to this and conclude that also timeliness of the information as well as its security and robustness are challenges for supply chains and offer blockchains as a solution. According to Barton (2018) a typical

blockchain includes four characteristics: shared ledger, permissioning, smart contracts and consensus, all of which aim for increasing transparency of data, security, durability, integrity and trust between partners. Saberi et al. (2019) differentiate blockchain from traditional internet by saying that instead of moving information and copies of things, blockchain moves value and original information.

The main consequence which arises from the use of blockchain is decentralization and the change that there is not a need for a third party intermediator in the network, which increases trust in the relationship (Nofer, Gomber, Hinz & Schiereck, 2017). Blockchain can be used to transfer various product information in the supply chain, for example, about the nature, quality, quantity, location or the ownership of the product (Saberi et al., 2019). Furthermore, blockchain technology has some direct impacts on every sustainability dimension. Social aspect it can better by maintaining a transparent record which assures possible buyers, for example, that a product is actually manufactured as ethically as promised or help companies to identify unethical suppliers (Saberi et al., 2019). On environmental side, blockchain can decrease carbon emissions in production or transportation (de Sousa Jabbour, Chiappetta Jabbour, Sarkis, Gunasekaran, Furlan Matos Alves & Ribeiro, 2018). Financial benefits it offers through the increased transparency which strengthens the customers trust (Saberi et al., 2019) or by providing an effective connection for transactions when using different currencies from multiple and global sources (Eyal, 2017).

Industrial internet of things (IIoT) as a concept first surfaced in 1999, and there is no consensus about the definition of IIoT but according to Haddud, DeSouza, Khare and Lee (2017) it refers to the integration of different physical objects that communicate with each other through internet. The communication happens via RFID technology, meaning microchips that transmit and receive identification information to and from a wireless reader (Da Xu, He, & Li, 2014). Company adopting IIoT can expect improvements in operational processes, risk mitigation, traceability, cost reduction, flexibility and scalability (Zhou, Chong & Ngai, 2015). In addition, IIoT applications have a potential to offer a better transparency and visibility of information (Haddud et al., 2017) which is a great potential for supply chains. De Vass, Shee, Miah (2020) consolidated multiple earlier definitions and formed their definition for supply chain context: internet of things is an internet connected platform which can sense, identify, transfer, network and share information "for timely

planning and coordination of logistics processes" both in a company and between supply chain members.

The use of IIoT applications has led to benefits in, for example, logistics (Yu & Wang, 2016) and manufacturing (Roblek, Meško, & Krapež, 2016). Also, in the area of smart cities, IIoT has been suggested to help in waste collection solutions (Navghane, Killedar & Rohokale, 2016). According to Accorsi, Bortolini, Baruffaldi, Pilati & Ferrari (2017) with the use of IIoT application, the adoption of sustainable supply chain practices becomes easier, and it has a potential to reduce waste, costs, social impacts and emissions, thus having an effect on every dimension of the sustainability. Even though the use of IIoT in the sustainable supply chain context has begun to attract more attention during the most recent years (Manavalan & Jayakrishna, 2019) there is still a great shortage of empirical and exploratory studies on the topic (de Vass et al., 2020).

The fourth industrial revolution has a great potential to affect various ecological, social and financial issues (Morrar et al., 2017). However, digital technologies are not only improvements and happiness for businesses, but they may also lead to challenges as well. Robots may replace human labor, the use of data increases information security issues and new forms of waste, i.e. electronic waste may emerge (Rojko, 2017) and not to mention the amounts of energy these new technologies require. Still, if managed carefully and with strategy, positive outcomes are able to overcome the negative. Supply chains can benefit greatly from the implementation of these technologies.

Most of the advantages offered by digital technologies can be achieved when those tools are used in integrative way. Together the technologies possess bigger possibilities compared to if they are applied separately and without cohesion (Porter and Heppelmann, 2014). In addition to improvements in productivity or sustainability, these technologies generate a massive and varying data sets, which, if integrated with the organizational capabilities help companies to build data-based platforms (Jeble, Dubey Childe, Papadopoulos, Roubaud & Prakash, 2018). This idea is shared by Lee, Bagheri and Kao (2015) who posited that industry 4.0 heavily relies on implementation of digital technologies in order to collect data in real time and to be able to analyze it, and by Li et al. (2020) who concluded that the digital tools are the backbone of company's information processing capabilities, which can help

organizations with their efforts in information sharing (Wu, Rosen, Wang & Schaefer, 2015) or in big data analytics (Li et al., 2020). Thus, the industry 4.0 tools are expected to integrate with each other and with the existing, more traditional technologies. Although, the research in the area of sustainability, industry 4.0 technologies and supply chain management combined is limited, some studies have tackled this interesting issue (Bag et al., 2018). One bigger solution for the topic is suggested to be big data and its use in a analytical manner. This thesis highlights the importance of big data analytics but the benefits of it can be achieved only if the technologies are combined together in order to form efficient platforms.

2.3.3 Supply Chain Platforms

The development of traditional supply chain (SC) methods, as well as emerging technologies are enabling new ways to organize processes in companies. Pettit and Wang (2016) proposed the concept of supply chain platforms as a way to digitally combine the traditional and novel information and communication technologies together. SC platforms are infrastructure that is digitally driven and usually established by the focal company in order to consistently and rapidly exchanging supply chain related data throughout its whole supply network (Rai, Patnayakuni & Seth, 2006). Digitizing all SC processes and activities will help companies to optimize the entire supply chain (Batista, Bourlakis, Smart & Maull, 2018). For example, digitization will result in optimal outputs by removing various wastes and activities that don't create value (Bibby & Dehe, 2018). Additionally, these digital platforms have an ability to enhance integration and transparency between SC members, real-time information sharing and data integrity (Rai et al., 2006). Building platforms like this is no longer something done only by pioneering and experimenting companies. In today's highly global and competitive competition, it has become a necessity to reshape SC activities into a digital form to track the suppliers in real-time (Yadav, Kumar, Luthra, Garza-Reyes, Kumar & Batista, 2020).

The role of digital technologies and industry 4.0 in managing supplier relationships has gained some attention in the earlier research (e.g. Zhou, Chong & Ngai, 2015; Ben-Daya, Hassini & Bahroun, 2019). More recently, Li, Dai and Cui (2020) highlighted the increased information transferring and systems integration due to digitally connecting SC processes. Also, they added that organizations tend to establish digital SC platforms, encompassing processes from raw materials to delivery of final product, in order to reach compatibility

with their customers and suppliers because that is necessity for companies' survival in the competition. It has become a must to build resources that digitally connect own processes with the supplier's or customer's corresponding processes. To achieve that, the company must first possess the basic digital tools for the more complex platforms. Ivanov, Dolgui and Sokolov (2019) noted that companies commonly integrate and configurate the basic digital technologies when establishing digitally enabled infrastructure.

As mentioned in section 2.3.1 (Figure *6*), industry 4.0 technologies can be divided into two; front end technologies and base technologies, which offer the intelligence and connectivity to the former (Frank et al., 2019). Smart supply chains are one of the front end technologies. This implies that the company must first possess the fundamental technologies before it can think about establishing more comprehensive SC platforms. Govindan, Cheng, Mishra and Shukla (2018) posited that the advanced industry 4.0 technologies can be dynamically reconfigured to form a network that is digitally and that can enable improved communication and information exchange in the supply chain. So the technologies together make it possible to establish this digital network. Also, Li et al. (2020) argued that impact of digital technologies is realized through well-structured SC platform. Only once this requirement is met the organization can connect its activities with other members of the supply chain and achieve the desired outcomes (Pfohl, Yahsi & Kurnaz, 2016). In addition to the beforementioned benefits, SC platforms can help organizations achieving various other goals as well.

Digital supply chain platforms enable the gathering, analyzing and transferring of information in a massive scale, as well as improved cooperation and integration (Büyüközkan & Göçer, 2018). Furthermore, this link makes it possible to connect suppliers to the customers (Li et al., 2020), thus simplifying the process and increasing the satisfaction. The actual mechanism advancing this is the capability to access data on-demand and in real-time (Frank et al., 2019). Even though being a massive improvement itself, increased connectivity and information sharing can help achieving firm's sustainability goals as well (Bruque Cámara, Moyano Fuentes & Maqueira Marín, 2015). SC platforms function as a mediator between the digital technologies and company's environmental and social performance (Li et al., 2020). To conclude, first the company must be able to acquire and implement various digitalization technologies. Second it is possible to integrate these

technologies to build SC platforms that integrate both, internal processes, as well as processes with other members in the supply chain. Third, this established connection can be leveraged in collaboration. However, the data that is generated with the digital tools and the platforms formed from them, is often abundant and complex and need further analysis. This topic is addressed next.

2.3.4 Big data

Amount of data increases continuously and rapidly. The digitalization of every possible aspect of businesses, governments and life in general, large data sets are generated and available for use (Dubey, Gunasekaran, Childe, Luo, Wamba, Roubaud & Foropon, 2018) and various organizations have started to utilize the data in their decision making processes during the last decades (Galbraith, 2014). These, often massive data sets are commonly referred as big data (BD). Huang and Chaovalitwongse (2015) saw big data as an umbrella term for any set of data which are large, complex, difficult to store or process with existing methods. Furthermore, big data has been defined primarily by using 5 Vs to describe the nature of it (Wamba, Akter, Edwards, Chopin, & Gnanzou 2015). According to them these 5 Vs are: *Volume* which refers to the large amounts of generated data, *Velocity* which refers to the rate at which new data is generated, *Variety* which highlights the diverse characteristics of the data, i.e., it can be text, numbers, pictures or videos for example, *Veracity*, which refers to the trustworthiness and reliability of the data, and *Value* which refers to the possibilities to gain benefits from the data.

When companies aim for improving their sustainability, they often face the trade-off between the triple-bottom-line dimensions. However, Dubey, Gunasekaran, Childe, Papadopoulos, Luo, Wamba and Roubaud (2019) pointed out that big data can provide prominent advantages in all of the three dimensions simultaneously. For example, with big data it is possible to gain benefits in decision making about resource utilization (Belaud, Prioux, Vialle & Sablayrolles, 2019) or it can help monitoring emission levels or assist in environmental impact measurements (Badiezadeh, Saen & Samavati, 2018). It offers possibilities with social aspect of the sustainability as well. With big data, the transparency and traceability of the supply chains gets higher (Badiezadeh et al., 2018). However, only the access to data is not the way to the success. Currently, companies are gathering and

storing massive amounts of data, generated from various processes of their business, but fail to capitalize the underlying value of it (Singh & El-Kassar, 2019). The actual potential of BD is related to the organizational capability to analyze it with the right tools and manners (Dubey, Gunasekaran, Childe, Papadopoulos, Luo, Wamba and Roubaud, 2019). Only by looking deeper into the data and truly analyzing it, can big data turn into a primary source of responsibility for organizations (Shokouhyar, Seddigh, & Panahifar 2020). So, the companies must obtain big data analytics capabilities.

2.3.5 Big data analytics

Big data alone is worthless. The value comes from the integration with business analytics (BA), i.e. the organizational skills to produce forecasts and statistical information from numbers (Bag, Wood, Xu, Dhamija, & Kayikci, 2020). This comprehensive incorporation of BD and BA is called Big Data Analytics (BDA). BDA is field that combines the knowledge and methods of, for example, computer science, statistics, mathematical models and data science, whose considerable progress during the recent years have made it possible to now analyze BD in real time (Shokouhyar et al., 2020). Furthermore, according to Wamba, Gunasekaran, Akter, Ren, Dubey & Childe (2017) and Jeble, Dubey, Childe, Papadopoulos, Roubaud & Prakash (2018), BDA is an emerging discipline that, with the help of different statistical techniques, algorithms and analytical tools, aims to provide actionable results and patterns from the massive data sets. The whole purpose of this process of turning data into insights is to offer better information for the decision-makers in the organizations (Choi Wallace & Wang, 2018).

In addition to helping in making better decisions, BDA can function as a way to acquire competitive advantage (Bag et al., 2020). Data analytics has three separate levels, all of which require a certain perspective to work as intended (Dubey, Gunasekaran, Childe, Luo, Wamba, Roubaud & Foropon, 2018). Namely, according to Dubey et al. (2018), the levels are: first, and the most preliminary is descriptive analytics which calls for a systematic approach for data capturing and data visualization based on mathematical models, second level is called predictive which aims to develop a theoretical framework based on historical data and to predict the future events, and third, the most advanced level is called prescriptive and on that level the goal is to simulate and possible outcomes by varying the inputs of the

created models and to find the most optimal result for a given problem. In order to success in these endeavors, organizations must have and be able to obtain needed skills and capabilities. Therefore, many researchers have applied the dynamic capability view to explain the BDA and to give guidance how to implement it.

Big data challenges require skills that are highly flexible, efficient and scalable (Sivarajah, Kamal, Irani, & Weerakkody, 2017). As mentioned in section 2.2 dynamic capability view (DCV) describes an organization's ability of combining, building or reallocating both internal and external competences and skills in order to answer to the changing environment, thus it may explain and result in competitive advantage in a dynamic business environment (Teece et al., 1997). Akter, Wamba, Gunasekaran, Dubey, & Childe (2016) applied DCV into BDA context and argued that BDA has potential to create competitive advantage for company what is operating with insufficient transparency. Dubey, Gunasekaran, Childe, Papadopoulos, Luo, Wamba and Roubaud (2019) add to that and present BDA capability as a higher order construct that can, with proper strategic resources and culture, namely technical skills, organizational learning and managerial skills for example, help to improve organization's social and environmental performance. Bag et al, (2020) mentioned BDA management and BDA talent as the most important capabilities for BDA implementation. Shokouhyar et al. (2020) on the other hand divide the needed capabilities into technologies and talent. The technological infrastructure is the key, as they are the backbone for the more sophisticated analytical methods (Raut et al., 2019) i.e., the basic technologies must be adapted, and the SC platforms established before the BDA capabilities can be developed and implemented further. Only after that, practical impacts are achieved.

2.3.6 Big data analytics in supply chain

Analyzing big data has a direct and positive effect on supply chain operations management performance (Gunasekaran, Papadopoulos, Dubey, Wamba, Childe, Hazen, & Akter, 2017). Also, in addition to possibly creating competitive advantage over rivals, BDA systems have a chance to enhance supply chain agility (Côrte-Real & Oliveira, 2016). Hazen and Skipper (2018) argued that BDA significantly upgrades the strategic and operational capabilities in supply chains. These are some basic instances of improvements brought by BDA for the supply chains, but they seem to ignore the sustainability effects. The potentials of BDA in

supply chain are studied in some extent in the earlier research, however, its possibilities in sustainability sector are not as well examined and as Jeble et al. (2018) pointed out, BDA has a substantial effect on supply chain's social and environmental performance as well, and not only on the economical side.

So, there are some existing studies on the topic. For example, BDA can assist companies in the green supplier selection (Singh, Kumari, Malekpoor, & Mishra, 2018), in customer green cooperation (Raut et al., 2019) or in green logistics (Doolun, Ponnambalam & Subramanian, 2018). Furthermore, Kaur and Singh (2018) found that BDA helped in sustainable procurement whereas Dubey, Gunasekaran, Childe, Wamba and Papadopoulos (2016) investigated its impact on sustainable manufacturing. It can be seen that BDA capability is not the final goal for an organization. It, as well as the enabling capabilities (technical, managerial, etc.), are only ways for something else. In addition to the beforementioned benefits, resulting from BDA, Dubey, Gunasekaran, Childe, Luo, Wamba, Roubaud and Foropon (2018) suggested that BDA directly improves interorganizational collaborative performance and information sharing between the members of supply chain. BDA tools will ensure the active participation of the supplier, thus improving the data and knowledge sharing process between them, which will then result in higher levels of cooperation and achieving bigger sustainability targets (Raut et al., 2019). Also, Liu, Chen and Liu (2020) found out that by using BDA, companies can reduce information asynchronization with suppliers, thus improving the information sharing with them and then enhancing environmental collaboration through the whole supply chain.

The beforementioned benefits, which stem from the digital technologies, the combination of these, i.e. supply chain platforms, and from the data being generated and analyzed, are not enough to reach the goals without actively and systematically sharing that gathered information throughout the supply chain. This must happen both up- and downstream. Company's ability and willingness to participate in sharing the information are crucial.

2.4 Information sharing

It is well known that the extent to which members in supply chain share and exchange information to each other, plays a critical role when trying to improve the efficiency of the SC (e.g. Heide & Miner, 1992; Mohr & Spekman, 1994; Walters, 2008). As the competition nowadays is between different supply chains rather than between individual companies, the information sharing between members of the same chain creates advantages compared to the competing chains (Ha, Park, & Cho, 2011; Li & Lin, 2006). Barratt and Oke (2007) argued that by tightly connecting supply chain members and enforcing information sharing, higher supply chain visibility is obtainable. The successful adoption of information sharing practices requires trust, integration of humans and willingness to share risks and benefits (Fantini, Pinzone & Taisch, 2020). However, when it comes to industry 4.0 context, the research on information sharing is scarce (Müller, Veile & Voigt, 2020). The digital environment sets some requirements, but it also enables greater improvements if addressed in a proper way.

2.4.1 Information sharing and Industry 4.0

The implementation of digitalized information sharing is depended on the already existing IT systems (Kembro, Näslund & Olhager, 2017). Additionally, the variety of data (Hofmann & Rüsch, 2017) and the overall large efforts of adapting information sharing systems (Lusiantoro, Yates, Mena Varga, 2018) may hinder the willingness to participate in information sharing scheme. Organizations need to aim at overcoming these challenges and to combine their systems, processes and activities with other supply chain members. Kim, Cavusgil and Cavusgil (2013) pointed out that the more the technological systems of SC partners are in alignment, the easier it is to implement practices for information sharing and improved collaboration. The closer alignment will also result in better information quality and reduce the implementation costs (Kembro et al., 2017). In general, the industry 4.0 has the potential to increase the transparency and level of information sharing in the whole supply chain (Esmaeilian, Sarkis, Lewis & Behdad, 2020). The transparency is key in modern supply chains that aim for long-lasting improvements.

Consequently, most of the benefits from the combination of industry 4.0 and information sharing are only achievable if full data transparency is obtained across the whole SC (Müller

et al., 2020). These two concepts are a powerful combination for organizations that are seeking to improve their overall performance, not just their financial numbers. Information sharing can help finding issues from the SC and improve the solving process of them. By actively communicating and trying to find more efficient solutions, companies can achieve their goals in economic, but also in sustainability related matters. The research on information sharing in industry 4.0 context being rather limited, its extension to also containing aspects of sustainability are even more scarce.

2.4.2 Information sharing and sustainability

Melander and Pazirandeh (2019) in their study found out that companies that have collaborative practices in place and that share knowledge in digital environment, are capable to improve their environmental sustainability. Additionally, BDA promoted information sharing can ensure the active participation of suppliers and enhances their involvement in sustainable practice implementation (Raut et al., 2019). Tan, Wang, Liu, Kang and Costa (2020) used IoT and big data to generate information, after which blockchain technology was used to share it when developing green logistics methods. Gholizadeh, Fazlollahtabar and Khalilzadeh (2020) utilized big data when optimizing vehicle routing and improving the environmental performance of a supply chain.

As shown in the literature review, there is no abundance of examples that show the connection between information sharing and sustainability in industry 4.0 environment. However, recently some studies have begun to emerge on the field. This is also the gap in which this thesis aims at contributing. Next, all the theoretical concepts presented in this chapter are summarized and a holistic view about the situation about sustainability in a data-driven supply chain is showcased.

2.5 Sustainable data-driven supply chain

Since a few decades, sustainability has been the major force shaping the business environment and how companies reorganize their daily operations and long-term strategies. The increased awareness of the customers and the constantly tightening regulations have made firms to innovate new ways to follow the trend in order to stay competitive. The current era of industry 4.0 is revolutionizing the status quo. In that way it is no different from the

previous industrial revolutions. Just like steam power at the turn of the 18th and 19th centuries, electricity and connectivity at the end of 19th century or information technology at the end of 20th century, the current and fourth industrial revolution stemming from advanced digital technologies is radically creating novel opportunities. However, the ongoing change is different in one significant way. Whereas the earlier revolutions have mainly focused on cost reductions and increasing productivity, the current one can enhance the environmental and social aspects as well (Bag, Telukdarie, Pretorius & Gupta, 2018). As companies are trying to simultaneously improve the structure of their supply chain and achieve sustainability, they have increasingly begun to implement industry 4.0 solutions which has emerged as one of the most prominent solution (Lin, 2018).

However, despite grown interest towards the topic and its possibilities, the research field is still quite immature. Chiappetta Jabbour et al. (2020) found that even though the benefits of combining supply chain and digital technologies are widely recognized, the integration of these concepts with sustainability is still less known. The research on managing supply chain sustainability through data-driven industry 4.0 technologies has been limited (e.g. Shokouhyar, Seddigh & Panahifar, 2020; Bag et al., 2018). Additionally Bag, Gupta and Telukdarie (2018) highlighted the need to develop a framework for supply chain management including all sustainability aspects and digital technologies as enabler. Even though being an emerging phenomenon, the integration of SSCM and industry 4.0 is based on familiar characteristics, which have previously been focused on with the concepts of green and lean (Duarte & Cruz-Machado, 2017). Also, neither the possible benefits are new.

By implementing this integration into the supply chain, a company can achieve more profits, better quality and improved working conditions for their employees (Hofmann & Rüsch, 2017). A concrete example could be factory workers using smart phones for running the operations and communicating (Bag et al., 2018). Also, some actual tools for implementation have started to emerge. CEnAT is an integrative tool that combines various novel industry 4.0 technologies together in a way that enables utilizing the generated information and connect SC operations more effectively to achieve, for example, carbon reductions (Saberi, Kouhizadeh, Sarkis & Shen, 2019).

In order to success in implementing digitalization into the supply chain and achieving sustainability benefits, there are some key things to remember. The underlying individual technologies are an indispensable element to build on (Singh & Teng). These technologies have a crucial role when trying to build comprehensive platforms for information sharing or dynamic capabilities based on them and gradually moving towards a circular and more sustainable economy (Bag, Yadav, Wood, Dhamija & Joshi, 2020). Digitizing the whole supply chain and promoting sustainability while doing so is the path companies are executing currently. The aim is ambitious but obtainable as long as the discussed elements are considered. One cannot assume that by simply implementing one or two solutions that apply some sort of digital approach, the sustainability would increase without further efforts.

This concludes the theoretical background of the thesis. Next, chapter presents the SLR-process.

3 SYSTEMATIC LITERATURE REVIEW

In this chapter the used methodology for analyzing the research field is presented. The reviewing process of the earlier research is a key fundament of any new study. In general, the systematic literature review (SLR) process is an attempt to gain knowledge of the current situation about the topic of the research so that fields for future research are identified (Evangelista, Santoro & Thomas, 2018). Easterby-Smith, Thorpe and Jackson (2008) divided the review process into three phases: 1) to provide knowledge about the already existing research and their findings, 2) to write the SLR in a manner which stays on the theme of the study and describes it comprehensively, and 3) to continuously improve and enhance the process during the whole process. This systematic approach is able to eliminate the problems, which may arise from more subjective methods, and offers a more rigorous and objective results (Evangelista et al., 2018). Thus, the objective of this systematic literature review is to analyze the extant literature on the use of digital technologies in sustainable supply chain environment. More specifically, how these disruptive technologies are used in order to achieve better sustainability performance. Another objective is to identify research gaps in previous research in order to find new direction for future research.

The approach used in this study follows the one used by Evangelista et al. (2018) who combined the works of Tranfield, Denyer and Smart (2003) and Seuring and Müller (2008). Tranfield et al. (2003) suggested a three-phase approach, which was then expanded by Seuring and Müller (2008) who included complementary steps into these three main phases. These phases are Planning, Implementation, and Analysis and results. The whole structure of the SLR process is presented in the Figure 7.

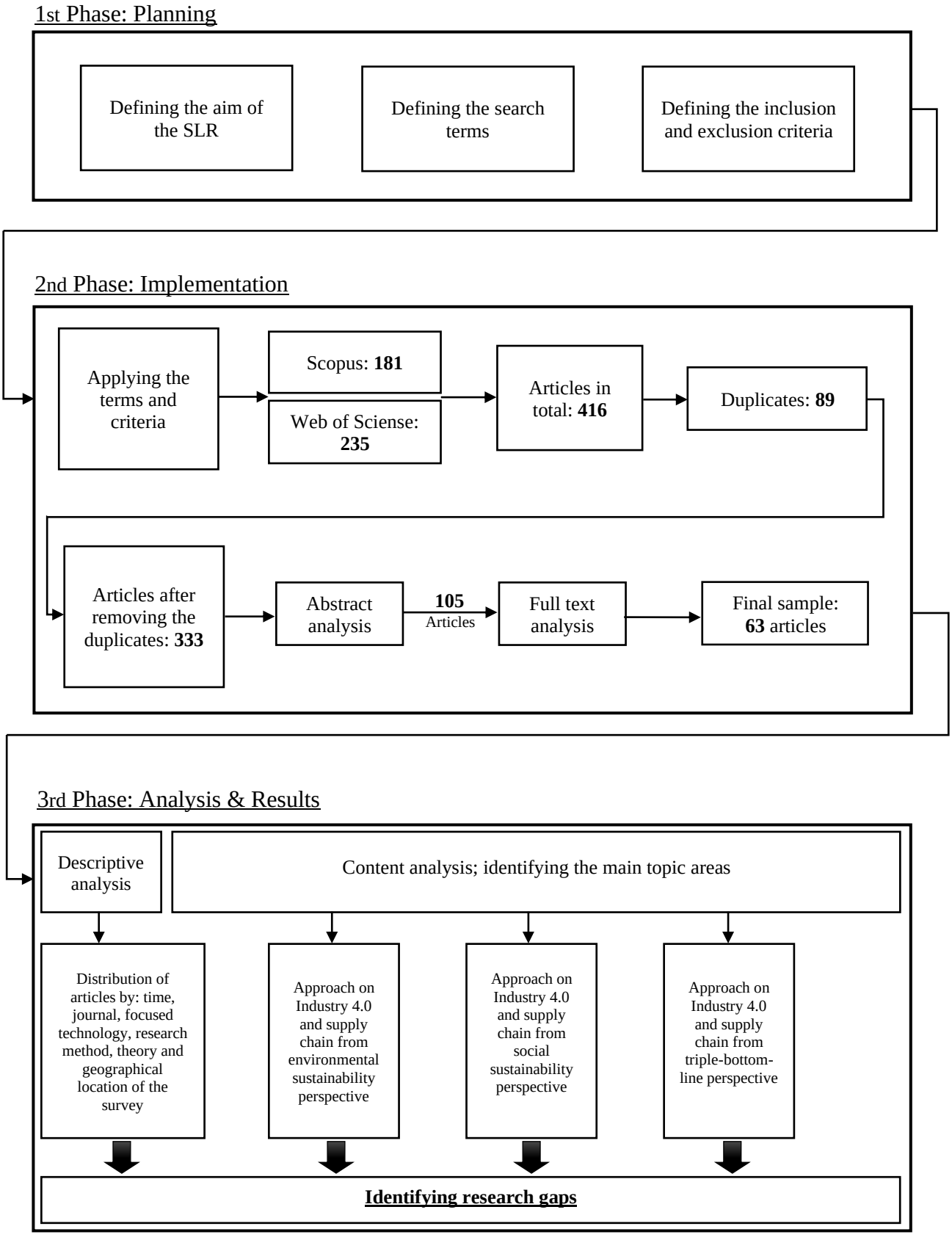

Figure 7. Systematic literature process.

3.1 Planning phase

The first step in the SLR is to clearly define the objectives of the review. The main target of this study is to identify how the new Industry 4.0 technologies are utilized in the supply chain context to achieve sustainability benefits. More specifically, the purpose is to find the link between the various technologies and sustainability, i.e. through which the impact of the digital tools is implemented in supply chains. In order to do that lists of keywords are developed in the second step. The topic of this research consists of multiple separate themes, namely digitalization as a wider concept, its tools, information sharing and sustainable supply chain. To identify the preliminary keywords, some relevant papers dealing with the themes were analyzed. For example, the works of Liu, Chen and Liu (2020); Chiappetta Jabbour, Fiorini, Ndubisi, Queiroz, and Piato, (2020); Isensee, Teuteberg, Griese and Topi (2020); and Bag, Telukdarie, Pretorius and Gupta, (2018) were studied and the initial most important search terms were identified. Later, the second step was to present and discuss the terms with two supervisors of the thesis. These two experts, with professional background and a comprehensive knowledge about the field, then validated the draft list of keywords. This process led to the final lists of keywords (Table *2*). The first list contains the topics of digitalization and information sharing, whereas the second includes keywords for sustainable supply chain.

Table 2. Search terms for SLR process.

Theme	Keywords
Industry 4.0 & Information sharing	(("industry 4.0" OR "digitali?ation" OR "cyber physical system*" OR "embedded system*" OR "information sharing") OR (("smart" OR "digital*" OR "data driven") W/3 ("technolog*" OR "tool*" OR "system*")) OR ("big data" OR "data analytics" OR "business analytics" OR "blockchain" OR "RPA" OR "robotic process automation" OR "artificial intelligence" OR "AI" OR "industrial internet of things" OR "iiot"))
	AND
Sustainable supply chain management	("green" OR "sustain*" OR "clean*" OR "environmen*" OR "respons*") W/2 (“supply chain” OR "supply network" OR "procurement" OR "purchasing" OR "logistics")

In the actual implementation process, these two strings are combined and used together. By this way it is possible to find as many relevant papers as possible, which discuss either the impact of the whole Industry 4.0, or just a one single technology, on the supply chain sustainability. After the validation of the key words, inclusion and exclusion criteria for the papers to be selected in the SLR process were developed. This is the third and final step in the planning phase. A total of four criteria were used. The time frame of the papers in this study is 2000-2020. Then, only articles written in English and published in peer-reviewed journals have been considered. Finally, only articles with a managerial perspective are considered, meaning that articles with, for example, a technical perspective are left out from this SLR.

3.2 Implementation phase

In the second phase of the literature review, the search strings with the inclusion and exclusion criteria formed during the previous phase are entered into two databases, namely Scopus and Web of Science (WoS). This resulted in 181 articles in Scopus and 235 articles in WoS. After this the lists were then compared and the duplicates were removed, leaving a total of 332 papers. These studies were then analyzed based on the abstracts, after which 218 articles were eliminated for being out of topic and leaving 104 articles for the next step. Then, the remaining articles were analyzed based on their full text and 42 articles were excluded due to, for example, having main focus in some other perspective than business managerial or only briefly addressing digitalization or sustainability while the main theme was something else. These steps resulted in a total of 63 peer-reviewed journal articles, which discuss about the interconnection between Industry 4.0, its technologies and sustainable supply chain management. The Table 3presents the iterative process that led into the end result.

Table 3. Phases and outputs of the search strategy.

	Scopus	**WoS**
Documents retrieved	181	235
Net of duplicates between databases	-	84
Papers out of the scope (first criterion)	128	100
Net after the first criterion	54	50
Papers out of the scope (second criterion)	19	22
Final number of papers analyzed: 63	35	28

3.3 Analysis and results phase

The third and final phase of the review consists of analyzing the articles in two ways. The first step is based on the characteristics, such as distribution over time, distribution by journals etc. The results of this step, i.e., the descriptive graphs about the SLR are presented in the next section. During the second step, however, the focus is on the actual contents of the selected articles and they are analyzed more thoroughly after which they are classified.

3.3.1 Articles over time

The selected time period (2000-2020) turned out to be rather long as no article prior to 2016 passing the criteria was published. The Figure *8* shows a rapidly growing interest towards the issue as the number of published papers in 2020 is over double the number of papers in 2019 and over triple the number of papers in 2018. This demonstrates the novelty of the field and validates the need for further research on the topic.

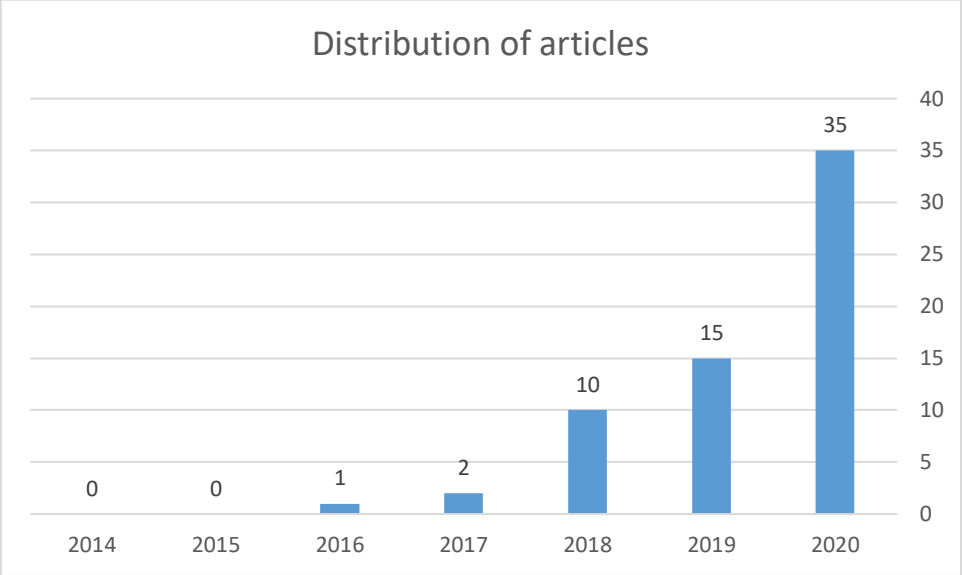

Figure 8. Distribution of the articles over time.

3.3.2 Articles in different Journals

The analyzed articles were published in 38 different journals. However,
Table *4* only presents nine as the rest 29 only had one article published. The two journals with most articles published are *Journal of Cleaner Production* (11 articles) and *Sustainability* (6 articles).

Table 4. Articles in different journals.

Journal	**Number of articles**
Journal of Cleaner Production	11
Sustainability	6
Resources conservation and recycling	4
International Journal of Production Research	3
International journal of information management	2
International Journal of Logistics Management	2
Journal of Enterprise Information Management	2
Logforum	2
Management of environmental quality	2
Journals with 1 article	29

3.3.3 The main topic of the articles

Out of the 63 articles, 18 addressed the digitalization as a wider concept, whereas 45 had a narrower perspective and focused on one or more specific digital tool. The Figure *9* describes this situation. Most interest has gained Big Data and Analytics, followed by Blockchain, Internet of Things and Artificial intelligence.

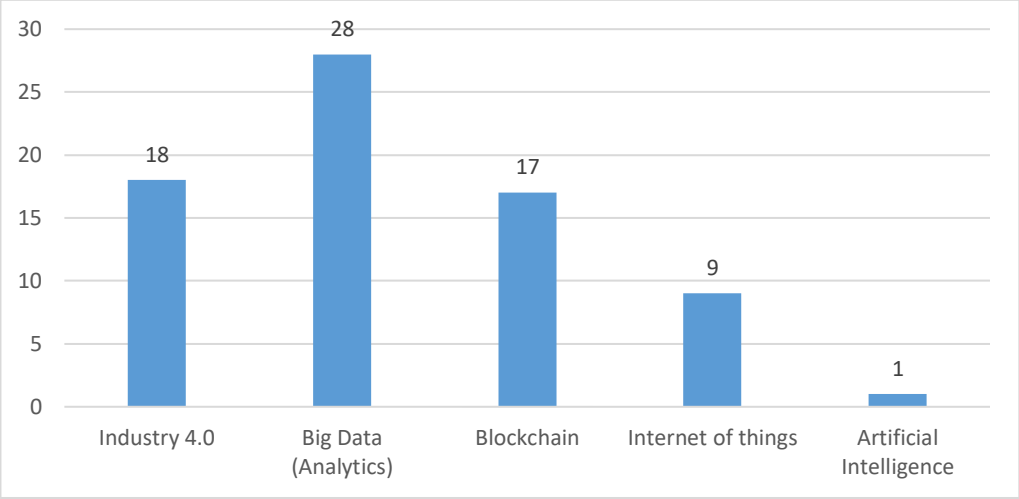

Figure 9. Focus points of the articles.

3.3.4 The used methods in the articles

Almost the half of the articles applied either surveys or theoretical methods (15 and 14 respectively), whereas systematic literature reviews (9) and mathematical models (6) were less used. Also, 15 articles applied a combination of multiple different methods and finally, only four articles presented a certain case (Figure *10*).

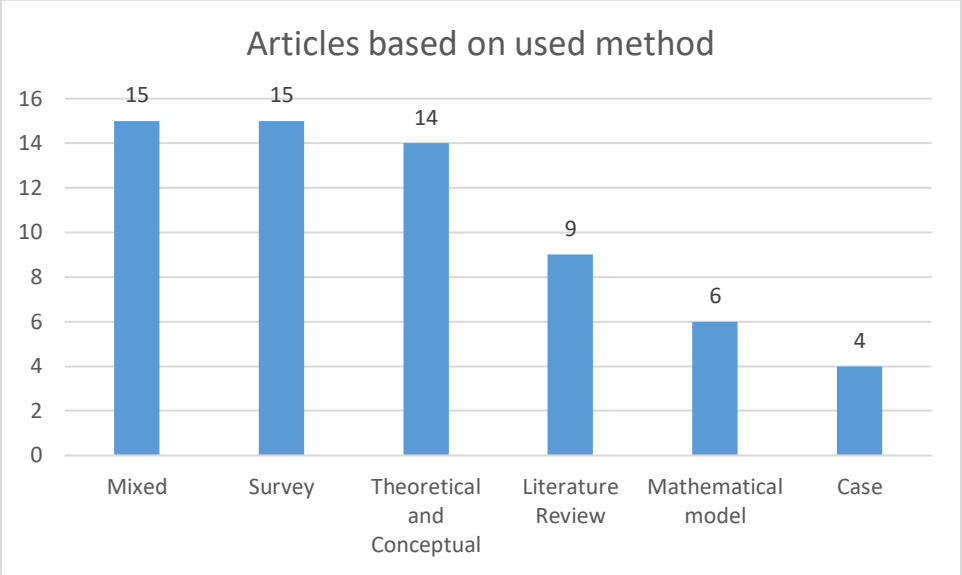

Figure 10. Used methods in the articles.

3.3.4 Applied theories in the articles

Not everyone of the articles had applied a theoretical framework. Only in 14 articles from the total of 63, at least one theory was presented. More specifically, 11 articles applied one theory and three articles applied at least two. As the Table 5 shows, Dynamic capability and Resource based views have been the most used theories.

Table 5. Applied theories in the articles.

Theory	Articles	Number of articles
DCV	Mandal (2018); Singh & Singh (2019); Singh & El-Kassar (2019); Dubey, Gunasekaran, Childe, Papadopoulos, Luo, Wamba & Roubaud (2019); Bag, Wood, Xu, Dhamija & Kayikci (2020); Shokouhyar, Seddigh & Panahifar (2020)	6
RBV	Jeble, Dubey, Childe, Papadopoulos, Roubaud & Prakash (2018); Junge (2019); Sarkis, Kouhizadeh & Zhu (2020); Tsolakis, Niedenzu, Simonetto, Dora & Kumar (2020)	4
Stakeholder theory	Wang, Zhang & Zhang (2020); Sarkis, Kouhizadeh & Zhu (2020)	2
Carroll's pyramid of CSR	Lu, Ren, Zhang, Rong, Ahmed & Streimikis (2020)	1
Contingency theory	Jeble, Dubey, Childe, Papadopoulos, Roubaud & Prakash (2018)	1
Institutional theory	Sarkis, Kouhizadeh & Zhu (2020)	1
Network Theory	Tsolakis, Niedenzu, Simonetto, Dora & Kumar (2020)	1
Principal-Agent Theory	Tsolakis, Niedenzu, Simonetto, Dora & Kumar (2020)	1
Social network theory	Kerdpitak, Hotrawaisaya & Khaengkhan (2019)	1
Systems theory	Bag, Gupta, Kumar & Sivarajah (2020)	1
Transaction Cost Analysis Theory	Tsolakis, Niedenzu, Simonetto, Dora & Kumar (2020)	1

3.3.5 Geographical distribution of the surveys

For 34 of the selected articles, it was possible to identify the country (or group of countries) in which the empirical survey has been conducted (Table *6*). The country where the highest number of surveys has been developed is India which (10 papers). It is followed by China and South Africa with three papers each. Iran, Italy and Thailand were the setting for two

papers each, whereas eight other countries had only one article. Also, four papers dealt with a group of countries instead of just one.

Table 6. Geographical distribution of the articles.

Location of the survey	**Number of articles**
Single Countries	
India	10
China	3
South Africa	3
Iran	2
Italy	2
Thailand	2
Brazil	1
Greece	1
Lithuania	1
Malaysia	1
Pakistan	1
Spain	1
Sweden	1
USA	1
Groups of countries	
Africa	1
EU	1
USA, Europe	1
Saudi Arabia, UAE, Egypt, and Lebanon.	1

3.4 Content analysis

This section highlights the results of the content analysis of the selected papers. In this phase the 9 literature reviews (9, 10, 17, 21, 22, 37, 44, 50 & 62) have been excluded, which left 54 articles to be analyzed (the list of these articles is reported in Appendix 1). Six literature reviews related to the topic of this thesis were identified (10, 17, 21, 22, 44 & 50 in Appendix 1). The literature reviews are summarized in Table *7*. Ćwiklicki and Wojnarowska (2020)

focused on the relationship between industry 4.0 and circular economy. Both, Esmaeilian, Sarkis, Lewis, and Behdad (2020) as well as Rejeb and Rejeb (2020) studied blockchain and its relationship with supply chain sustainability. Zhang, Yu and Zhang (2020), and Chiappetta Jabbour, Fiorini, Ndubisi, Queiroz and Piato (2020), researched the sustainable supply chains in the context of big data. Muñoz-Villamizar, Solano, Quintero-Araujo and Santos (2019), on the other hand, analyzed the relationship between SC sustainability and digitalization as a whole. Due to the field being in its infancy, the existing reviews remain on quite a general level and concrete suggestions for the moderating element between digitalization and sustainability in supply chains are absent. The aim for this thesis is to add to the existing literature and to shed light on the relationship between industry 4.0 and supply chain sustainability. This is done from a perspective of various single digital technologies but also from an industry 4.0 perspective, which is a more comprehensive perspective. Additionally, this literature review adds information sharing as an element and proposes it as the enabling element between the sustainability and digitalization in supply chains.

Table 7. Literature reviews identified during the SLR process.

Article	Objectives	Addressed research gaps	Proposed RQs	Time interval	Number of papers in the final sample	Future suggestions
Borregan-Alvarado, Alvarez-Meaza, Cilleruelo-Carrasco & Garechana-Anacabe (2020)	Generate contribution related to SC and SSC in the context of I4.0 and additive manufacturing (AM)	evolution of science in the fields of Industry 4.0 and Additive manufacturing.	No specifics	2010-2019	6571	To search greater sustainability in the manufacturing sector.
Ćwiklicki & Wojnarowska (2020)	Identify the connection between the CE and I4.0.	Co-exsistence of I4.0 & CE, their barriers, enablers and search focus.	"What is the direction of the relationships between CE and Industry 4.0?" "What are the key spheres necessary for introducing CE supported by Industry 4.0 technologies?"	2017-2020	32	The meaning of Industry 4.0 for the supply chain? The role of legislation in CE and the relations between government and industry.
Esmaeilian, Sarkis, Lewis, & Behdad (2020)	To provide an overview of BC technology and I4.0 for advancing SC towards sustainability.	-	-	1990-2019	-	(1) To develop new performance indicators and LCA methods, (2) To develop new data-based decision-making methods, (3) To explore best practices and novel case studies, and (4) To investigate the interaction between human and machine.
Zhang, Yu & Zhang (2020)	Literature review on SSCM using big data.	SSCM using BD.	-	2012-2019	777	To construct a CE system and sustainable development model.
Rejeb & Rejeb (2020)	To synthesize the research on BC and its relation to SSC.	The combination of BC with SSC.	"How can blockchain technology facilitate supply chain sustainability?"	"No specific date range"	79	To synthesize different types of literature and to rely on databases with more extensive coverage.
Shashi, Centobelli, Cerchione & Ertz (2020)	To describe and analyze how technology was addressed in the ASC context.	-	"To identify how technology has been studied in relation to ASC"	1999-2017	90	How investments, in digitization contribute to the processes, agility and performance

Chiappetta Jabbour, Fiorini, Ndubisi, Queiroz, & Piato (2020)	To synthetize published papers that deal with implications of BD for SSCM.	-	"What do we know about the use of big data in digitally-enabled sustainable supply chains?"	2015-2019	33	(1) push efforts in using BD in order to model sustainability in supply chains. (2) explore the interfaces of BD with other industry 4.0-related technologies for promoting SSCM. (3) study how to create a data-driven culture to improve successful big data initiatives among sustainable supply chain members. (4) understand how BDA can drive CL actions in SSC. (5) conduct more research to explore BDA's support when promoting resilience in SSC (6) explore challenges and barriers when implementing BDA to improve SSCM. (7) investigate the role of organizational capabilities when dealing with problems and promoting BD technology for sustainability in SC.
Muñoz-Villamizar, Solano, Quintero-Araujo & Santos (2019)	To analyze articles on SCM in the context of sustainability and digitalization.	To analyze articles on SCM in the context of sustainability and digitalization with bibliometric analysis approach.	-	2002-2018	484	(1) SCM, concepts and practices and (2) energy related technologies.
Hazen, Skipper, Ezell & Boone (2016)	To examine relationships between BDPA and SSCM	-	-	-	-	How to use 8 different theories to study BD and sustainability in supply chains.

The remaining articles are grouped into three blocks (see Table *8*). The rationale for this classification is based on both a) the sustainability approach adopted in each paper and b) the related digital technology supporting that specific approach. As a result, the three categories identified are as follows: environmental, social and triple-bottom-line view on sustainability. The first group includes papers focusing specifically on green or environmental issues, whereas the second group contains articles that deal with social matters. The papers included in the third group consider the combination of these themes and as they show a comprehensive approach to sustainability. The economic view on sustainability is not emphasized as it is often seen as the most fundamental element of sustainability and the other two dimensions are extensions. Only after having stable economic grounds, can an organization begin to think about the other aspects of sustainability as well. In essence, economic sustainability is used to measure the profitability of a firm (Niu, Mu, Chen, & Lee, 2019) and without having that, the company cannot focus on other aspects of sustainability. For this reason, in this thesis, the approach on sustainability is divided to environmental, corporate social responsibility and triple-bottom-line. Additionally, these groups are divided further based on the specific digital technology applied. As one paper may have focused on multiple different technologies, it can appear in more than one section in the (Table *8*). The row Industry 4.0 consists of papers that don't mention any specific digital technology but deal with digitalization as a whole.

Table 8. Classification of the SLR articles.

		Sustainability approach			Total
		Environmental	Social	3-bottom-line	
Digital technology applied	BD(A)	[8], [18], [24], [32], [48], [54], [61], [63]	[2], [33], [49], [57]	[1], [3], [12], [15], [23], [26], [31], [45], [51], [52], [55], [58]	24
	BC	[6], [27], [42], [43], [47], [54], [61]	[7], [36], [57]	[14], [20], [39], [46], [56]	15
	IoT	[42], [43], [47], [48], [54], [60], [61]	[57]	[34]	9
	AI	-	-	[5]	1
	Industry 4.0	[13], [19], [25], [35]	[16]	[4], [11], [28], [29], [30], [38] [40], [41], [59]	14
Total		26	9	28	

Next, the following three sections offer a brief overview into the identified topic areas. The existing research in each area is reviewed.

3.4.1 Environmental approach

Big data and analytics have been used to enhance environmental sustainability in different ways. Multi-objective optimization models have been developed by, for example, Zhao, Liu, Zhang and Huang (2017) who minimized carbon emission risk and economic costs in a green supply chain and by Gholizadeh, Fazlollahtabar and Khalilzadeh (2020) who, in addition to minimizing overall costs, minimized information fraud in information sharing and maximized the efficiency of vehicles. Jiao, Ran, Zhang, Li and Zhang (2018) used BD while creating approaches for closed loop supply chains that minimize emissions and uncertainty. Also, Mangina, Narasimhan, Saffari and Vlachos (2020) analyzed large data sets and found solutions to reduce the amount of CO2 emissions in European road freight transport. Belaud, Prioux, Vialle and Sablayrolles (2019) utilized BDA in the agri-food supply chain and developed a five-step method to enhance the sustainability of waste management. Paper by Zhang, Zhong, Farooque, Kang and Venkatesh (2020) presented BD in integration with BC

and IoT and developed a framework for implementation life-cycle-assessment for improving environmental sustainability in supply chains. Tan, Wang, Liu, Kang and Costa (2020) shared this comprehensive view and proposed related applications for developing green logistics.

In addition to these integrative approaches, Blockchain (BC) has been studied separately as well. Bag, Viktorovich, Sahu and Sahu (2020) investigated barriers related to the BC implementation in green supply chain management and identified cultural differences among supply chain partners and collaboration challenges as one of the most critical barriers for the adoption process. Kouhizadeh and Sarkis (2018) presented various possible use cases for BC technology to enhance environmental sustainability, for example in vendor selection, supplier development and waste management. Both Sarkis, Kouhizadeh and Zhu (2020) and Rane and Thakker (2019) investigated the combination of BC and Internet of Things (IoT). The former observed that these technologies can potentially and simultaneously be the solution and the reason for environmental degradation in the supply chains, whereas the latter analyzed these technologies in overcoming challenges in green procurement and developed a framework to incorporate them to supply chain in order to make it more transparent and efficient.

Yuen, Choy, Lam and Tsang (2018) developed a system for outbound logistics knowledge management for monitoring and handling products that are temperature sensitive. Their model solely relies on the IoT technology. In their paper, Scholz, De Meyer, Marques, Pinho, Boaventura-Cunha, Van Orshoven, Rosset, Künzi, Kaarle and Nummila (2018) combined IoT technology with analytics of the gathered data in the context of forest supply chains. They showed that information sharing and collaboration, enabled by the technologies, is required to achieve better efficiency and sustainability. Rane, Thakker and Kant (2020) focused on the integration between BC and IoT and found that the cooperation initiatives with the buyer is the most important enabler for greening the supply chain.

Some papers discuss the Industry 4.0 without mentioning any digital technology specifically. Dev, Shankar and Qaiser (2020) provided a theoretical and practical framework for combining the umbrella term of "Integrated Industry 4.0" and circular economy. Melander and Pazirandeh (2019) posited that digitalization is a major vessel for collaboration and

green innovation in supply chains. Gružauskas, Baskutis and Navickas (2018) presented a way to incorporate industry 4.0 with strategy development in order to minimize the trade-off between costs and sustainability and to, for example, decrease the CO2 levels. Junge (2019) presented a framework that describes the impact of digital technologies in manufacturing for sustainable supply chain management.

3.4.2 Social approach

Shaifq, Ahmed and Mahmoodi (2020) found that BDA is capable to enhance the social performance of suppliers. Bag, Gupta and Wood (2020) focused on barriers related to BDA implementation in humanitarian supply chain and to find the existing interrelationships between them. Mani, Delgado, Hazen and Patel (2017) showed that by utilizing BDA, companies can mitigate various social risks, such as workforce safety and health, unethical behavior or theft through BDA, thus improving social sustainability. Venkatesh, Kang, Wang, Zhong and Zhang (2020) took a more comprehensive approach as they combined BDA, BC and IoT in order to create a integrative system architecture that enables a seller to monitor the social sustainability of their supply chain.

The study from Mubarik, Rasi and Faraz (2020) revealed that BC technology can significantly improve the integration between members in supply chain, and thus ensure the transparency and traceability. Bai and Sarkis (2019) developed an appraisal model for BC evaluation and selection for supporting transparency and risk mitigation.

Ebinger and Omondi (2020) developed a heuristic framework that incorporates various industry 4.0 approaches that enhance the supply chain transparency. For example, they focused on traceability and tracking, partner selection, and risk assessment in their model.

3.4.3 Triple-bottom-line approach

Many have approached the BDA's effect on sustainability in a general way. Dubey, Gunasekaran, Childe, Papadopoulos, Luo, Wamba and Roubaud (2019) found that BDA has a significant impact on the environmental and social performance of a company. Shokouhyar, Seddigh and Panahifar (2020) had similar results when investigating the link between BDA and sustainability in the context of Iranian pharmaceutical supply chains. The

findings by Bag, Wood, Xu, Dhamija and Kayikci (2020) showed that BDA management capabilities have a strong effect on the innovative green product development and supply chain sustainability in the South African mining industry. Del Giudice, Chierici, Mazzuucchelli and FIano (2020) suggested that the effect of circular economy HR management on firm sustainability performance is moderated by big data driven supply chain. When investigating Thai tourism, Kerdpitak, Hotrawaisaya and Khaengkhan (2019) found out that BDA planning, control, coordination and investment positively and significantly impact the sustainability of the supply chains. Also Mandal (2018) suggested similar results. Jeble, Dubey, Childe, Papadopoulos, Roubaud and Prakash (2018) posited that organizational culture and organizational learning have a great impact on building BDA capabilities which then leads to improved sustainability performance. Wang, Zhang and Zhang (2020) explored the relationship between external corporate social responsibility and green supply chain management and found that BDA capability positively moderates that effect. In order to rank the sustainability of supply chains, Badiezadeh, Saen and Samavati (2018) created a mathematical model. Rodriguez and Da Cunha (2018) proposed a conceptual framework that, through BDA, connects drivers for innovation, absorptive capacity and sustainable supply chain innovation performance. Singh and El-Kassar (2019) concluded that the company's ability to achieve sustainable performance relies on the commitment to participate in sustainable initiatives and big data practices that are included in the company's strategy.

Guo, Sun and Lam (2020) found that BC has an ability to increase information transparency and disclosure which helps reducing the consumers concerns over the eco-labels used in fashion supply chains. Di Vaio and Varriale (2020) investigated a BC enabled airport collaborative decision making platform that enhances the information sharing possibilities, thus increasing the punctuality of the flights and reducing their fuel consumption. Tsolakis, Niedenzu, Simonetto, Dora and Kumar (2020) studied designs for BC based sustainable food supply chains in the context of Thai fish industry. Nayak and Dhaigude (2019) found that competition, financial constraints and culture are the most critical success factors for sustainable supply chains using BC. Saberi, Kouhizadeh, Sarkis and Shen (2019), on the other hand, identified four barrier categories, namely inter-organizational, intra-organizational, technical, and external barriers, for BC adoption.

Mastos, Nizamis, Vafeiadis, Alexopoulos, Ntinas, Gkortzis, Papadopoulos, Ioannidis and Tzovaras (2020) utilized IoT in scrap metal waste management and presented its possibilities in improving the sustainability throughout the supply chain by, for example, reducing the CO2 emissions. The results by Bag, Gupta, Kumar and Sivarajah (2020) showed that AI-based GSCM dimensions have a positive influence on GSCM strategy.

Nascimento, Alencastro, Quelhas, Caiado, Garza-Reyes, Rocha-Lona and Tortorella (2019) found that the integration of circular economy and industry 4.0 leads to, for example, reducing negative environmental outcomes and generating new local jobs. Similarly, Lu, Ren, Zhang, Rong, Ahmed and Streimikis (2020) concluded that industry 4.0, circular economy and cleaner production have synergies that can improve both environmental and social sustainability. Daú, Scavarda, Scavarda and Portugal (2019) suggested that in order to transform linear supply chain to more circular, a link between sustainability dimensions, industry 4.0 and corporate social responsibility needs to be addressed. According to Bag, Yadav, Wood, Dhamija and Joshi (2020), by improving industry 4.0 resources, a company can enhance its sustainability in logistics. Ramirez-Peña, Sánchez Sotano, Pérez-Fernandez, Abad and Batista (2020) investigated ship building supply chain in the context of industry 4.0 and found out that it must be green and lean to be effective. Luthra and Mangla (2018) identified organizational, and technological challenges as the biggest challenges for industry 4.0 projects in sustainable supply chains. Rajput and Singh (2019), on the other hand, list interface designing and automated synergy model as the most influential barriers. They also presented artificial intelligence, and service and policy framework as enablers. Similarly, Luthra, Kumar, Zavadskas, Mangla and Garza-Reyes (2020 investigated the drivers for industry 4.0 in sustainable supply chains and found governmental support policies, and collaboration and transparency between members in supply network to be the most significant ones. In addition to just identifying challenges, Yadav, Luthra, Jakhar, Mangla and Rai (2020) also presented a framework including solutions to overcome the barriers.

To summarize the findings of the SLR, the focus on purely environmental issues, together with the triple-bottom-line approach has been significantly more studied than the pure social approach. BD(A) is clearly the technology that has gained the most attention. Also, BC has been studied extensively, whereas the papers focusing on IoT, especially alone, is scarce. Despite its popularity, AI seems to be understudied. Ignoring the categories momentarily,

the greatest themes were the barriers for adopting these novel technologies and industry 4.0 practices. Additionally, the topic of required organizational capabilities for a successful implementation has gained attention. However, only few articles touched the topic of what is the link between industry 4.0 and SC sustainability. This thesis adds to the research in this field.

3.5 Hypothesis formulation

Digitalization is one of the biggest buzz words currently. It is also a major emerging trend that is influencing the sustainability of the companies (Parida & Vincent, 2019) and their supply chains. However, there is no single definition for digitalization (Denner, Püschel & Röglinger, 2018). For example, Freddi (2017) defined it as a concept which offers countless novel possibilities to consume and work, thus changing how companies will function in the future, whereas Sarc, Curtis, Kandlbauer, Khodier, Lorber & Pomberger (2019) described it as the combination of digital technologies and everyday life, calling this integration as Industry 4.0. These terms contain many sub-terms, and they overlap in multiple ways, but the amount of research about the relation between Industry 4.0 and sustainability is scarce (e.g., Bag et al., 2018; Esmaeilian et al., 2020; and Bai et al., 2020). Industry 4.0 consists of multiple different digital technologies such as cloud computing, internet of things, blockchain, big data and analytics (Jabbour, Foropon & Godinho Filho, 2018). It is recognized that these technologies can aid companies to achieve a higher sustainability level (Gobbo, Busso, Gobbo & Carreao, 2018). Out of the various different technologies in the context of digitally enabled supply chain, big data has gained the most attention amongst the scholars (Chiappetta Jabbour, Fiorini, Ndubisi, Queiroz, & Piato, 2020).This was also found to be true in the systemic literature review process, which is why, while addressing various digital technologies, this study highlights big data analytics and focuses more on its impact.

Furthermore, Visconti and Morea (2019) pointed out that there is a lack of studies that show how big data supports sustainable supply chains. In addition to the availability and use of digital technologies, also the organizational characteristics have an effect on sustainability projects' success. Isensee, Teuteberg, Griese & Topi (2020) pointed out that academics have mainly studied the topics of organizational culture, sustainability, and digitalization separately without establishing a connection between all of them. In this research,

organizational culture is addressed especially from the perspective of how supply chains share information amongst them. The amount of information in the world is multiplying constantly which makes it impossible for a single company to work alone. There is a growing need to cooperation and integration between companies in supply chains. This study aims to contribute by establishing a link between digitalization, information sharing and sustainability and show how they are connected.

The advancement in Industry 4.0 technologies has led to greater demand for both, intra- and inter-organizational integration (Bag et al., 2018). Companies' ability and willingness to share information are key elements of this collaboration. Yu, Chavez, Jacobs and Feng (2018) suggested a supply chain being data-driven has a significantly positive impact on information sharing. Müller, Veile and Voigt (2020) discovered that the earlier research has rarely focused on the Industry 4.0 from the perspective of information sharing and concluded that in order to realize the possible benefits of the Industry 4.0, it is imperative to share data across the whole supply chain. The information between companies is often shared via supply chain platforms (Liu, Chen, & Liu, 2020), which then provides access to information on-demand, while also promoting real-time interaction and integration (Frank, Dalenogare & Ayala, 2019). Kache and Seuring (2017) proposed that "integrated data exchange platforms" allow companies to reach a collaborative state through information-sharing. This idea is shared by Melander and Pazirandeh (2019), who found that digitalization has made it possible for companies to jointly develop systems helping them to receive data. According to Dubey, Gunasekaran, Childe, Blome and Papadopoulos (2019) the ability to access, analyze and manage huge volume of data emerging from various industry 4.0 technologies, with the support of robust information architecture, i.e. supply chain platforms, form perhaps the most prominent aspect of Industry 4.0 which is enhancing the information sharing capabilities in supply chains, that is big data predictive analytics (BDPA). Also, as found in the SLR process, BD(A) appeared to be the most studied digital technology in the SSCM context.

BDA helps to remove any information asynchronization and thereby strengthens the information sharing (Liu et al., 2020). BDA also ensures the availability of relevant, timely, accurate, visible, complete, and sensitive information, and does it in a way that builds a framework for information sharing in the supply chain (Raut, Mangla, Narwane, Gardas,

Priyadarshinee & Narkhede, 2019). Dubey, Gunasekaran, Childe, Luo, Wamba, Roubaud and Foropon (2018) argued that information visibility in supply chain networks and BDA are complementary elements and found that if companies utilize BDA, they are more likely to improve the level of collaboration. Also, BDA has a possibility to enhance information sharing and coordination among companies in supply chain, which can help to reach sustainability (Dubey et al., 2019). Various elements of Industry 4.0 aim to upgrade the processes how information shifts between companies in the supply chain, and even though the research on the field has not yet reached the maturity, some early studies have found evidence on the matter. Thus, the first hypothesis of this study is:

H1: Industry 4.0 positively influences information sharing.

In today's rapidly changing business environment with countless number of opportunities and threats, there is simply no way to have all the knowledge about green initiatives within a single company (Melander & Pazirandeh, 2019), and in order to profit from the possibilities offered by the emerging digital technologies, companies need to transform on a network-wide level, meaning for example, aiming to value co-creation with supply chain partners to jointly maximize sustainability benefits (Parida & Wincent, 2019). Sharing information and knowledge can assist companies in improving other internal capabilities (Isensee et al., 2020) and for example, the gathering and sharing of data will lead to more transparent supply chain (Wong, Wines, & Li 2017). According to Beier et al. (2018), transparency can offer reputational benefits and it is needed to support sustainability management and reporting while also providing benefits in strategical level when aiming for sustainability. Firm's must focus on and invest in developing ways to actively aim for these benefits.

The researchers have recognized the importance of industry 4.0 for sustainability but have given little attention on the means that firms utilize (Esmaeilian et al., 2020). The academics have not yet fully researched the internal mechanisms, capabilities and processes through which companies implement the strategies formulated with digital technologies, supply chain platforms and BDA (Singh & El-Kassar, 2019). By combining environmental supply chain management practices with BDA, firms are able to develop capabilities that assist them in reaching a better sustainability performance (Amui, Jabbour, de Sousa Jabbour & Kannan,

2017). The need for such capabilities is increased in today's dynamic and uncertain markets. In order to adapt to the uncertainty, firms need to develop dynamic capabilities to achieve competitive advantage (Bag, Wood, Xu, Dhamija & Kayikci, 2020). Dynamic capabilities are commonly defined as "the firm's ability to integrate, build and reconfigure internal and external competencies to address rapidly changing environments" (Teece, Pisano, Shuen, 1997). Thus, companies must learn how to combine their resources, i.e. supply chain platforms or data, which can be both internal and external, in order to obtain wanted sustainability results.

Some studies suggest BDPA as a major capability that enhances the supply chains sustainability (e.g. Jeble, Dubey Childe, Papadopoulos, Roubaud & Prakash, 2018; Dubey, Gunasekaran, Childe, Luo, Wamba, Roubaud, & Foropon, 2018; and Dubey, Gunasekaran, Childe, Papadopoulos, Luo, Wamba, & Roubaud, 2019). Chiappetta Jabbour et al. (2020) argue that companies need to develop complementary capabilities to ease the utilization of the big data technology benefits for sustainability. Thus, in this study information sharing capability is seen as a more affecting capability, which in combination with BDA and other industry 4.0 elements helps the organizations to reach a higher sustainability level.

Information sharing capabilities refer to the combination of technologies, architecture and other components which aim for information collection, processing and sharing (Galbraith, 1973 and Tushman and Nadler, 1978). Premkumar, Ramamurthy and Saunders (2005) posited that information sharing capabilities are achieved with the support of information technology, that is, through industry 4.0 tools, supply chain platforms and BDPA. In addition, Cegielski, Allison Jones-Farmer, Wu & Hazen (2012) defined information sharing capability as "capability to utilize and structure information in a meaningful fashion that supports decision making". Based on these, Li, Dai and Cui (2020) stated that the digital technologies possessed by a company form its internal information architecture, i.e. supply chain platforms which then function as channel for more extensive information sharing assisting the sustainability pursuit.

A capability to share information with other companies in supply chain is needed in today's competitive environment. The information sharing is not a shortcut, one needs more than a capability and willingness to cooperate. The process must complement the already existing

information and data, and then sustainability goals can be achieved (Liu et al., 2020). Also, in order to be able to improve the sustainability performance, information sharing capabilities must be supported with correct information systems i.e., supply chain platforms (Meacham, Toms, Green & Bhadauria, 2013). In this vein, the second hypothesis is proposed:

H2: Information sharing capabilities have a positive effect on sustainability.

This study aims to show the relationship between Industry 4.0 and sustainability, and also, how information sharing affects this relationship. Firstly, link between Industry 4.0 and information sharing is established, and secondly, between information sharing and sustainability. In this research the concept of Industry 4.0. is expanded in the following way: starting point for a company is to first have access to and basic knowledge about various digital technologies, such as cloud computing, blockchain, data platforms and big data predictive analytics. These technologies are then applied in order to develop and implement supply chain platforms, which function as mediator and improver of the supply chain information. Then, data analytics is emphasized as a critical element regarding information sharing, and finally, this study aims to show that the organizational capability to share information with the other members in supply chain has a significant impact on supply chain sustainability. The research framework is shown in the Figure *11*.

To summarize; based on to the earlier presented, the framework in this study stems from the following: e.g. Bag et al. (2018) integrated the concepts of Industry 4.0 and sustainability using the dynamic capability view. They argued that dynamic capabilities enable companies to combine, develop and reallocate resources for sustainability, and found that among other capabilities, horizontal integration and vertical integration explained how the concepts are linked. However, they mainly studied enablers for Industry 4.0 without addressing how the digital technologies actually improve sustainability in supply chains. In this study, information sharing is derived from the dynamic capabilities, and is seen as the most important capability enhancing the sustainability in the supply chains. Furthermore, this study seeks to identify the mechanism between Industry 4.0 and supply chain sustainability and suggests that it is actually the information sharing capabilities, through which the sustainability is achieved.

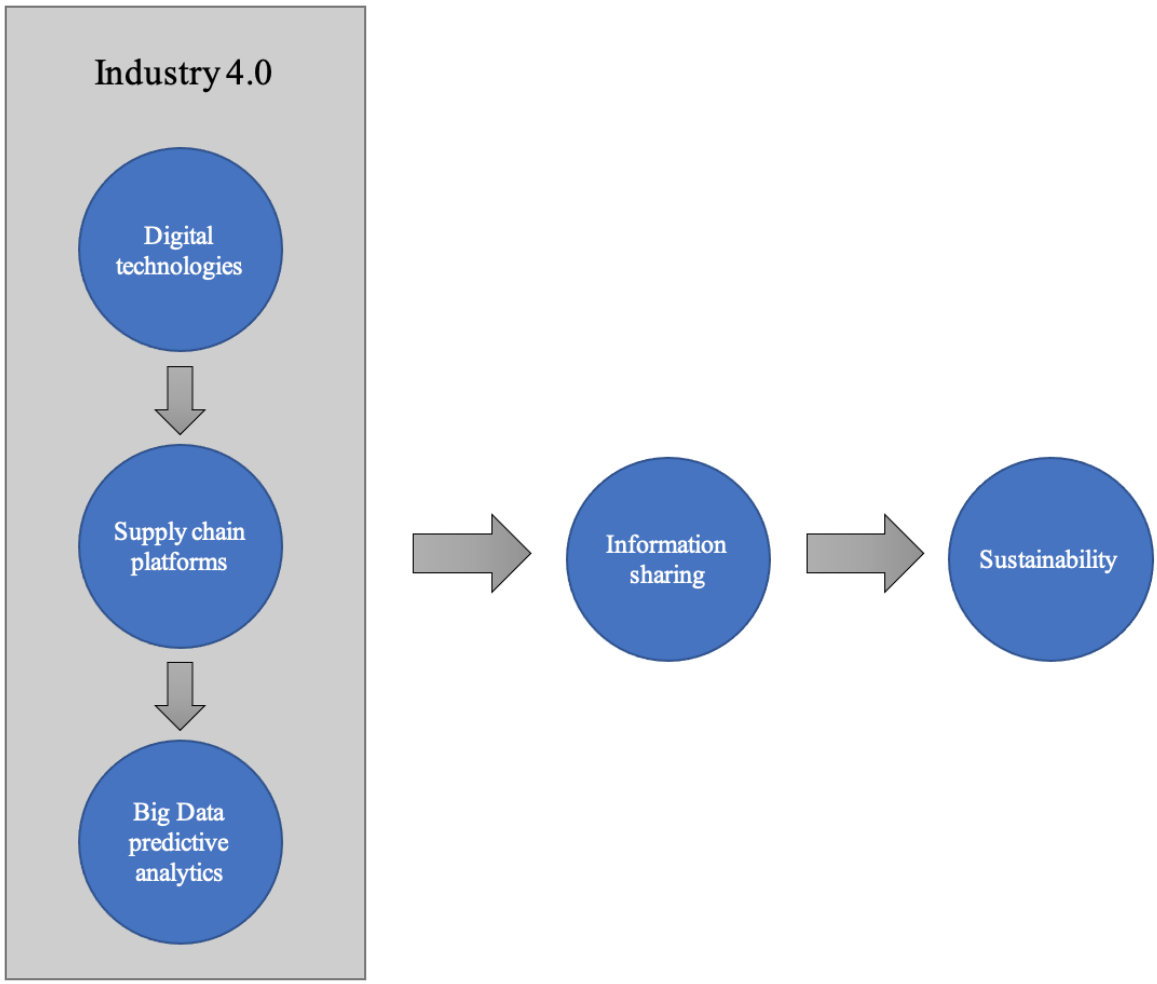

Figure 11. Research framework.

Also, Li et al. (2020) pointed out that only few academics have studied how digital technologies impact sustainability through digital supply chain platforms. In their research, they argued that digital technologies formulate the interior information architecture, which represents a company's capabilities to information processing. They posited that in order to realize the sustainability benefits, offered by various digital technologies, a well-functioning supply chain platform is required. This study also agrees with Li et al. (2020), who saw digital technologies as crucial elements of the company's information processing capabilities, which are driving towards sustainability enhancing supply chain platforms. Even though sharing their argument that the emerging digital technologies form a unified construct and that together they comprise the company's information processing capabilities, however, this study broadens the view by dividing supply chain platforms into two concepts: 1) the actual software and hardware, and 2) the information sharing capabilities. First, a firm

needs to have a sufficient infrastructure of various digital information technologies. Only after that they can effectively construct the supply chain platform architecture which in cooperation with BDA increases the organizations information sharing capabilities. The main argument of this study is that this path eventually leads to higher sustainability.

Next, the research methodology is presented, and the results reported. Also the validity and reliability of the study is addressed

4 METHODOLOGY

In this chapter the choice of methodological approach and analysis methods is explained. Additionally, a description of data collection process as well as the steps of the empirical research is provided. This thesis applies quantitative methods and analyzes data gathered with a survey instrument that was targeted to Finnish companies. By using quantitative methods, it is possible to generalize the results of a larger population (Dubois & Araujo, 2007). In this sense, an explorative model is developed in order to better understand the main issue concerning the relationship between industry 4.0, information sharing and sustainability in supply chains. This helps in identifying the main characteristics of the problem and to generate new ideas and perspectives, on which the subsequent research can build on.

4.1 Data sample

The survey data of the study has been collected from large and medium sized Finnish manufacturing companies. The respondents to the survey are those responsible for managing companies' purchasing and supply management. Respondents represented senior management, middle management, experts, and operational procurement personnel. The industry and the minimum size limits for companies have been aimed at targeting companies where procurement is likely to have a significant impact on turnover and that respondents have experience and insight into procurement and supply chain management. A total of 147 responses were received from the target group and the response rate was 38%. The questionnaire contained items from the research topics that respondents were asked to rate on a Likert-type scale (1-5). The response to the survey was analyzed using statistical analysis methods. The questionnaire included constructs on digitization, information sharing and responsibility, and more broadly on business operations.

4.2 Survey constructs

The survey was built on constructs that were derived from earlier studies. The constructs used are 1) Digital technologies that include various novel technologies available for companies to use, 2) Supply chain platforms that describes how a company utilizes digital

assets when coordinating its supplier base, 3) Big data analytics (Brinch, Stentoft, Jensen & Rajkumar, 2018) that includes items measuring how a company gathers, analyzes and applies large data sets, 4) Information sharing (Fan, Li, Sun & Cheng, 2017), and 5) Sustainability practices that was used to measure how the companies utilize and apply various sustainability procedures in their operations.

4.3 PLS-SEM

This thesis utilizes partial least squares structural equation modeling (PLS-SEM) approach (Hair, Risher, Sarstedt & Ringle, 2019). According to Hair et al. (2019) PLS-SEM is suitable, for example, when the model includes at least one formative construct or when the sample size is limited or is not normally distributed. Also, the complexity of the model further validates the use of the PLS model. SmartPLS 3.0 software was used to create the model.

4.4 Validity and reliability

The reliability of the constructs was assessed with a construct reliability (CR) analysis, which evaluates the average variance extracted (AVE) of the constructs (Fornell & Larcker, 1981). If the value for CR is above 0.50, it indicates approvable reliability (Kline, 2011). Additionally, the collinearity of the model, i.e. the common method bias was tested. For all the latent variables in the model (constructs 2-5), variance inflation factors (VIFs) were generated. Based on this test, no VIF was above 3.3, and thus it can be said that the data set is free from common method bias (Hallikas, Immonen & Brax, 2021).

Table *9* presents key numbers related to the variables and constructs and shows that every validity criterion is fulfilled, as for example, AVE values vary from 0.500 to 0.619. As the AVEs are above 0.5, it indicates an acceptable convergent validity for the model. In addition to AVE values, the table also presents the loadings, means, standard deviations and CR values of the items. The digital technologies don't have loadings reported because it was a formative construct.

Table 9. Construct descriptive statistics.

	Loading	Mean	Sd	Cr	Ave
Digital technologies				-	-
IIoT, Industrial Internet of Things	-	3.020	1.013		
Cloud platforms	-	3.816	0.948		
BC	-	2.935	0.978		
BDA	-	3.528	1.127		
Machine learning	-	3.247	1.156		
RPA	-	3.286	1.274		
AI	-	3.285	1.179		
Supply chain platforms				**0.874**	**0.500**
ERP system in procurement	0.752	3.882	1.298		
ERP in purchasing processes	0.809	4.340	1.163		
Electronic supplier network coordination	0.656	3.187	1.122		
IT systems integration	0.65	2.537	1.258		
PO system usability	0.773	4.136	1.117		
Spend reporting tool	0.644	4.062	1.019		
Product data management systems	0.644	3.358	1.282		
Big data analytics				**0.936**	**0.619**
Collection automation	0.803	2.823	1.123		
Storing	0.794	3.293	1.150		
Cross data & system analysis	0.833	2.755	1.146		
Advanced methods	0.822	2.324	1.021		
Visualization	0.756	2.592	1.061		
IT-enabled processes	0.843	2.796	0.990		
Decision determination	0.750	2.510	0.999		
Problem & Opportunity identification	0.720	2.667	0.971		
Pattern recognition	0.749	2.170	0.950		
Information sharing				**0.890**	**0.575**
Proprietary information from partners	0.674	3.442	1.011		
Risk related information	0.855	3.442	0.874		
Timely information	0.774	3.388	1.006		
Functional teams	0.748	3.082	0.877		
Organizational culture	0.758	3.483	0.844		
Partners commitment	0.729	3.367	0.834		
Sustainability practices				**0.929**	**0.521**
Supplier self-evaluations	0.661	3.224	1.002		
Standards (ISO 14001 etc.)	0.716	3.768	1.159		
Supplier registers	0.74	3.062	1.372		
Responsibility clearances for purchased products.	0.714	3.028	1.309		
Regular audits	0.751	3.568	1.245		
International standards in purchasing	0.802	3.489	1.219		
Supplier selection	0.778	4.053	1.014		
Root-cause identification	0.618	4.027	0.934		
CSR reporting requirements for suppliers	0.737	2.437	1.116		
Sustainable performance measurements	0.741	3.099	1.200		
Binding sustainability terms	0.673	3.531	1.029		
LCA in purchasing	0.712	2.835	1.127		

4.5 PLS path model

In this section, the research model is presented. The sample size for bootstrapping was 147 which was equal related to the original data sample. During the analysis, the data was resampled 5000 times (basic bootstrapping), which is argued to be adequate for the parameter estimation in the model (Henseler, Ringle & Sinkovics, 2009). Furthermore, the overall quality of the model was tested and validated using three steps: 1) collinearity and overall fit, 2) explanatory power, and 3) path significances. The variance inflation factor (VIF) didn't show collinearity for the latent factors of the model as the VIF values varied (1.000-1707) below the critical level 5.0. The overall fit was assessed using RMStheta (root mean square residual covariance, critical value > 0.12) in order to specify the error in estimation of the model (Cepeda-Carrion, Cegarra-Navarro & Cillo, 2019). The model fit of RMStheta = 0.137 indicates that there is no serious misspecification in the model.

The explanatory power is assessed with R^2, which describes the proportion of the variance that is explained by the endogenous variables. The R^2s in the path model for the latent variables were: Supply chain platforms = 0.17, Big Data analytics = 0.36 , Information sharing = 0.32, and Sustainability practices = 0.23. These numbers show that the model has sufficient explanatory power, despite sample being relatively small.

Table 10. The structural model for hypothesis testing

Hypothesis	Path	t-statistics	p-values
	Digital technologies → Information sharing	0.438	0.662^{n}
H1	Digital technologies → SC Platforms	3.871	0.000****
	SC Platforms → BDA	8.633	0.000****
	BDA → Information sharing	5.635	0.000****
	SC Platforms → Information sharing	1.977	0.048***
H2	Information sharing → SSCM practices	8.473	0.000****

n) Not significant, *) Statistically significant at p < 0.1, **) Statistically significant at p < 0.05, ***) Statistically significant at p < 0.01, ****) Statistically significant at p < 0.001

The path model tested (Table10) shows that the Industry 4.0 has a statistically significant influence on information sharing, thus confirming the first hypothesis. Also, the path from which the industry 4.0 concept consists of is validated, i.e. digital technologies lead to supply chain platforms and to increased use of big data analytics. The information sharing then has a significant influence on sustainable supply chain management practices in the companies, which confirms the second hypothesis. However, the path from digital technologies to information sharing directly has no significant influence. These results validate both hypothesis and the conceptual framework of this thesis. More extensive picture is presented in appendix 1. So, the organization must first adopt digital technologies based on which it can build supply chain platforms and then by applying big data analytics, it can improve the information sharing capabilities in the supply chain. This then leads to improved sustainable supply chain management practices in the whole network.

5 DISCUSSION

Drawing from the dynamic capability view this study researched the relationship between digital technologies, information sharing and sustainability in supply chains. Specifically, this study investigated the role of information sharing and its enabling capabilities when companies are pursuing to improve their sustainability with digital technologies. The world is constantly getting more digital and interconnected. At the same time the public pressure from customers towards the companies is forcing them to find new ways to improve the sustainability both in their own processes, but also in their suppliers' and their suppliers' processes as well.

The inspiration to conduct this research stems from a thought that digital technologies itself aren't adequate when aiming for better sustainability performance. Something is needed in between. Dynamic capability view proposes that companies should develop resources that are difficult to imitate, valuable, rare and not easily substitutable. Whereas digital technologies are easily imitable, the culture and practices of sharing knowledge throughout the whole supply chain is more dynamic and complex, thus making it more difficult to copy. The current research lacks suggestions about what these capabilities could be. The approach of this thesis into contributing to this gap is twofold: to systematically analyze the existing literature, and then, to create an explorative model to describe the phenomenon.

The systematic literature review (SLR) showed that the interest towards this topic is on the rise as of the 63 articles reviewed, 35 were published in 2020. Majority of the studies were conducted in developing nations as only nine articles were located in Europe or USA. Approximately a third of the papers addressed Industry 4.0 as a whole, whereas the others focused on one or more digital technologies specifically. Big data and analytics was by far the most investigated (28 occurrences), followed by Blockchain (17), Internet of things (9), and Artificial intelligence (1). In total, only 14 articles applied a theory and dynamic capability theory (6), and resource-based view (4) were the most frequently used in the sample. Content analysis-wise, the papers were divided into three categories based on the sustainability approach used. 26 papers focused only on environmental issues, and 9 on social, whereas 28 papers applied a triple-bottom-line approach. The economic perspective is not mentioned separately as it is often seen as a highly integrated element of the other pillars of sustainability; there can't be environmental or social sustainability if the company

isn't financially sustainable at the first place. Disregarding the three categories, some topics arose above others. For example, barriers and enablers for adoption of digital technologies and the big data related capabilities were discussed in many papers. However, only a handful of articles touched the information sharing in relation to the digital technologies and sustainability, and even fewer addressed the topic of what could be the factor between the emerging industry 4.0 technologies and supply chain sustainability.

The results of the exploratory model prove the significancy of digital technologies but show that they are not the way to reach the sustainability alone. A more comprehensive architecture is required, which comes in the form of supply chain platforms. These are digital platforms that consists of the various digital technologies and which are used to manage the highly complex supplier base. These platforms and systems generate a massive amount of data that needs to analyzed in order for it to be usable in day-to-day processes. In this step, the big data analytics comes into picture. The results show that the link between SC platforms and information sharing is not significant ($p>0.01$), but after BDA is applied the path gets statistically significant. Thus, the empirical results validate the suggested model. The path from digital technologies and supply chain platforms formed from them via the enhanced use of BDA and information sharing capability to improved sustainability in the whole supply chain is statistically significant.

The results of this study, both from the SLR and the empirical mode, validate the existing literature but offer some new ideas as well. This study shows that the use of digital technologies can help companies achieving the desired sustainability goals, which supports the findings of Gobbo et al. (2018). By adapting and utilizing these emerging digital technologies, companies can improve their operations and find and eliminate actions that are unnecessary and that prevent sustainability. The results also present evidence for the findings of Li et al. (2020) who argued that the digital technologies are the backbone for the well-functioning supply chain platform. If companies want to achieve the possible benefits offered by the digitalization tools, they need to be able to combine the technologies and to get them to work together.

Visconti and Morea (2019) posited that papers that show how BD can support sustainability is supply chains are lacking. In line with Yu et al. (2018), the results of this thesis prove that

a supply chain being data driven has great benefits to information sharing. Solely generating data with various platforms does not help in information sharing endeavors but the help of BDA is required. The companies must be capable to utilize the massive amounts of data they gather nowadays. Sophisticated data analysis methods assist in finding the core of message, from the numbers and other forms of data, and this can then be exploited in the business processes, in information sharing between organizations, for example. All this makes it possible to generate data, analyze it, make decisions based on them and then share them simultaneously. The capability to share information exactly when it is necessary is getting possible. These findings correlate with the study by Dubey et al. (2019).

However, the capability to share information effectively is the ultimate objective only for few organizations. It should be a way to achieve other goals. The results show that the information sharing, enabled by technologies, platforms and big data analytics, in fact, enhances the sustainability practices in companies and their supply chains. This is supported by, for example, Wong et al. (2017) and Beier et al. (2018). By sharing timely and relevant data amongst the members in the supply chain, the organizations can achieve sustainability improvements. It is crucial to communicate and cooperate in today's highly competitive and complex business environment in order be profitable, or even survive.

As posited by Müller et al. (2020) the existing research has paid only little attention to information sharing in Industry 4.0 context. Also, as found out during the SLR process, but also by Isensee et al. (2020), digitalization, organizational culture, and sustainability have often been studied separately. This study contributes to the existing literature by combining the concepts of Industry 4.0, information sharing, and sustainability. More specifically, this study answers for the call to investigate the element between Industry 4.0 and supply chain sustainability. This research offers a novel perspective and combines the concepts of Industry 4.0, information sharing and supply chain sustainability and shows their connection. The main argument of this research is that the information sharing is seen as a dynamic organizational capability that can enhance the use of gathered and analyzed data in a way that will lead to increased sustainability performance in the whole supply chain.

6 CONCLUSIONS AND IMPLICATIONS

This study has investigated the relationship between digital technologies, information sharing and sustainability in supply chains. The thesis process began with describing the key concepts regarding the research setting. Then, a systematic literature review, during which the existing literature was reviewed and analyzed. Based on the findings from SLR, the research gap was defined, and the hypothesis formulated. Then, an explorative PLS path model was developed to test them. The results show that in order to gain sustainability benefits with digital technologies, companies must constitute supply chain platforms and be able to analyze the data gathered with them. Then the generated information needs to be shared with right members in the network in order to actually achieve the improved sustainability.

The conducted systematic literature provided an overview on the current situation of the existing research on the field and helped in identifying the research gap. This research addresses the gap between digitalization and sustainability and proposes information sharing as the major element between them. This study is also one of the first to study the concepts of digitalization, information sharing and supply chain sustainability in a holistic way, rather than in isolation. In addition to the abovementioned, this study adds to the theory by analyzing the interaction between humans and machines (Esmaeilian et al., 2020) and by examining how to create a culture that is truly data-driven in order to promote sustainable big data initiatives amongst supply chain partners (Chiappetta Jabbour et al., 2020).

When it comes to managers, this research provides a rough conceptual framework on the topic of sustainable supply chains and industry 4.0. The framework helps in understanding the relationships between the concepts and clarifies the fact that the technologies itself aren't the way to success. Managers needs to realize that it is the combination of these tools, which is required. Additionally, it is important to comprehend the need for analyzing the gathered data critically and efficiently, and to create valuable information from it. Only then is it possible to get access to the actual sustainability enabling element - information sharing. In today's fierce business environment it is the supply chains that compete together, not the individual companies anymore. For this reason, it is imperative for companies operating within the same supply chain to share information. This research shows the importance of first acquiring the basic technologies which are then combined to form supply chain

platforms. They are then used to manage and coordinate the supplier network, and in the process, they generate data that needs to be analyzed with big data analytics methods. Managers today require timely and relevant data to support their decision making. The criticality of the trustworthiness of the data cannot be disregarded as, partial or even inaccurate data may lead to crucial consequences.

Information sharing has many applications in modern supply chains when aiming for sustainability. It can, for example, drastically decrease the total costs and efforts. A scenario in which one company that has already adapted a procedure of some sort and then shares and teaches it to the other members of the network, is much cheaper more convenient and less time consuming, compared to one in which every company would have to make the initial investments by themselves.

This study has some limitations that could be addressed in future studies. Firstly, the systematic literature review was conducted using only two databases. This may have resulted in limiting out some key papers. So, in future studies, it is suggested to use a larger variety of databases in order to get more comprehensive results. Secondly, the survey was carried out exclusively in Finland, which poses clear limitations. A future researcher could expand this setting into a larger geographical area to investigate the generalization of the presented results. Thirdly, this study applied only quantitative methods. To get wider results in the future, it is recommended to use quantitative methods as well to reach more robust results.

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APPENDIX 1. The articles included in the systematic literature review

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APPENDIX 2. Path significances.