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Master's Thesis

Master's Programme in Supply Management

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UTILIZING SUPPLY CHAIN ANALYTICS TO IMPROVE SUPPLY CHAIN SUSTAINABILITY

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ABSTRACT

Lappeenranta-Lahti University of Technology LUT
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Utilizing supply chain analytics to improve supply chain sustainability

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The objective of this thesis is to identify how supply chain analytics can be utilized in sustainable supply chain in order to improve sustainability. Additionally, this study aims to examine possible future opportunities and barriers in this area. To achieve these objectives previous studies of on these subjects were addressed and qualitative research was conducted using semi-structured interviews. In total five Finnish companies from different industries were interviewed.

The results of this study indicate that supply chain analytics can be effectively used to improve supply chain sustainability in multiple areas. In this study three main sustainability factors were identified and further studied. These three factors were demand planning, transparency and transportation. Based on theoretical and empirical findings, these three sustainability factors were found to be important from both sustainability and supply chain analytics perspective.

According to the findings of this study companies also tend to experience similar barriers or challenges when implementing or using supply chain analytics. Challenges identified in this study were also aligned with findings done in previous studies. Besides similar challenges, it was found that the companies appeared to have also industry specific challenges.

As theoretical and empirical finding of this study indicate supply chain analytics is not yet widely used in improving supply chain sustainability. The results however indicate that there are multiple opportunities are already identified in this area. Therefore, it is predicted that supply chain analytics will become more integrated part of supply management and sustainability in the future.

TIIVISTELMÄ

Lappeenrannan-Lahden teknillinen yliopisto LUT
School of business and management
Master's Programme in Supply Management

Niina Taipale

Toimitusketjuanalytiikan hyödyntäminen toimitusketjun kestävyyden kehittämisessä

Pro gradu -tutkielma
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81 sivua, 7 kuvaa, 1 taulukko
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Tämä pro gradu -tutkielma keksitty tutkimaan toimitusketjuanalytiikan mahdollisuuksia toimitusketjun kestävyyden ja vastuullisuuden kehittämisessä. Lisäksi tutkimuksen tavoitteena on tunnistaa mahdollisia tulevaisuuden mahdollisuuksia, joita toimitusketjuanalytiikka tarjoaa tällä osa-alueella. Lisäksi tutkielmassa pyritään tunnistamaan tämänhetkisiä esteitä toimitusketjuanalytiikan hyödyntämiselle. Näiden tavoitteiden saavuttamiseksi tutkielmassa tehtiin laaja katsaus olemassa olevaan kirjallisuuteen sekä toteutettiin kvalitatiivinen tutkimus. Tutkimusmenetelmänä käytettiin puolistrukturoitua haastattelua. Haastatteluihin osallistui viisi suomalaista yritystä eri toimialoilta.

Tutkimuksen tulokset osoittavat, että toimitusketjun vastuullisuutta voidaan kehittää useilla eri osa-alueilla toimitusketjuanalytiikan avulla. Tässä tutkimuksessa löydettiin kolme osa-aluetta, jotka nousivat erityisen voimakkaasti esille sekä tässä että aiemmissa tutkimuksissa. Nämä osa-alueet olivat kysynnänennustaminen ja -hallinta, läpinäkyvyys ja kuljetukset. Nämä kolme osa-aluetta osoittautuivat merkityksellisiksi sekä kestävyys, että toimitusketjuanalytiikka näkökulmasta.

Tutkielmassa huomattiin, että yritykset kokevat sekä samankaltaisia, että toimialakohtaisia haasteita hyödyntäessään toimitusketjuanalytiikkaa. Tutkimuksessa esiinnousseet haasteet toistuivat myös aiemmassa kirjallisuudessa. Tutkielman löydökset myös osoittivat, ettei toimitusketjuanalytiikka hyödynnetä vielä täysimittaisesti, mutta sen arvioidaan tuottavat merkittäviä kestävyyshyötyjä tulevaisuudessa. Toimitusketjuanalytiikan ennustetaan myös tulevan yhä kiinteämmäksi osaksi toimitusketjun johtamista ja kestävyyskehitystä.

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This thesis process has been a lot like my university studies in general; sometimes exhausting and never ending but eventually rewarding and over before you know it. These years at LUT have taught me a lot and also given me amazing friendships. So first I would like to thank all my friends for the countless hours of studying together, prolonged coffee breaks, collaborative panicking and of course all the amazing moments outside of our studies. My special thanks goes to Linda who has been invaluable support especially during this thesis process.

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Last but not least I want to thank my family and especially my mom for all the support along the way.

In Helsinki, March 21st 2020

Niina Taipale

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1. Introduction

As sustainability has gained importance in general, its relevance in supply chain management has also risen significantly in recent years (Kersten, Seiter, von See, Hackius & Maurer 2017). Literature shows that the number of publications related to sustainable supply chain management has increased steadily in the past decades but during the past ten years the amount of publications has exploded (Winter & Kneymeyer 2013). However, while the number of sustainability related articles has risen inside supply chain literature, supply chains are still underrepresented in overall sustainability literature (Seuring & Müller 2008). As supply chains have been identified to produce over 90% of the company's total environmental impact and social issues have been strongly linked to supply chain activities, it is clear that sustainable supply chain management needs more attention (Bovén & Swartz 2016).

For long sustainability has been considered only from environmental perspective and thus, its importance and effect have only been evaluated from the environmental perspective. However, as recent studies have shown, sustainability efforts do not only concern environmental factors and social aspect of sustainability has also gained significance and can no longer be neglected. Additionally, sustainability can in fact even provide financial profits and competitive advantage (Carter & Rogers 2008; Khan, Hussain & Saber 2016). Thus, there are multiple internal and external factors identified to drive this change towards more sustainable supply chains, some of those drivers being more compulsory than others (Carter & Rogers 2008; Mann, Kumar, Kumar & Mann 2010; Seuring & Müller 2008).

Another rising trend in supply chain management is the usage of data and analytics. Digitalization and developing technology have created new opportunities in the form of for example IoT, Big Data, RFID tags and AI. In addition, and partially because of this development, companies are gaining more and more data about their business processes and becoming more aware of the opportunities for using that data. Studies have found that opportunities of data-driven processes can be measured

on both financial and operational levels (McAfee & Brynjolfsson 2012). In fact, data and analytics has been stated to have potential to transform entire business process (Wamba, Akter, Edwards, Chopin & Gnanzou 2015). This change is also starting to slowly enter supply chain management and thus, the popularity of supply chain analytics is increasing. Since all long-term trend and goals in supply chain management are somewhat related to digitalization and utilization of data, gaining more knowledge of this subject is critical to both practitioners and scholars (Kersten et al. 2017).

As noted, both sustainability and supply chain analytics have a key role in the future development of supply chains. However, by combining these two even greater advantages can be achieved. For example, Jeble, Dubey, Childe, Papadopoulos, Roubaud & Prakash (2018) found that supply chain analytics can have a positive impact on all sustainability dimensions. Supply chain analytics can improve sustainability for example by providing timely and accurate data, as sustainable development is often hindered by the fact that companies don't have sufficient knowledge about true impact of their actions on the environment or social issues (Tseng, Wu, Lim & Wong 2019). These opportunities provided by the combination of sustainability and supply chain analytics have been recently identified by multiple scholars (Hazen, Skipper, Ezell & Boone 2016; Jeble etl al. 2018; Dubey, Gunasekaran, Childe, Papadopoulos & Wamba 2017; Keeso 2014; Zhu, Song, Hazen, Lee & Cegielski 2018; Mani, Delgado, Hazen & Patel 2017; Tseng et al. 2019). However, there is still a lack of empirical studies regarding this subject (Dubey et al. 2019; Wamba et al. 2015). Most of the existing studies also tend to focus on examining whether there is a connection between usage of supply chain analytics and improved supply chain sustainability, but there seems to be a lack of studies addressing the reason for this connection.

1.1 Research problem and objectives

The aim of this study is to address the gap in literature regarding the use of supply chain analytics to drive sustainable supply chain management. The current literature has addressed the issue as a question whether supply chain analytics can affect sustainability or not. Only a few studies have drilled deeper to understand which supply chain aspects or parts can be affected by supply chain analytics. However also these studies tend to focus only on the connection. The question of how supply chain analytics can affect sustainability of supply chain remains unanswered. Hence, the objective of this study is to address this gap. To support this research objective, this study also aims to understand what barriers there are for adopting supply chain analytics and what future opportunities supply chain analytics can offer from sustainability perspective. To gain insight to this issue also more complete picture of the main concepts is conducted. Based on these objectives following research questions are formed.

Main research question is:

"How can supply chain analytics help in improving supply chain sustainability?"

Supporting sub-questions are:

"What is supply chain analytics?"

"What are the potential barriers for adopting supply chain analytics?"

"What are the future opportunities of supply chain analytics from sustainability perspective?"

This study is conducted followingly. In the first part of this study the concepts of sustainability and sustainable supply chain management are issued on a higher level. On the second part of theory sections, the focus is on supply chain analytics. In this part the concept itself is defined as well as the basic characteristics it holds. To achieve the objective of this study the concept of supply chain analytics is then

examined from supply chain sustainability perspective. The empirical part of this study focuses on the issue from the perspective of the practitioners. Based on qualitative research conducted by interviewing different company representant more complete view of the issue is formed and the insight gained from the theoretical part is complemented.

1.2 Conceptual framework

The conceptual framework of this study aims to present the key concepts of this study and the relationships between them. As the research questions show, the main objective of this study is to examine the relationship between supply chain analytics and supply chain sustainability. Based on findings of previous studies three sustainability factors - demand planning, transparency and transportation - were selected as the main interest points for this study (e.g. Kache & Seuring 2017; Tseng et al. 2019; Kaipia, Dukovska-Popovska & Loikkanen 2013; Lieb & Lieb 2010; Souza 2014). These key concepts and relationships are presented in figure 1.

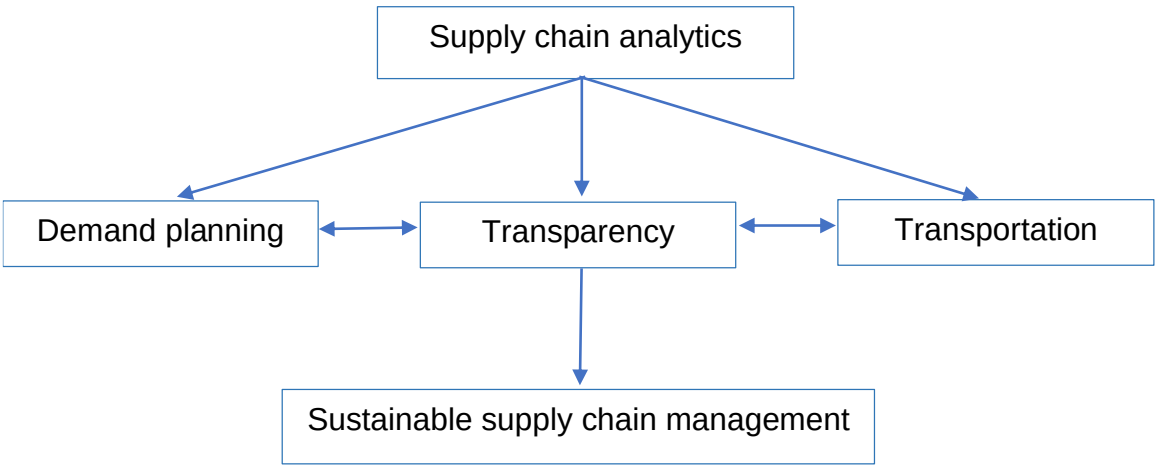

Figure 1. Conceptual framework

The aim of this study is to address the relationship between supply chain sustainability and supply chain analytics. Due to the complexity of sustainability three main sustainability areas were identified for the purposes of this study. These areas are displayed in figure 1 and as the figure shows there is also interrelation between these sustainability aspects. Demand planning, transparency and transportation were selected due to their relevance from supply chain analytics perspective and high importance for sustainability. Thus, sustainability in supply chain analytics is mainly considered through these aspects in this study.

1.3 Key concepts of the study

In this section the key concepts used in this study are defined. These concepts are discussed more thoroughly in the theoretical part of this study.

Sustainability = balance between three aspects- economic prosperity, environmental quality and social equity (Elkington 1997).

Sustainable supply chain = "the creation of coordinated supply chains through the voluntary integration of economic, environmental, and social considerations with key inter-organizational business systems designed to efficiently and effectively manage the material, information, and capital flows associated with the procurement, production, and distribution of products or services in order to meet stakeholder requirements and improve the profitability, competitiveness, and resilience of the organization over the short- and long-term" (Ahi & Searchy 2013).

Supply chain analytics = use of analytical tools and approaches in supply chain environment in order to make more informed decisions and ultimately improve supply chain performance (Zhu et al. 2018; Souza 2014).

Supply chain transparency = the availability of information for supply chain member regarding the sustainability of products and processes performed internally and externally by any supplier tier.

1.4 Research methodology

The theoretical part of this study is strongly based on earlier studies of the issue. The literature aims to use a wide array of articles from different scholars and time periods to ensure the accuracy and comprehensiveness of the study. However, as usage of supply chain analytics is quite recent phenomenon especially on sustainability issue, more recent studies are emphasized. Due to lack of direct studies of supply chain analytics and sustainable supply chain management together, results of different studies are combined to form more complete view.

The empirical part of this study is a qualitative research. Qualitative approach was selected for this study because of the nature of the research issue. As stated, there is lack of studies that would give insight into how supply chain analytics is used to improve supply chain sustainability. As qualitative research is typically used to answer *how* questions and thus to gaining insight to less known phenomenon it was best suited for examining this issue (Eriksson & Kovalainen 2008) Primary data collected through 5 semi-structure interviews was used in this study. The interviews were used to gather information of the issue and to further analyse the underlying phenomenon.

As this study is qualitative and the number of interviewees is limited, it is clear that this study only covers limited perspective on the issue. As many qualitative studies the aim of this study is to shed light on the issue and to provide knowledge for further studies. Therefore, complete and universal view of the issue can’t be formed based on this study.

2. Sustainable supply chain management

To be able to assess how supply chain sustainability can be improved, it is first critical to be able to understand the underlying concepts. As both concept of sustainability as well as the concept of sustainable supply chain management are complex and even hard to define, conducting precise and complete definitions for these concepts is critical. Therefore, the following chapters focus on forming complete view of these phenomenon.

2.1 Sustainability

Even though sustainability seems to be the rising concept in today's business environment, sustainability itself is not a new concept. Economists have been interested in sustainability for centuries and since sustainability has entered management literature in 1990's it's importance has increased rapidly (Linton, Klassen & Jayaraman 2007). Despite of the long history there still isn't clear consensus on the definition of sustainability (Carter & Rogers 2008; Ahi & Searcy 2015). Probably the most commonly known and cited definition for sustainability or more precisely for sustainable development was proposed by Brundtland's Commission (1987). This definition states that "s*ustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". Since Bruntland's famous definition there has been multiple different definitions that have emphasized different aspects of sustainability. However, Elkington's (1997) triple bottom line approach to sustainability, which is based on Bruntland's definition, has been widely recognized and used as the concluding definition for sustainability. According to triple bottom line approach sustainability can be achieved by considering three different aspects – economic prosperity, environmental quality and social equity (Elkington 1997). Elkington's triple bottom line definition for sustainability is presented in figure 2.

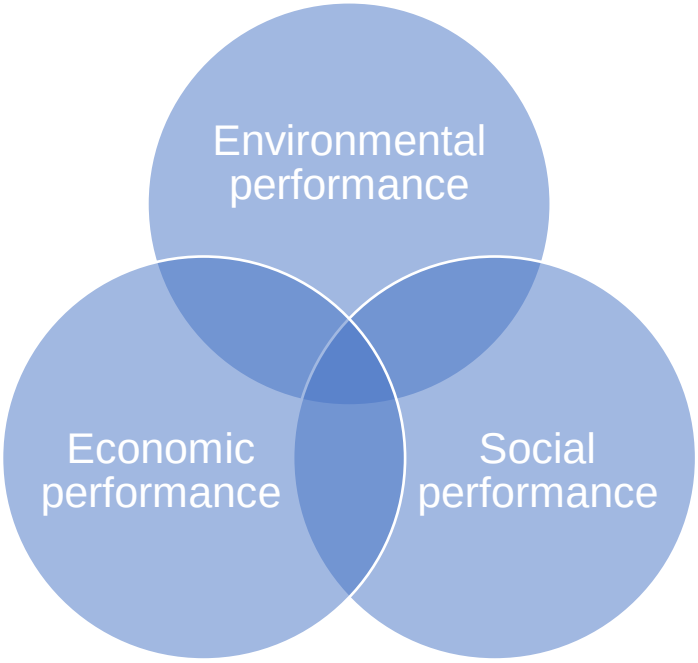

Figure 2. Sustainability triple bottom line (Carter & Rogers 2008)

More specifically economical sustainability means that the company is able to ensure liquidity and produce returns to its shareholders (Dyllick & Hockerts 2002). To be environmentally sustainable, eco-system should not be endangered, emissions produced should be at a rate that the environment can naturally absorb or assimilate them, and natural resource usage should be less than their natural reproduction. (Dyllick & Hockerts 2002) Social sustainability in turn has bipolar definition referring to both individual and collective dimensions (Lehtonen 2004). This means that to be socially sustainable companies must consider the effects for communities in the bigger picture as well as social effects its actions cause to individuals, such as employees (Dyllick & Hockerts 2002).

Even though sustainability is defined as a combination of three dimensions, these different dimensions are not equally treated. Dubey et al. (2017) state that social dimension is overshadowed by environmental and economic dimensions in the current literature. This phenomenon can be clearly seen in the literature where environmental issues dominate sustainability related literature (Ahi & Searchy

2013). Another issue found in sustainability literature is the lack of research on the integrated approach that would take all sustainability dimensions and the interrelation between them into consideration (Ahi & Searchy 2015).

2.2 Sustainable supply chain management

To extend sustainability to supply chains an integration between triple bottom line approach and the concept of supply chain management is needed. According to Pagell & Wu (2009) sustainable supply chain will not produce net harm to environment or social system but is still capable of creating profit in a long term. If customers are willing this kind of sustainable supply chain would be able to continue to do business forever. Carter & Rogers (2008) add to this definition that in sustainable supply chain these three aspects are integrated to the coordination of business' interorganizational processes. This integration is the base for improving the long-term economic performance of the supply chain as well as performance of an individual company. However, for the purposes of this study Ahi & Searcy's (2013) definition for sustainable supply chain is used, since it is comprehensive and relatively recent definition. They define sustainable supply chain as "*the creation of coordinated supply chains through the voluntary integration of economic, environmental, and social considerations with key inter-organizational business systems designed to efficiently and effectively manage the material, information, and capital flows associated with the procurement, production, and distribution of products or services in order to meet stakeholder requirements and improve the profitability, competitiveness, and resilience of the organization over the short- and long-term."*

As there are multiple different definitions for sustainable supply chain management, there is also different terms which refer to it. Different terms and synonyms have been regularly used to describe what is defined as sustainable supply chain management. Most commonly used synonyms include green supply chain

management, responsible supply chain management and corporate social responsibility. In addition, different variations of sustainable sourcing, such as green purchasing, responsible purchasing and ethical purchasing, can also be used as synonyms to sustainable supply chain management. (Pagell, Wu & Wasserman 2010)

2.2.1 Drivers for sustainable supply chain management

To understand the popularity and importance of sustainable supply chain management it is critical to address the factors that drive sustainable development in supply chain environment. Several drivers have been identified for sustainability efforts and the importance of each driver differs between companies. Here the most commonly mentioned and the most influential drivers are further introduced.

Legislation has been identified as driver for supply chain sustainability by multiple scholars (Mann et al. 2010; Carter & Rogers 2008; Ortas, Moneva & Alvarez 2014). Legislation can drive sustainability adoption in two ways. First, legislation can form constraints that force companies to adopt sustainable practices as companies either need to comply with legislation or exit the markets (Mann et al. 2010). Besides acting as constraint legislation can also encourage companies to voluntarily implement more sustainable practices. By improving sustainable performance voluntarily legislation related risks can be reduced or company can rewarder for example in form of tax benefits (Carter & Rogers 2008).

Customer pressure is another remarkable driver for sustainable supply chain management. Due to rising importance of sustainability in general, customers are beginning to demand more sustainable products. By investing in sustainability issues companies can avoid risks related to reputation loss and boycotts (Seuring & Müller 2008). This can be described as adapting to customer demands to avoid

risks. Customer demands can also drive sustainability improvements in another way. Companies may improve their sustainability to achieve competitive advantage through customer attraction (Sajjad et al. 2015). As customers are becoming more environmental and socially aware, companies can can attract customers by embracing these values and thus gain competitive advantage. For customer pressure to drive sustainable improvements it is critical to be able to proof the state of supply chain's sustainability (Sajjad et al. 2015).

According to Brockhaus et al. (2013) the economic perspective is critical in implementing sustainability. Their research showed that companies are willing to implement sustainable initiatives if they also provide economic benefits. Also Tseng et al. (2019) found that achieving economic stability and economic benefits act as drivers for adopting sustainable practices. Fortunately, sustainability initiatives have been identified to provide also economic benefits which could drive sustainable development. Sajjad, Eweje & Tappin (2015) state that improving sustainable performance of the supply chain can provide economic benefits not only directly but also in a long term. For example, by avoiding sustainability related risks, it is possible to ensure sustainable and long-lasting growth, which according to triple bottom line is part of achieving sustainability. Both Carter & Rogers (2008) and Sajjad et al. (2015) also name growing business opportunities, increased efficiency, reduced production and labour costs to be economic factors that are pursued through sustainable supply chain management.

Whereas the other drivers have indirectly driven sustainable development of supply chains, also actual sustainability concerns have been identified to drive sustainability. Current alarming environmental situation and the environmental impact of company's activities also drive companies towards more sustainable practices. However, it is hard to distinct the extent to which this concern independently drives sustainable development and how much of it originates from other drivers such as customer pressure and legislation. (Mann et al. 2010) Social

sustainability related issues such as workforce safety and human rights have also been identified as drivers for adoption of sustainable supply chain management (Tseng et al. 2019).

2.2.2 Barriers for adopting sustainable supply chain management

Sustainability has gained importance in all business areas and supply chain management is not an exception. However, companies are still struggling to adopt sustainability initiatives. Therefore, it is critical to identify the barriers that cause inefficient implementation of sustainable supply chain management practices.

Ahi & Searcy (2015) identified the complexity of sustainability as the key barrier for building sustainable supply chain. They state that implementing sustainability is a complex process which involves numerous factors. This complexity is due to a complexity of sustainability in general. As already suggested when defining sustainability, the concept tends to be hard to grasp and thus also difficult to turn in to actions. Different supply chain actions also affect different sustainability dimensions in multiple ways creating a complex, interrelated web of causalities (Abbassi & Nilsson 2012).

Abbasi & Nilsson (2012) identified costs as the most frequently mentioned barrier for implementing sustainability initiatives. They state that although sustainability is rated as important and desired aspect of supply chain, financial profits tend to drive supply chain management more prominently. Seuring & Müller (2008) endorse this view as they identified high costs as the most important barrier for sustainable supply chain management as well. As noted earlier many studies have proved that sustainability efforts can also produce financial benefits. Companies tend to however be hesitant to implement sustainable actions since the initial investments and profit losses might overshadow the long-term benefits (Carter & Rogers 2008).

As with many other organizational changes, lack of corporate strategy and commitment tend to form barriers for adopting sustainable practices (Tseng et al. 2019). Implementing sustainable supply chain management practices requires first clear corporate level strategy. However, good strategy itself is not enough. Successful implementation requires actions from the management as well as from employees. Sajjad et al. (2015) found that often the implementation process is hindered because there is lack of commitment from both management and employees. They state that people in the organization tend to have negative perception of sustainability and feel that it isn't important consideration in their personal work, or they are reluctant to make required changes to work practices.

3. Supply chain analytics

Supply chain analytics is not yet well-established term in supply chain management literature. Only few articles use term supply analytics or supply chain analytics but instead different terms like big data analytics, business analytics and predictive analytics are used interchangeably to describe the same phenomenon. In this study the term supply chain analytics is used as it combines different definitions and techniques under one concept. Supply chain analytics refers to use of analytical tools and approaches in supply chain environment in order to make more informed decisions and ultimately improve supply chain performance (Zhu et al. 2018; Souza 2014). Souza (2014) specifies that supply chain analytics especially aims for more accurate interrelation of supply and demand. More specifically supply chain analytics can be seen as a combination of three aspects defined by Chae & Olson (2013).

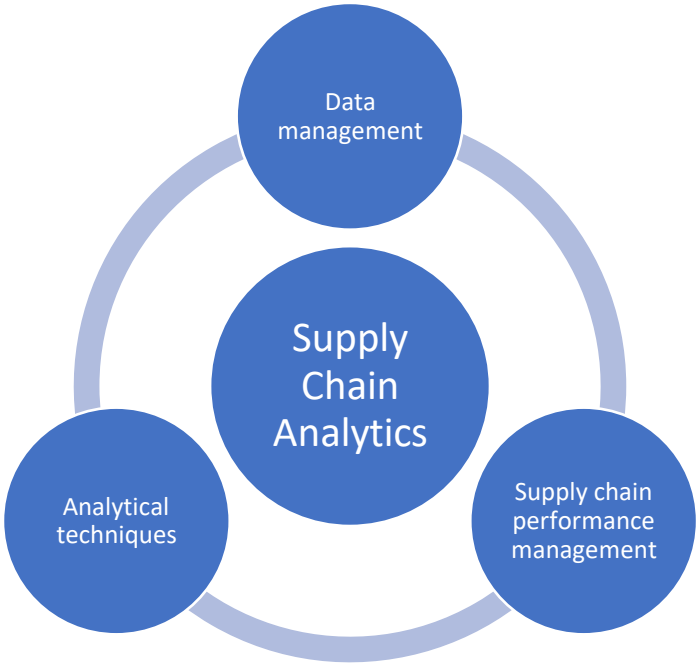

Figure 3. Framework for supply chain analytics (Chae & Olson 2013)

As present in figure 3 these three defining components are database or data, analytical knowledge discovery techniques and supply chain performance

management. These three components are interrelated as analytical techniques require data and business performance management is based on the first two. As said supply chain analytics is not as widely used in literature and therefore articles tend to use other terms to describe what is considered as supply chain analytics here. Most often big data analytics is used and as Wang et al. (2016) state, big data analytics is an integral part of supply analytics. Therefore, big data analytics can be used almost interchangeably since supply chain analytics is only a broader concept which includes big data analytics.

3.1 Big data analytics

As noted earlier big data has a critical role in supply chain analytics. As Souza (2014) states, big data has had a crucial role in the increased importance supply analytics. Therefore, it is critical to define what is meant by the term big data. Highly accepted and used definition for big data is to describe it through 3V's; volume, variety and velocity (McAfee & Brynjolfsson 2012; Gandomi & Haider 2015; Lamba & Singh 2016). Volume refers to the amount of data (Gandomi & Haider 2015). Variety of data refers to the heterogeneity of data which is a result from various types of data sources (Gandomi & Haider 2015). Velocity then refers to the speed of which data is generated and thus to the speed to which is should be acted upon (Gandomi & Haider 2015). Besides these traditional 3V's there is also two other aspects that are regularly used to describe big data. Veracity refers to the unreliability of data caused by the nature of certain data sources such as social media (Gandomi & Haider 2015). Variability in turn is linked to velocity. As velocity refers to the high speed on which data is generated, variability indicates the variation of this speed since the data flow is rarely consistent and instead it often has peaks and lows. (Gandomi & Haider 2015) Based on these five key elements of big data can be defined as an approach to manage, process and analyze 5Vs to gain actionable insight which can be used for creating sustainable value, measuring performance and achieving competitive advantage (Wamba et al. 2015). Jacobs (2009) states that point of time should be considered when defining whether data is

considered as big data. He agrees that big data is data that requires looking beyond conventional data handling methods but adds that these methods should be reflected on the point in time meaning that data that was considered big data in the past might not be big data today. Especially among practitioners there is inconsistency in usage of the term big data but one common description is that big data can be used to understand of industry's data and trend. By understanding the data companies can gain advantage as the gained knowledge can be used as a base for decision making. (Richey, Morgan, Lindsey-Hall & Adams 2016) This view highlights that big data should not only be considered from analytical point of view but more as an enabler for achieving competitive advantage through advanced collection, storage, organization and analysis of data (Wamba et al. 2015).

To integrate big data to supply chain environment a framework proposed by Lamba & Singh (2016) is used. As presented in figure 4 their framework considers the same 3V's as defined above but the source of the 3V's are considered in supply chain context.

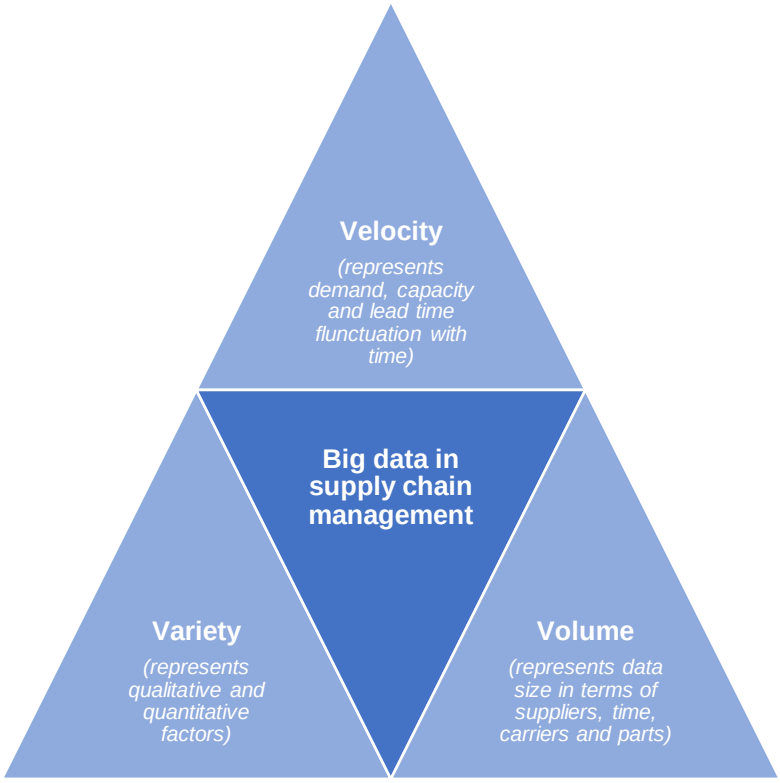

Figure 4. Framework for big data in supply chain management (Lamba & Singh 2016)

According to Lamba & Singh (2016) volume or data size originates from the number of suppliers and components and having large historical data sets. Variety can be considered either as quantitative or qualitative variety. Quantitative variety refers to clear quantitative parameters such as product types, demand data, time periods, number of supplier and number of products. Qualitative variety consist of factors that are often uniquely defined, such as supplier selection criteria or different ranking criteria. Lastly, velocity in supply context refers mostly to same factors as volume, for example demand patterns, product variety and the variance inside the factors.

3.2 Types of analytics

Different supply chain analytical methods are used differently in supply chain and their utilization and applicability differs. Descriptive analytics focuses on describing current and past events in the supply chain (Kamble, Gunasekaran & Gawankar 2020). In supply chain environment descriptive analytics is used to understand the current state of the supply chain (Souza 2014). The main purpose of descriptive analytics is to analyze existing process and to identify problems and opportunities within them and thus it is mainly used in operational management (Wang et al. 2016; Wu et al. 206).

Predictive analytics explores historical data to determine patterns and to project future events as well as to explain underlying reasons for those future events (Wang et al. 2016). In supply chain management this typically means demand forecasting (Souza 2014). Predictive analytics is applicable on both strategic and operational levels (Wu et al. 2016). According to Dubey et al. (2019) predictive analytics is currently the most used analytical method in supply chain analytics.

Prescriptive analytics is used in more complex situations and it typically uses multicriteria decision making, simulations and optimization techniques (Wang et al. 2016). Prescriptive analytics focuses on what should be happening and it is typically used in optimizations and as decision support tools (Souza 2014). According to Wang et al. (2016) prescriptive analytics has the widest applicability in supply chain environment both in strategic and operational side. The interest in predictive analytics has risen in recent years in supply chain environment as its future potential has been recognized but currently actual implementation is still limited (Kersten et al. 2017). Tiwari, Wee & Daryanto (2018) state this limitation in implementation of prescriptive analytics is mainly due to its relative complexity compared to other types of analytics.

4. Supply chain analytics and sustainable supply chain management

Big data and supply chain analytics have been identified as one of the main enablers for sustainable supply chains as it has been proven that supply chain analytics can positively affect company's sustainable performance (Dubey et al. 2019; Kamble et al. 2020). Data utilization and analytics have been identified to be both; driver for improving sustainable supply chain performance as well as being driven by the desire to transform supply chain to more sustainable one (Tseng et al. 2019). There are multiple ways in which supply chain analytics can affect supply chain sustainability and the effects impact multiple different supply chain dimensions. Thus, the overall impact can have major effect on supply chain sustainability. According Wang et al. (2016) supply chain analytics can improve supply chain's sustainability by effectively and efficiently collecting and analysing data which can be used to provide insightful information about supply chain actions for the purposes of forecasting, analysing and evaluating sustainability related issues. Tseng et al. (2019) summarize that supply chain analytics have the ability improve sustainability and reduce sustainability related risks by replacing imprecise "gut feeling" based evaluation with data-driven thinking and thus creating actual, measurable value instead of approximations. Supply chain analytics can help especially with sustainability issues that companies have long struggled with that are related to inability to evaluate sustainable performance because there is not enough reliable information or data regarding sustainability issues (Dubey et al. 2019). Even though scholars have widely identified importance of utilizing data in improving supply chain sustainability, practitioners are still struggling to integrate supply chain analytics as part of their sustainability improvement processes (Mani et al. 2017; Hazen, et a. 2016).

As mentioned earlier three sustainability factors were selected as key interest points in this study. Following section aims to explain why these three factors were selected. Transparency and more accurate demand planning are two frequently

mentioned application areas for supply chain analytics (Kache & Seuring 2017; Tseng et al. 2019; Wang et al. 2016). The level of supply chain transparency is highly reliant on information received from supply chain members as well as their ability to generate that information internally. As supply chain analytics focuses especially in generating accurate and useful data from supply chain activities and using that data to create insight, it also improves the perquisites for supply chain transparency (Bastian & Zentes 2013). By improving supply chain members' ability to generate data and utilize that data, it is possible to have more insight to what is actually happening in each supply chain phase and what are the actual effects of it. The same also applies to demand planning. Demand planning accuracy is also reliant on the information received along the supply chain about the end customer demand (Kaipia et al. 2013). This information is typically generated based on the information about past demand and possible future predictions. By utilizing actual data and effective analytical models to make these predictions, more accurate results can be achieved. This also highlights the interconnection between transparency and demand planning accuracy as the information about demand should effectively flow along the supply chain. Additionally, transportation is one significant supply chain area that can be affected by supply chain analytics. Many researchers have found that by using supply chain analytics transportation can be more effectively optimized (Lieb & Lieb 2010; Kache & Seuring 2017; Souza 2014). Supply chain analytics can affect by transportation optimization by providing accurate data about different factors that affect the logistics decisions as well as by providing tools to make those optimizations (Wang et al. 2016).

As all of these three dimensions, transparency, demand planning and transportation, have also been identified to have significant effect on supply chain sustainability both by themselves and indirectly as they affect also other sustainability related dimensions (Kersten et al. 2017; Carter & Rogers 2008; Tang & Zhou 2012; Kaipia et al. 2013; OECD 2010; Mani et al. 2017). Therefore, these three dimensions are elaborated in the following chapters.

4.1 Transparency

Transparency created by supply chain analytics has been identified as one of the top trends in supply chain management (Kersten et al. 2017). The reason for this development is clear; transparency has a significant role in improving the overall supply chain sustainability and it has even been identified the most significant building block in sustainable supply chain management (Carter & Rogers 2008). As Krause, Vachon & Klassen (2009) stated company is only as sustainable as its supply chain and suppliers. Therefore, the sustainability of each supplier in all tiers has a significant effect on the overall sustainability as well as the sustainability of higher tier companies. Hence, to ensure supply chain sustainability there needs to be enough information about sustainability issues in all supply chain levels and to generate that information and knowledge, transparency between supply chain members is required. In this study transparency is understood as the degree of access that each supply chain member has on relevant information about products, processes and flows of capital (Bastian & Zentes 2013). To add the sustainability dimensions to this Egels-Zandén, Hulthén & Wulff's (2015) definition is used. This definition considers both internal and external transparency and transparency is seen as a combination of being aware of suppliers in all tiers, sustainability conditions of those suppliers and purchasing practices in the supply chain, and of course being aware of the sustainability related effects of company's own actions. Thus, transparency of sustainable supply chain is considered as the availability of information for supply chain member regarding the sustainability of products and processes performed internally and externally by any supplier tier. Traceability, which sometimes is used interchangeably to describe transparency, has a critical role in enhancing high level of transparency. Traceability in this context refers to ability to trace the history of the product or service in relation to origin of the material and components, processing and distribution in order to ensure environmental and social compliance and validity of such claims (García-Torres, Albareda, Rey-García & Seuring 2019).

Information asymmetry between supply partners and different stakeholders has for long been a major barrier for transparency and thus to sustainability improvements in supply chains (Dubey et al. 2019). As Carter & Rogers (2008) explain companies should aim to transparent communication with different stakeholders to achieve sustainability. Carter & Rogers (2008) state that in supply chain context transparency about sustainability shouldn't only focus on reporting but also engaging stakeholders to sustainability improvements. Engaging suppliers and logistics partners is especially important for achieving desired sustainability goals since, as noted before, their actions directly affect these goals. Supplier's actions can for example hinder the adoption of sustainable management practices. (Sajjad et al. 2015) As for example Khan et al. (2016) study shows, information sharing between supply partners can further the reduction of both social and environmental costs which proves that transparency has a significant role in improving supply chain sustainability.

As noted, transparency has a critical role in ensuring and proving supply chain sustainability to multiple stakeholders. As Fritz, Schöggl & Baumgartner (2017) found, transparency and data sharing is the key for supply chain sustainability. Their study states that as sustainability related aspects and issues are constantly changing due to internal changes and development and because of external factors such as legislation. Therefore, transparency is needed to assess the current situation, identify potential issues and development areas. Hence, as other chapters in this study will highlight, transparency affects all most all sustainability aspects. Besides transparency being significant opportunity for improving sustainability, the sustainability created through high transparency is also estimated to create long term value for the supply chain (Richey et al. 2016).

The importance of transparency is also noted in supply chain analytics literature as several scholars have identified improved supply chain visibility and transparency as one of the most important opportunities created by supply chain analytics (Kache

& Seuring 2017; Roßmann, Canzanillo, von der Gracht & Hartmann 2018; Wamba et al. 2015). As Bastian & Zentes (2013) suggest transparency is reliant on the quality, availability, accuracy, accessibility and actuality of supply chain data. Therefore, it is clear that supply chain analytics can have huge impact on supply chain transparency by providing data itself and by generating that insight to the data. Kamble et al. (2020) specify that supply chain transparency is a result of collecting data through the whole supply chain and all its activities, such as sales, forecasts, demand, inventory, lead times and customer preferences. Also Yu, Chavez, Jacobs & Feng (2018) found in their study that utilizing data in supply chain management positively impacts information exchange, interfirm activity, supply chain responsiveness and coordination, all of which have significant implication to supply chain visibility and transparency, and especially to information asymmetry. Even though analytical capabilities seem to improve transparency in all supply chain levels Zhu et al. (2018) suggest supply chain analytical investment should be especially made to demand forecasting, resource allocation and operations planning. According to their study these areas have the most significant impact on transparency. As Kache & Seuring (2017) summarize supply chain analytics can provide end-to-end supply chain transparency.

Improving and especially measuring social sustainability has been identified as one of the major issues in sustainable supply chain management. Studies have proven that supply chain analytics has the ability to positively impact social performance (Jeble et al. 2018; Dubey et al. 2019). Transparency created by increased amount of data and supply chain analytics is a significant enabler for this. Supply chain analytics enables identification of current conditions regarding social development through analysing the available data and then converting that to useful information (Tseng et al. 2019). Hence, through transparency supply chain analytics is able provide tools to measure and examine sustainability are that is typically been hard to grasp.

4.2 Demand planning

According to Mani et al. (2017) especially forecasting future events and trends with supply chain analytics is gaining popularity. As Kaipia et al. (2013) state accurate demand planning has a key role in sustainable supply chain management since forecasts produced form the base for many other supply chain functions, such as production, logistics and packaging. Demand is the core of any activity performed by a company because it dictates whether production should take place and in what quantity. Hence demand also controls consumption of resources. Since the consumption of resources, and especially scarce natural resource, significantly affect supply chain's sustainability, controlling the use of resources is a critical element in improving sustainability. (Tang & Zhou 2012) As said demand is basis for use of resources and therefore it is crucial to use accurate demand forecasts to ensure that resources are consumed in a right quantity.

Supply chain analytics can in turn enable more efficient and accurate demand planning and inventory management (Kache & Seuring 2017). Improved forecasting and the resulting improved decision making have been noted as key success factors achieved through supply chain analytics and data usage (Richey 2016). As found in study conducted by Roßmann et al. (2018) supply chain analytics offers significant improvements to demand forecasting and helps reducing inventory levels. They found that both demand planning and stock control are highly impacted by utilization of supply chain analytics. They state that by using supply chain analytics accuracy of demand planning will increase significantly which reflect directly to the inventories. As noted earlier since demand has a dictating role in supply chain management and it affects many activities that have negative impact on sustainability, improved demand management can have significant impact on supply chain sustainability. This conclusion is endorsed by Ji, Gunasekaran & Yang (2014) who found in their study that more accurate demand forecasts improve supply chain sustainability by mitigating carbon footprint of the supply chain.

Wang et al. (2016) point out that supply chain analytics can be effectively used to make demand planning and inventory management more responsive to actual demand which typically leads to reduction of unnecessary inventories and lower resource wastage. One key reason for demand planning not being able to respond to actual demand has been the lack of data and especially lack of accurate data. According to Kersten et al. (2017) only 50% of data demand in supply chains is satisfied. Data has been lacking in both the required volume as well as needed accuracy since it is often not collected for demand forecasting purposes but rather modified from other data sources. (Taylor & Fearne 2009) Another reason for inability to make accurate demand forecasts is seasonal variation and market changes. According to Kersten et al. (2017) analytics can provide improvements especially when demand fluctuations, such as seasonality and irregularities, occur. They state that in traditional demand planning fluctuations are hard to foresee but accurate and intelligent analytics can provide more precise information of the markets and thus more reactive demand planning is achieved. The same also applies to changing market trends which can significantly affect future demand (Richey 2016).

4.2.1 Inventory and warehousing

Warehousing and related material handling cause a significant amount of the total environmental effect caused by supply chains due to their energy intensiveness. High energy consumption of warehousing is caused by need for lighting, heating, cooling, ventilation, air conditioning and additionally because of the energy required by different equipment needed for material handling (Ries, Grosse & Fichtinger 2017). The carbon footprint caused by the high energy consumption can however be reduced and optimized for example by minimizing stock levels and managing inventories more efficiently (Bonney & Jaber 2011). As stated, supply chain analytics can improve demand forecasting accuracy and through that reduce

inventory levels and as Dey et al. (2011) confirm, this can also have a positive impact on supply chain sustainability through reduced carbon footprint. Also Bonney & Jaber (2011) found that minimizing stocks can reduce the negative environmental effects caused by warehousing. Besides reducing the amount of emissions produced, lower or more optimal inventory levels optimize the use of these resources as warehousing activities performed will create value in the supply chain. In longer term, lower inventory levels also lead to smaller facilities since the required space is optimized to respond to actual needs. Smaller or more efficiently used facilities in turn require less energy per product which reduces the amount of emission produced in the supply chain. (Franchetti, Bedal, Ulloa & Grodek 2009)

4.2.2 Wastage

Supply chain analytics and better demand management can also reduce the amount of waste produced in supply chains. Fritz et al. (2017) found waste to be one of the significant sustainability aspects that could be improved through usage of data and supply chain analytics. They state by utilizing supply data waste can be prevented and in addition resources can be more efficiently reused, collected, separated and disposed if prevention is not possible. As Mena et al. (2011) state by managing waste more efficiently negative environmental impacts can be reduced since for example resources and transportation are used more efficiently. Rao & Holt (2005) and Kaipia et al. (2013) also add that by minimizing waste also supply chain actions causing negative environmental impact without producing any value will be minimized. Since poor forecasts and inefficient demand management have been identified as causes for waste, supply chain analytics can be a significant enabler for efficient waste management as it provides more accurate forecasts leading to more accurate actions along the supply chain (Mena, Adneso-Diaz & Yurt 2011; Kache & Seuring 2017).

High level of wastage is a major problem especially in supply chains handling perishable goods and poor forecasts have been identified as one of the most common causes for this (Mena et al. 2011). Wu & Huang (2018) even identified reduction of food loss and waste to be the most influential factor regarding food supply chain sustainability. One key reason for that significance is that waste produced by the supply chains itself has a negative impact on sustainability but in addition this negative effect is amplified because the wasted product has already had negative social and environmental impact. If the product is wasted this negative impact is still produced but the desired value is not created (Kaipia et al. 2013).

4.2.3 Bullwhip effect

Additionally, more accurate demand planning and transparency achieved through supply chain analytics have been found to reduce sustainability issues caused by bullwhip effect (Paik & Bagchi 2007; Zhao et al. 2018). Bullwhip effect is used to describe a phenomenon where effect of small demand variation increases and amplifies along the supply chain (Wang & Disney 2016). Bullwhip effect is most significantly affected by demand forecast updating which refers to the amplification of demand and thus safety stock along the supply chain (Lee, Padmanabhan & Whang 1997). Bullwhip effect's impact on supply chain sustainability is not well established in the academic literature and for example social consequences of bullwhip effect are not noted in the literature (Wang & Disney 2016). However, the impact of bullwhip effect on sustainability can be addressed by considering the impact of bullwhip effect's consequences, such as excessive inventory levels, ineffective transportation and waste (Zhao et al. 2018).

Hoffmann (2017) suggest that by utilizing big data and supply chain analytics, bullwhip effect can be reduced considerably. First of all, by using past data to forecast future demand instead of using direct demand signals can prevent excessive reactions that causes bullwhip effect. More extensive amount of data,

created for example by big data, also offers more data points and thus more information about the demand which then enables reacting based on actual demand. (Hoffman 2017) According to Paik & Bagchi (2007) using actual customer demand as a basis for demand planning is critical for reducing bullwhip effect. As their study also concludes it is important that all supply members use this same customer demand information. This requires high transparency and information sharing in the supply chain. Therefore transparency and information sharing have also been identified as another major contributor for mitigating the negative environmental impact caused by bullwhip effect (Zhao et al. 2018; Wang & Disney 2016). Higher transparency and information sharing enable better and more accurate decision making, more accurate movement of product as well as more optimal transportation and inventory coordination (Barrat & Oke, 2007). As also stated in earlier chapters, supply chain analytics can enable high supply chain transparency through data sharing and thus, contribute in mitigating the negative environmental impact caused by bullwhip effect.

4.3. Transportation

From environmental perspective transportation has a critical role in supply chain sustainability. Huge amounts of products and raw materials are transported around the globe every day and this produces large amounts of GHG emission and therefore transportation has significant negative impact on the environment (Dey, LaGuardia & Srinivasan 2019). Overall transportation has found to produce as much as 15% of the overall GHG emissions globally (OECD 2010). As sustainability issues have become more important, companies have taken several measures to mitigate the negative impact caused by transportation. A study conducted by Lieb & Lieb (2010) found that many companies have used analytical approach to achieve their sustainability goals.

Especially predictive analytics is predicted to provide great benefits in transport optimization (Kersten et al. 2017). In their study Kache & Seuring (2017) identified that in the field of logistics supply chain analytics creates significant opportunities. Their study found that through supply chain analytics it is possible to track and trace products as well as trucks or other means of transportation. By having accurate data about movement of goods it is possible to optimize the routing and loading of the trucks which for example reduces the number of total kilometres driven. Minimizing the kilometres driven has been identified to improve supply chain sustainability as it reduces the amount of emissions produced by transportation (Lieb & Lieb 2010; Bonney & Jaber 2011). This is also supported by Mani et al. (2017) who identified that several social and environmental problems caused by transportation can be reduced by using supply chain analytics. In their study they found that by having timely data from the fleet, such as fuel consumption and driving behaviour, it is possible to reduce emissions through optimization. They also used this data to track social issues such as workforce safety, unethical behaviour and security. They were also able to address these social sustainability issues by identifying for example hazardous areas and risky employee behaviour. Besides optimization information gained by extent data can also be used to monitor different key performance indicators which can help to identify new or re-emerging sustainability issues (Lieb & Lieb 2010).

In addition, Dey et al. (2011) state that supply chain carbon footprint can be also reduced by optimizing the shipments in regards of loading. By minimizing empty driving of trucks, the amount of emission produced during non-value adding actions can be reduced. Supply chain analytics can enable this reduction since it can be used to effectively optimize vehicle routing in a way that reduces time driven without any cargo (Kache & Seuring 2017). Dey et al. (2011) also state that in order to minimize empty driving, routing has to be optimized which in turn requires information sharing between supply partners. As transparency and more efficient information sharing can also be achieved through supply chain analytics, it can be

stated that supply chain analytics can also positively affect this aspect of supply chain sustainability.

4.4 Barriers and enabler for supply chain analytics

As with any technological advancement or organizational change, there are specific barriers and enablers that can either hinder or advance implementation and usage of supply chain analytics. The purpose of this chapter is to first identify factors that act as enabler for supply chain analytics and secondly, to find factors that hinder the implementation process or usage are also examined.

4.4.1 Enablers for implementing supply chain analytics

As supply chain analytics highly relies on having accurate, timely and large enough data sets, main enabler for initialization of supply chain analytics is efficient data management (Barton & Court 2012). Therefore. the ability to generate data, and especially ability to generate quality data, is a key enabler to any supply chain analytic activities (Arunachalam, Kumar & Kawalek 2018). In supply and sustainability context data can be acquired from multiple sources across the supply chain. In the past internal systems have been the main source of data but due to technological development more and more data is generated through sensors, IoT, RFID tags and other actions performed during the supply process (Arunachalam et al. 2018). Due to increasing level of collaboration between supply chain members, data can also be acquired from other supply chain members. Hence, the volume of data has expanded but the form and source of it have also changed. As significant amount of the data generated is now unstructured, a significant success factor for supply chain analytics is the ability to process that data. To conclude ensuring data quality is the success factor that enables the implementation of supply chain

analytics since it is impossible to perform any analytics without good, clean data (Sanders 2016).

As the volume and complexity of data increases the capabilities to integrate and manage data become more important. According to Barton & Court (2012) besides having good data company must also have capabilities and tools to effectively analyze the data in order to transform the data to actionable insight. Arunachalam et al. (2018) describe these data integration and management capabilities as ability to collect, integrate, transform and store data from different, heterogenous sources. In addition to efficient data management, implementation of supply chain analytics also requires ability to actually perform the analysis (Arunachalam et al. 2018). Analytics capabilities include technical capabilities as well as employee skills.

However, having sufficient capabilities and tools for implementing supply chain analytics as part of company's daily practises is not yet enough. As with any business initiatives, integrating supply analytics as a part of company strategy and culture have been identified to also drive supply chain analytics, especially when it comes to sustainability (Rogríguez, Giannakis & Da Chuna 2018). For supply chain analytics to become integrated part of organizational culture three cultural characteristics are required; analytics has to be considered as an asset, management has to support the use of analytics and required data has to be available to anyone who needs it (Kiro & Shockley 2011). Sanders (2016) adds to the data availability that right data must be available in a right form to those who need it.

As noted, to integrate supply chain analytics as part of company's strategy and culture, top management support is needed. Wamba et al. (2015) however complement this view by adding that active engagement is required from the top management to successfully implement supply chain analytics. One significant reason for this is identified by McAfee & Brynjolfsson (2012). They state that top

management opinion is highly respected and used in company's decision making. However, to be truly data-driven, decision making needs to rely highly on data and it should not be overshadowed by top managements intuitive decisions. Therefore, top management has a key role in enabling this change in the company as the change is highly dependent on top managements behavior.

4.4.2 Barriers for implementing supply chain analytics

As any technology also supply chain analytics has its challenges. Studies have shown that regardless of the hype around supply chain analytics, it has not been widely adopted yet. For example, study conducted by Schoenherr & Speier-Pero (2015) showed that only 40 % of the companies used analytics actively in their supply chain management and about a half of the companies neither used nor did have any plans to use analytics in the future. Maybe the most concerning finding was that about 30 % of the respondent wasn't familiar with analytics. This shows that even though supply chain analytics and data usage in general have been a rising trends practitioners are have not been able to turn this opportunity in to action or they are haven't even attempted to do so. There are several reasons for this but often the key reason is lack of understanding the capabilities and resources required to successfully supply chain analytics practices (Arunachalam et al. 2018).

The most common reason for inability or unwillingness to adopt big data or analytics to supply chain management is lack of technological resources and employee skills (Kache & Seuring 2017; Kersten et al. 2017; Richey et al. 2016). This may be caused by lack of sufficient IT systems and thus inability to process the amount of data or not having appropriate tools available to further analyze the acquired data (Kache & Seuring 2017; Arunachalam et al. 2018). Lack of resources and capabilities cause for example inability to share data (Kersten et al. 2017). Besides lack of technical resources another significant barrier is lack of employee resources or skills (Kersten et al. 2017). Schoenherr & Speier-Pero (2015) identified

inexperienced employees as the most important barrier for adopting analytics as part of supply chain management process. Also Richey et al. (2016) found that companies experience significant lack of knowledgeable and skilled employees which hinders the adoption process.

Even if technology or data itself doesn't cause barriers for adoption of supply chain analytics poorly managed adoption process and unsuccessful change management might still cause the adoption process to fail (Arunachalam et al. 2018). Adopting new technologies and ways of work requires transformational change as well as cultural change (Kache & Seuring 2017). If these changes are not sufficiently managed and employees do not adopt new technologies as expected the implementation process might fail completely (Schoenherr & Speier-Pero 2015). As employee's personal conviction about the opportunities of supply chain analytics is identified as a main driver for successful adoption these factors are even more critical (Schoenherr & Speier-Pero 2015). In this phase especially top management support is identified as key enabler for successful adoption (Schoenherr & Speier-Pero 2015).

In many cases the data itself can cause a barrier for adopting analytical practices. Lack of sufficient, supply chain or sustainability related data is often identified as key barrier for using supply chain analytics. However, in reality the problem might actually be inability to identify the correct data or lack of knowledge on how to use available data. (Schoenherr & Speier-Pero 2015) Another significant issue in utilizing data is related to data quality. Even if there is supply chain related data available there might be problems with data quality or uncertainty about data integrity which form barriers for usage of that data (Kersten et al. 2017).

Kache & Seuring (2017) identify supply partners' unwillingness to collaborate and lack of sufficient governance as one of the challenges in implementing supply chain analytics to supply chain management. Kersten et al. (2017) found that

approximately 25% of lack of data is caused by unwillingness to share data. Since efficient implementation of supply chain analytics requires collaboration between supply chain partners as well as efficient governance of information this unwillingness hinders implementation of supply chain analytics (Kache & Seuring 2017). Partners' unwillingness to data sharing can be caused by many reasons. In many occasions the reason is related to safety concerns (Kersten et al. 2017).

Companies can also be reluctant to adopt supply chain analytics because it the adoption process can be costly and time consuming. Especially at the beginning when supply chain analytics is to be deployed it might take months or even over a year before the technology is available for use (Arunachalam et al. 2018). In addition of the implementation project to be time consuming it also requires both financial and human resources which can be costly investment (Richey et al. 2016).

Usage of supply chain analytics is highly reliant on sufficient data and in this context, it often relates to quantity. This means that in order for the analysis to provide insight there must be enough past and timely data available. This increased demand for data requires increased data processing and storage capabilities (Lykou, Mentzelioti & Gritzalis 2018). Answering that need requires large data centres which consume huge amounts of energy. In fact in 2016 data centres already consumed 3 percent of the total global electricity supply which causes approximately 2 percent of the total GHG emission globally (Bawden 2016). High energy use is caused by the amount of power needed to run serves, providing energy for processors, monitors and other equipment as well as electricity needed to provide optimal conditions through for example lightning, cooling or heating systems (Lykou et al. 2018). When supply chain analytics is discussed in the supply chain sustainability context, also the sustainability effect of data usage must be evaluated.

5. Methodology

To gain deeper understanding on how supply chain analytics is used to drive supply chain sustainability, and to respond to the research questions, an empirical research was conducted. In this chapter the research methodology used is presented and both data and data collection process are described in detail. Lastly, reliability and validity of the study are reviewed.

5.1 Research methodology and data collection

Qualitative research is typically used to study complex phenomenon in real world context in order to gain new knowledge about the issue and to understand the real-world phenomenon better (Eriksson & Kovalainen 2008). As noted earlier in this study usage of supply chain analytics in sustainable supply chain is relatively new and not well-established study area and for that reason qualitative research was selected. Semi-structured interviews were used as data collection method. Semi-structured interview builds around predefined themes that are to be covered during the interview. Typically, some core questions are formed to ensure that the desired themes are covered, but the questions can vary depending on the context of the interview. The order of the questions may also vary, as the flow of the conversation may alter the natural order of different topics. Additionally, complementary or additional questions can arise during the interview (Saunders, Lewis & Thornhill 2016). Consequently, semi-structured interviews allow certain level of contextual flexibility while still ensuring that all relevant themes are covered (Farquhar 2012). This also allows the interviewees to answer the questions more freely (Eriksson & Kovalainen 2008). As the purpose of this study was to gain insight into how companies utilize supply chain analytics to improve their supply chain sustainability and to understand the individual opportunities and challenges they face, semi-structured interview is a suitable research method. With semi-structured interview the interview can be structured and somewhat restricted to focus on defined themes

while still allowing the interviewees to elaborate the issues inside eah theme that are relevant to the company in question. Varying importance and relevance of different issues also might require additional question to be raised.

As mentioned, data collected through interviews was used as primary data for this research. Total of five interviews were held with representatives from different companies. All companies were from different industries which allowed forming broader view of the issue as different industries may have differing approach to both sustainability and to supply chain analytics. All interviews took place between January and February 2020 and were held as face-to-face interviews. In one interview two company representatives were present. For the rest of the interviews only one person was interviewed. The interviewees were given the topic of the interview as well as general information about the themes to be discussed as background information before the interview. Same baseline questions were used in all interviews but the order of them varied and typically some additional questions were also posed as interviewees brought up different aspects of the themes. Interviews were held in Finnish to prevent possible misunderstandings and to allow the interviewees to express themselves without possible language barriers. The length of the interviews varied between 34 minutes and 80 minutes, as the table below shows. Industries of the interviewed companies are also listed to table 1.

Table 1. List of interviewees

Company	**Industry**	**Interview length**
A	Renewable energy	48 min
B	Retailer	58 min
C	Telecommunication	80 min
D	Food company	40 min
E	Software provider	34 min

Meaning of the key concepts, such as sustainability and supply chain analytics, were explained at the beginning of each interview to avoid misconceptions that could

arise from contextual differences in the use of these terms. The interviews then conducted of questions related to three main themes displayed in figure 5.

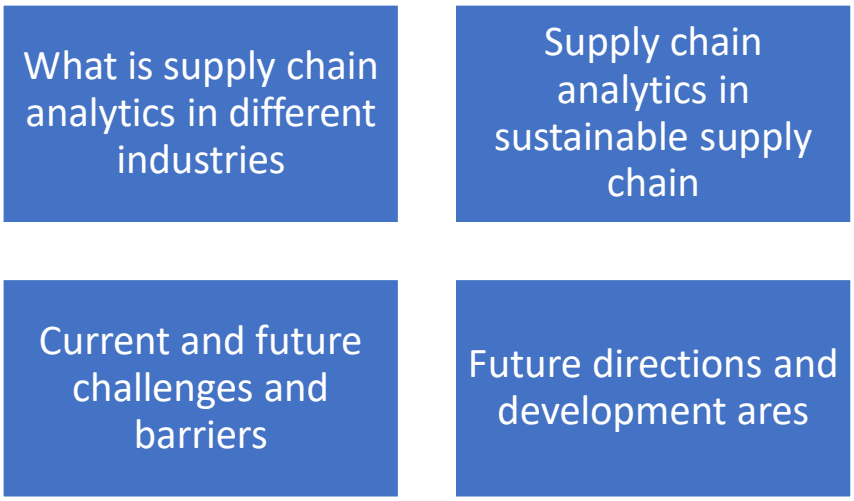

Figure 5. Interview themes

The first theme was related to current usage areas for supply chain analytics in supply chain sustainability and benefits gained on those areas. The second theme was future possibilities regarding supply chain analytics and sustainability and third challenges in both areas, sustainability and supply chain analytics, were discussed. The order of themes and questions varied between interviews and the exact questions also differed slightly. Also, some additional questions were raised during each interview. All interviews were recorded to enable further analysis. Each interview was transcribed later by using word-to-word technique to ensure accurate data for analysis.

5.2. Reliability and validity

Reliability and validity are common meters used to evaluate the quality of research. Reliability of a research refers to consistency and replicability of the study, meaning

that if the study was to be repeated using the same research procedures, same findings and results would be achieved. Validity in turn evaluates the ability of the research to measure what it is intended to measure. (Saunders et al. 2016) Validity can be further divided to three different types of validity: construct, internal and external. Construct validity evaluates the extent to which the research investigates the phenomenon it is supposed to investigate whereas internal validity refers to accuracy of the causal relationships found in the study. External validity in turn refers to generalizability of the results to other groups or settings. (Farquhar 2012) Reliability and validity are typically associated to quantitative research and applying them in qualitative research may not be straightforward. Especially reliability is often not directly applicable in qualitative research as qualitative research is typically not meant to be repeated (Saunders et al. 2016).

As this research is qualitative in nature and the data is gathered through semi-structured interviews, it is not likely that this study could be repeated. However, to enable the reader to evaluate reliability and validity of this study, transparent and detailed description of the research is provided. One notable issue affecting especially external validity is the number of companies included to this study. As the number of companies is very limited, the results of this study might not be generalizable to other industries. Additionally, only one company from each industry and one representant from each company was interviewed, so repeating the same study for example with different companies from the same industries could change the results.

6. Analysis and results

In this part of the study further analysis of the interviews is conducted. The aim of this part is to provide empirical view to usage of supply chain analytics in sustainable supply chains. The main themes discussed during the interviews are described in table 5 and the analysis is conducted based on those themes.

6.1 Supply chain analytics

As previous literature has noted the term supply chain analytics is complex and its meaning can vary. This variety in the use of term supply chain analytics was also observed in this study. Each interviewee had slightly differing definition for supply chain analytics, mostly reflecting the current state of company on that area. Few participants also noted that the term is difficult to define, and it can have varying definitions depending on the context. Therefore, the definitions provided by the interviewees were merely meant to describe what supply chain analytics means in their context. One common thing between the definitions provided was reporting or using collected data as KPI or other type of indicator to be monitored. Typically, also visualization and other means of displaying information were mentioned. The three analytics types, descriptive, predictive & prescriptive, were also mentioned along with utilizing optimizations and simulations to gain insight of the data. Despite of differing definition provided all interviewees agreed with the definition used in this study.

6.2 Supply chain analytics in sustainable supply chain

Companies interviewed had differing reasons for using data in their supply chain as also the motivations and guidelines behind sustainability improvement actions varied. Most companies stated that the goals for sustainability actions are set in

some company specific sustainability program. As sustainability programs tend to set the goals for sustainability actions, those programs also set requirements for the data and analytical needs. In addition, some interviewees also mentioned legal obligations and external sustainability requirements as guidelines for sustainability issues. Even sustainability related crises were mentioned as motivation for tracking sustainability more closely. What however must be acknowledge is that all company representants agreed that supply chain efficiency almost always leads to sustainability increase and vice versa, making sustainability a desirable goal also from for example financial perspective.

6.2.1 Data collection methods

Audits, due diligence, surveys and certificates were frequently mentioned as ways to gather sustainability data from suppliers. It was found that especially social sustainability data is gathered mainly through the before mentioned sources. The interviews showed that depending on the data collection method, sustainability data is either provided by the supplier or collected through third party investigation. Also public sources were mentioned as for example financial information can be publicly available for some suppliers. One company representant also added that using informal data sources, such as news, has been used to follow sustainability issues and possible changes on industry level.

On the environmental and especially emission side companies have differing ways to assess the level of emissions produced in their supply chain. GHG emission produced by transportation appeared to be easily accessible as third-party logistics partners can accurately calculate the emissions produced during specific transportation. However, when it comes to total emission produced in the whole supply chain, different companies use different ways to access that information. One company representative told that that due to the complexity of its supply chain it

doesn’t typically use absolute numbers and has instead developed another way to assess the GHG emissions in its supply chain. The interviewee argued:

“We don’t only have one industry where we would buy everything from. Instead purchasing is done from multiple industries. Because of that one operational model or approach can’t be used.”

Instead of trying to calculate exact number for each supplier, the company defines CO2 score for each supplier based on survey results. The questions posed to the supplier in this survey are more or less yes or no questions and the resulting score represents the awareness and maturity of the supplier on GHG emission issues. Based on that information the maturity of the complete supply chain can also be evaluated. The study however revealed that some companies are able to accurately calculate the GHG emission for the whole supply chain. This seems to be industry related as the nature of the product and suppliers, and complexity of the supply chain seemed to be the defining factors. For example it was found that if suppliers operate in similar industries it is easier to develop standardized ways to measure emissions produced and thus, create comparable measures. One company also noted that providing absolute number regarding the emissions produced in the supply chain is an obligation for them. When absolute numbers are used typically the suppliers are required to provide documentation that includes the amount of GHG emission produced prior in the supply chain. This value is used as basis for latter calculations performed when emissions are produced later in the supply chain. The study also revealed that even though the suppliers can in most cases calculate and provide the amount of GHG emissions produced, it is often not applicable or at least not an ambiguous number. This issue will be covered later in this study.

6.2.2 Transparency

In all companies, transparency seemed to be highly important goal for supply chain analytics. Data is mainly gathered to gain insight to the current state of sustainability issues in supply chain and to identify possible development areas or red flags. This transparency and data can be used in multiple ways in different supply chain processes. Transparency gained though data and analytics can be used to assess the current state of the supplier. All companies used supply chain analytics for this purpose, but the stage varied. One company told that they only gather sustainability data from few specific categories. In this case following was also highlighted

"It's not analytics in that sense that would use it to directly guide our operations but rather we use it at KPI. That the level has to be rising like this."

So currently sustainability data is used more like a KPIs to evaluate the current state of the suppliers in sustainability issues but not necessarily as basis for decision making as such. Most companies however used the sustainability data as basis for supplier onboarding, supplier selection and supplier development. It was found that on the supplier onboarding phase sustainability data is gathered from all suppliers at some level, but the depth of that process depends on the supplier size and importance. Data gathered in this phase is used as one of the decision criteria when deciding whether to onboard the supplier or not. Few companies also noted that if critical sustainability requirements are not fulfilled, for example some certificates are missing, they can identify those suppliers and together with the supplier plan a programme in order for the supplier to gain the missing certificate. This same data can also be used to assess possible risks related to new supplier or to identify possible development areas. Few companies mentioned that they use this sustainability data to identify critical suppliers they want to collaborate with to improve supplier's sustainability. Furthermore, this same data can be used to follow the progress supplier has made on different sustainability areas or to identify

possible development areas. The previous data can be for example used as comparison when evaluating if the supplier has developed in a specific sustainability area.

As noted earlier often supply chain sustainability is guided by sustainability programs and goals. It was found that supply chain analytics has a key role in achieving those targets as it enables tracking development and assessing the current state of sustainability. Without data it would be impossible to know for example whether total emissions in the supply chain have reduced or increased during the past year. As noted earlier this applies to suppliers, tracking company's own sustainability state as well as to the supply chain as a whole.

Transparency gained through data can also be used to increase transparency towards other stakeholders such as end customers. It was found that sustainability data is used also to report the level of supply chain sustainability to external stakeholders by providing some key metrics regarding for example level of renewable energy use in the supply chain. One company also mentioned that it provides information regarding the origin each of its products, which is critical aspect from sustainability point of view, on its website and all customers as well as other stakeholders can easily and freely access this information. Another company also brought up that by having accurate information about the earlier stages of the product, the sustainability in latter stages of the products life cycle can be ensured. For example, by knowing what raw materials used in the product better recycling instructions can be provided to the end user, enabling efficient and appropriate recycling of the product. Hence, data gathered during the supply chain can indirectly affect the sustainability of the product in later lifecycle phases. Interestingly it was noted that suppliers can also benefit from this transparency. Sustainability data gathered from the supplier and supplier's competitors can be used to form a complete view of the level of sustainability in general in a specific market or industry. This information can then be used to 'wake-up' suppliers that are currently not

meeting the average sustainability level of the industry. This process has two purposes; to show to the supplier that sustainability issues matter and help the supplier to develop and achieve better sustainability level.

6.2.3 Transportation

Transportation planning and optimization were regarded as one usage area for supply chain analytics. From sustainability point of view the most important aspect of transportation is emissions. As noted earlier most companies are able to calculate relatively accurately the amount of emissions produced by each transportation mode in their supply chain. Therefore, the data is typically available at least on some level. It was found that this data can be used to optimize the routing and transportation method. As it is possible to quite accurately define the level of emissions for each transportation method already in advance, different calculations can be made to determine which route or what combination of transportation methods would cause least emissions. In practice this means could for example meant that emissions are considered when deciding to which warehouse or end customer each load is sent to. One company representative also noted that as maritime transport causes significantly less emissions, often the goal of optimizing the routing is to avoid truck transport and get the container to a ship as soon as possible. Sometimes this means using less intuitive routings, which is why data and optimizations are used to verify the least emission intensive route and combination. Emissions caused by transportation can also be indirectly affected by supply chain analytics. These effects are however discussed in the following chapters when the direct application areas causing the reduction in transportation emissions are discussed.

6.2.4 Demand planning and warehousing

Some of the companies mentioned demand planning as an application area for supply chain sustainability. As also noted in the theoretical part, data is key factor

for achieving better and more accurate forecasts. Even though better forecasts themselves don't increase sustainability, better forecasts can be used to affect different barriers which cause sustainability related challenges. For example, it was found that better forecasts prevent excessive stocks which could turn in to wastage. Better forecasts can also prevent unnecessary transport since demand forecasts and stock levels are used when decisions regarding loading of trucks or transport methods are made. When the forecast can be trusted and desired stock levels are optimal, truck loading and transport method can be optimized as well. As a result, the most sustainable, and often also most efficient, transportation can be ensured. Additionally, supply chain analytics can also help prevent unnecessary traffic between end destinations, for example stores, caused by inaccurate deliveries which originate from poor forecasts and excessive stock levels in incorrect locations. One company representative also told that they forecast both, demand and raw material availability. These forecasts are used together to form optimal raw material – end product combination for specific markets, considering also sustainability factors.

Two ways in which more optimal stock levels can affect supply chain sustainability were identified. First, by having optimal stock levels, for example based on a week profile, wastage can be avoided. This applies especially with perishable products. Also, if right, needed products are using the warehouse space, it can be ensured that the energy used is in efficient use. Frozen goods were identified as one critical category on which lower stock levels can have direct effect to sustainability as freezers require significant amounts of energy. Additionally, optimal stock levels can help to prevent big incremental changes in environmental effect caused by warehousing. Warehouses typically produce fixed amount of emissions so lower stock levels don't as such lower the environmental impact of warehousing, but by optimizing stock levels the need for additional or bigger warehouse might be delayed or at some point smaller warehouse can be used. Building a new warehouse would cause negative environmental impacts already in the building phase. Additionally, it

would cause permanent rise to the emissions caused by warehousing due to increased energy consumption.

6.2.5 Other application areas

As broader goal, all interviewees emphasized that the ultimate goal for using supply chain analytics is to provide information for decision making at all stages of the supply chain and at all organizational levels. According to the interviews to achieve this goal it is important that sustainability data is available to everyone, not only to those who work directly in sustainability issues. It was found that often sustainability information is available to limited number of people or the information doesn't affect strategic decision making. Interestingly one interviewee told that in their industry emissions have monetary value, meaning that higher emissions could lower the value of the product. This company had found that this has been a critical factor as it has enabled sustainability to guide decision making and made it easier to include sustainability issues decision making. This implicates that ability to monetize sustainability issues might crucial factor for achieving the overall goal.

6.3 Barriers for adopting supply chain analytics

The empirical results show that companies tend to experience same kinds of challenges when implementing or using data and supply chain analytics to improve their supply chain sustainability. In addition to these common challenges all most all companies had faced some industry-specific issues. Both barrier types are discussed in the following chapters.

6.3.1 Data related barriers

The most critical and notable barrier faced by most companies is data quality and availability. As one of the company representants stated, good data quality is prerequisite for any data driven actions. Poor data quality was found to be a common issue, typically leading to bad and unreliable results. To certain extent poor data can be fixed but the data quality in all cases affects the quality of analysis, optimizations and the level of automation that can be achieved. Due to poor data quality more manual fixes and verification procedures are typically needed. This diminishes the positive effects that could be achieved through supply chain analytics. It was however noted that even though data quality issues can hinder the usage of supply chain analytics, the data will never be perfect and only way to cleanse the data is to use it. This means that at some point decision has to be made. At some point it must be decided that the data is good enough and the current deficiencies need to be acknowledged when using that data.

It was also noted that in sustainability issues the complexity partly arises from the nature of sustainability data. The complexity of using data in the field of sustainability arises from the fact that sustainability data is typically not transparent and unambiguous. It was pointed out that sustainability data is always a combination of qualitative and quantitative data from different sources. Combining this kind of data is a challenge.

Most companies noted that quantitative numbers such as GHG emission are not always comparable or accurate when it comes to sustainability. One company representative explained it followingly:

“It is easy to ask for a number. Then we receive 7 000 from one supplier and 5 000 from another. How do we verify that these are comparable or what can we actually do with these?”

It was further argued that different suppliers can calculate the emissions in different ways as each supplier has to choose what is included and from which tier onwards the emissions are calculated. As one company representative said even same tier suppliers can have very different positions in the production of a specific product and therefore each suppliers’ tier 1 and tier 2 level emissions can differ significantly. Hence, in order to compare the absolute numbers, the company should have profound knowledge about the calculation logic behind each number. It was also pointed out that due to varying operating environments, quantitative data is not necessarily comparable. As one interviewee summarized, the challenge is lack of unambiguous, generally accepted ways of measuring for example emissions. Hence, even if exact numbers about sustainability related issues can be accessed the numbers are not necessarily applicable to be used in analysis and therefore don’t impact decision making in the supply chain. Another emission and data related challenge is allocating emissions to product level. Typically, emissions are reported on a higher level, for example per production batch, or per container when it comes to transportation. Most companies however intend to measure emissions and carbon footprint on product level. Hence, the challenge is how to identify how much of the total emissions should be allocated to specific product and what emissions produced during the supply chain should affect the total footprint of a single product. One key issue is that one additional product doesn’t necessarily increase the amount of emissions produced, for example truck produces the same amount of emissions regardless of the loading level. Therefore, identifying the share of emissions that should be allocated for each product is a significant challenge.

6.3.2 Human related barriers

Besides data related issues also the human side challenges were found to be common challenges for most companies. As supply chain analytics becomes more integrated part of supply chain management also the core competences required from the employees change. It was pointed out that in the past supply chain work has been purchasing oriented whereas now the actual purchasing can be largely automated, and the role of a supply chain professional is more forward-thinking and analytic. Thus, taking supply chain analytics as part of everyday supply chain management, new competencies and capabilities are required from the employees. This raises a question whether the current professionals can adapt to this change or does it require generation change to be able to fully implement analytics as a part of supply chain management.

As noted utilizing supply chain management in sustainable supply chain has changed and keeps changing the daily work in supply chain management and capabilities the work requires. Hence it requires adequate change management. Managing this change is however a challenging task. As it was found, even if data and analytics hasn't been used before, there is still always some processes that the analytical tools will replace, for example demand must have been forecasted somehow. One interviewee explained that traditionally supply chain decisions have strongly relied on collective knowledge and opinions of different supply chain professionals and therefore it is challenging task to get people to trust supply chain decisions produced by analytical tools. This hinders the change. Inadequate change management can cause a situation where data and analytical tools are in place but not used as intended. This often leads to inefficiencies and poor outcomes.

Additionally, it was noted that supply chain managers might not know how to utilize the information provided by the data or are not interested in exploring the data. The reason behind this is often that the supply professionals don't necessarily have

analytical capabilities, such as ‘slice&dice’ kind of thinking, required to analyze the data. Therefore, it is challenging to find the issues or data that should raise interest. It was also pointed out that sustainability related supply chain data might especially suffer from lack of interest. For example, if supply chain managers want to analyze suppliers often financial issues come to their minds first.

Contrarily, some of the companies didn’t consider employee resistance or lack of skills as a challenge for utilizing supply chain analytics. One of these company representants for example mentioned that it aims to improve the analytical capabilities of the personnel as a whole to avoid situation where only analysts and developers are able to make sense of the data. This however wasn’t necessarily a challenge but more related to maturity of data usage.

6.3.3 Industry specific barriers

As for industry specific issues company D told that the bigger challenge it has faced is that the industry is not yet ready to utilize data on a larger scale. In its industry data is not yet easily accessible and quantifying sustainability is complex and slow process. The interviewee explained that the supply chains are long and complex as the supply chains include many suppliers of different sizes. In the supply chain the information often gets lost at some point or there are no means to gather data from all supply chain stages. For example, small suppliers at the beginning of the supply chain might not have sufficient infrastructure for data gathering and storing. Small suppliers might not have enough resources or motivation to invest in sufficient infrastructure which would enable data availability in the supply chain. It was also added that even if the infrastructure was in place it might require substantial amount of training to enable efficient data flow in the supply chain.

Also company C had faced industry specific challenges. The company operates in an environment where it has multiple suppliers from different industries and even same tier level suppliers might be operate very differently. Therefore, gathering sustainability data in centralized matter is difficult. Instead the nature of sustainability data is industry or company specific and hence, single-point analytical solutions are required. To overcome this challenge the company has had to develop its own solutions for gathering and using sustainability data.

Company A had few industry specific challenges. Both challenges were somewhat related to the nature of the product. Currently there are no standard, commercial software that would be suitable for company A's purposes as the nature of the product is different from most companies' and there are not many companies that would have exactly the same type of product. Therefore, company A has had to build its own custom software to be able to handle data and to perform any kind of analysis. Building custom software is slow and expensive and requires a lot of development work as all the of the development work is done by the company itself. This has been a challenge and, in some cases, hindered the usage of supply chain analytics. Another issue caused by the nature of the product is that the product divides to smaller and smaller unit in both ends of the supply chain, making it challenging and time consuming to gather and allocate correct data on both ends.

Also company B had experienced system related challenges. As sustainability data often includes multiple parameters in different forms, storing it is a challenge for IT systems. Especially the issue is that different suppliers provide the data in different formats. Combining these different data formats from different sources is challenge for IT systems. Therefore, developing analytical tools and processes often requires other IT projects as well.

6.4 Future directions and development areas

This chapter aims to identify future views and development areas on the field of supply chain sustainability and analytics. These development areas can be either possibilities that have been already identified as reachable or future possibilities that are not reachable in a current situation. The companies in this study are from different industries and are in relatively different maturity levels when it comes to utilizing supply chain analytics in supply chain sustainability. Therefore, the future views and development areas varied, but also some similarities were found.

All companies saw that supply chain analytics has huge potential for improving supply chain sustainability and the development will increase in the future. One respondent argued that changing supply chains and supply chain management to more forward-thinking and analytical is one of the major trends in the field. This requires ability to predict future and calculate probabilities for different scenarios which in turn requires data. Hence, it could be argued that data is a significant enabler for multiple future goals.

Nearly all interviewees saw more clear and standardized way of quantifying sustainability as desirable and potential direction for future development. Through quantification it would be easier to measure sustainability impacts of different product and actions. Furthermore, better quantification could enable defining some price tag for sustainability. As noted earlier when price can be defined for sustainability issues, sustainability becomes more effective in the decision making, especially on strategic levels. This standardization also reflects to IT systems as one of the challenges was that systems both inside the company and between different supply chain actors are not compatible data format wise. In addition to standardized way of quantifying sustainability, it was found that the amount and quality of third parties that directly evaluate sustainability issues will increase enabling easier access to sustainability data.

In addition to having better data in the future, it is also predicted that the tools will improve allowing better usability of data and analytical tools for wide scope of employees. This will ease the challenge faced on the human side as supply chain analytics and data becomes more approachable and thus easier to utilize in daily work. Besides having better tools, also utilizing current tools on a wider scope was identified as one future development area.

Few companies mentioned that optimizing supply chain through GHG emissions is a future goal for them. The current situation for these companies was to gain understanding about the emissions produced in the supply chain and once that is achieved the target is to start using optimizations and simulations to reduce amount of emissions produced. For example, this could mean simulating different transportation or production scenarios and emissions in those scenarios. This information gained about the emissions could then be used in decision making. Another emission related future direction noted by several interviewees was better and more specific information about the emissions. As found in the challenges chapter, allocating emissions to products or otherwise lower levels is currently a big challenge. This study however found that most companies believed that in the future this challenge can be defeated, at least on some level. If emissions can be allocated more efficiently it also allows more accurate monitoring of the effect achieved through different actions in the supply chain.

Some of the companies had already extensively utilized demand forecasting in their supply chain, but there were also companies which didn’t use demand forecasting in a wider scope yet. Those companies however said that better and more accurate forecasting could offer significant sustainability benefits. Furthermore, few companies noted that especially developing forecast to be more probability oriented would be desirable. Interviewees explain that it would be useful from sustainability perspective to be able to calculate probabilities for different scenarios and use those

to plan supply chain actions for different scenarios. Predicted sustainability benefits that could be gained through better forecasting were especially decrease in wastage, lower stock levels and thus lower emissions caused by warehousing. One company representative also noted that through supply chain analytics new products could be forecast more accurately.

One big theme for the future was found to be automation. Most companies noted that through better access to data and information produced by data, automation can be increased. Automation was especially predicted to improve data handling. For example, it was predicted that moving data between different systems, validation of data and allocating data for correct products will be automated even further.

One somewhat supply chain analytics related future direction that was brought up was blockchains. It was found that blockchains are seen as one significant enabler for more sustainable supply chains, especially when the supply chain is long and complex. Through blockchains sustainability data could gathered more efficiently, enabling usage of supply chain analytics in a widescale.

7. Discussion and conclusions

The aim of this study was to understand how supply chain analytics can be used to improve supply chain sustainability and to identify different barriers and benefits related to use of supply chain analytics as well as to understand what is meant by supply chain analytics. Previous studies on this subject have mainly focused on identifying application areas for supply chain analytics in sustainable supply chain but there has been a lack of studies that would have tried to understand how supply chain analytics can affect sustainability on each area. Additionally, it was noted that while challenges related to analytics and data usage have been widely discussed, not much attention is given to challenges that are specifically faced when utilizing data in sustainability related issues. To address these gaps in current literature, empirical study was conducted where 5 company representatives from different industries were interviewed. Also, a comprehensive review of the current literature on the issue was made to gain understanding of the issue and to support the empirical study.

7.1 Discussion of the results

In this part, the findings of the empirical research are summarized and reflect to the theoretical part of the study. By combining the results of the theoretical overview and insight gained from the empirical part, research questions can be answered.

How can supply chain analytics help in improving supply chain sustainability?

The main objective of this study was to identify how supply chain analytics can be utilized in supply chain to improve its sustainability. Prior studies on the issue

suggested that there are three main themes to which are affected by supply chain analytics: transparency, demand planning and transportation. Transparency was identified as the most influential aspect of supply chain sustainability as it acts as a building block for all sustainability related actions (Carter & Rogers 2008). Therefore, supply chain analytics' ability to significantly affect the level of transparency is a critical finding. Both empirical findings and prior studies indicate that supply chain analytics' ability to generate reliable data generates transparency which can affect sustainability in multiple ways. The empirical findings highlight that most importantly transparency gained through supply chain analytics enables companies to assess the level of sustainability in their supply chain and helps identifying possible sustainability risks and development areas. This in turn enables sustainability improvements in multiple sustainability related areas. Most notably, empirical and theoretical findings suggest that transparency is the basis of all sustainability development. For example, the following two usage areas, demand planning and transportation, are highly reliant on transparency.

Prior studies identified more accurate demand planning and forecasting as one of the most important application areas for supply chain analytics and found that also sustainability issues can be affected through this (Mani et al. 2017; Tang & Zhou 2012; Ji et al. 2014). This same phenomenon was also noted in the empirical findings, but the importance and level of utilization were not as wide as the previous studies suggested. Rather the empirical studies suggested that utilizing demand planning in sustainability issue is a future opportunity.

The findings of this study also indicate that transportation is one significant application are for supply chain analytics. Previous literature showed decreasing the amount of emissions produced during transportation is one of the most critical areas to be assessed from sustainability perspective (Dey et al. 2019; OECD 2010). According to prior studies supply chain analytics provides multiple opportunities to decrease emissions produced during transportation (Dey et al. 2011; Kache &

Seuring 2017; Lieb & Lieb 2010). This opportunity was also acknowledged in the empirical findings but the current usage of supply chain analytics to decrease the amount of emissions produced was found to be lower than the theoretical findings predicted. The empirical results indicated that supply chain analytics are currently used more as tool to assess the level of emissions produces. However, transportation was identified as important application areas and there were some suggestions also in the empirical findings of that supply chain analytics is used to decrease emissions caused by transportation.

What is supply chain analytics?

The results of this study indicate that supply chain analytics still not well-established concept. As it was found supply chain analytics can be defined in varying ways and often the context significantly affects the definition. Definitions can vary from merely collecting data and reporting it to using collected data in complex optimizations to predict future events. What was especially noted from the prior studies is that multiple different concepts can be used to described what is considered as supply chain analytics in this study. For example, big data analytics, predictive analytics and business analytics are of then used interchangeably with supply chain analytics. As a conclusion it can be stated that supply chain analytics in not yet mature enough to have standardized and generally accepted definition. However, the definitions are often closely related, and the difference are in the scope of what is included to the definition.

What are the potential barriers for adopting supply chain analytics?

Both previous studies and the empirical findings of this study suggest that there are three main barrier types when it comes to utilizing supply chain analytics in

sustainable supply chain; data, human or employee related and industry specific issues. Short summary of each type is provided in figure 6.

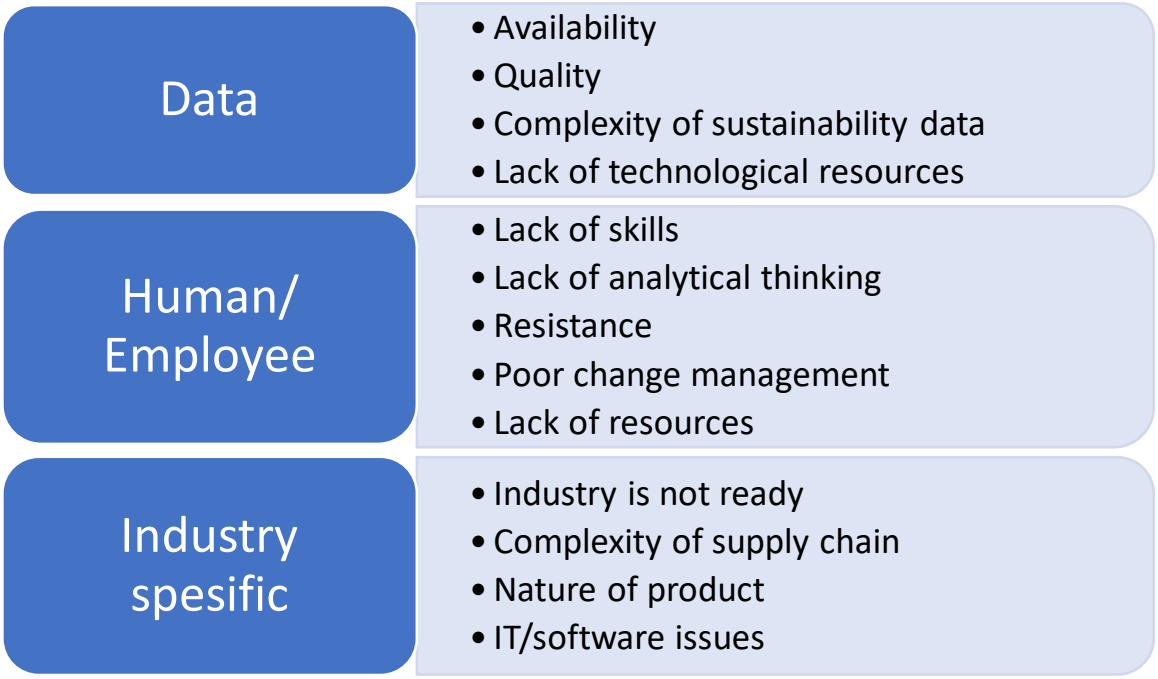

Figure 6. Barriers for adopting supply chain analytics

As previous studies suggest data related issues are the most common barriers for utilizing supply chain analytics to improve supply chain sustainability. As for example Schoenherr & Speier-Pero (2015) and Kache & Seuring (2017) state lack of data and insufficient systems and technologies are the main barriers for supply chain analytics. The results of the empirical study also indicated this. According to the empirical findings, data availability and especially data quality often pose a challenge to supply chain analytics. Most notably the issue seems to arise from the nature of sustainability data. Sustainability must be measured on both qualitative and quantitative level and combining and maintaining this kind of data is a major challenge. Both empirical results and previous studies suggest this also challenges the IT systems and software (Arunachalam et al. 2018; Kache & Seuring 2017). Thus, technological challenges were also identified as one significant challenge.

Throughout this study it was noted that employee related issues also hinder adoption of supply chain analytics. According to the empirical results lack of employee skills and motivation can be a significant barrier to adoption of supply chain analytics, especially on sustainability issues. This was also noted on the previous literature (e.g. Kersten et al. 2017; Schoenherr & Speier-Pero 2015). Both theoretical and empirical findings suggest that part of this employee related challenge is lack of adequate change management. Change management was found to be crucial and defining factor in successfulness of supply chain analytics adoption process and thus often the reason behind employee resistance or inability to utilize it.

What are the future opportunities of supply chain analytics from sustainability perspective?

Based on the empirical findings of this study supply chain analytics seems to be rising trend on the sustainability area as also noted in previous studies. While several opportunities have been identified, not all of the are utilized in practice (Mani et al. 2017; Hazen, et a. 2016). Therefore, one of the objectives of this study was to identify future development areas and opportunities related to supply chain analytics and supply chain sustainability. The key finding on this area are summarized to figure 7.

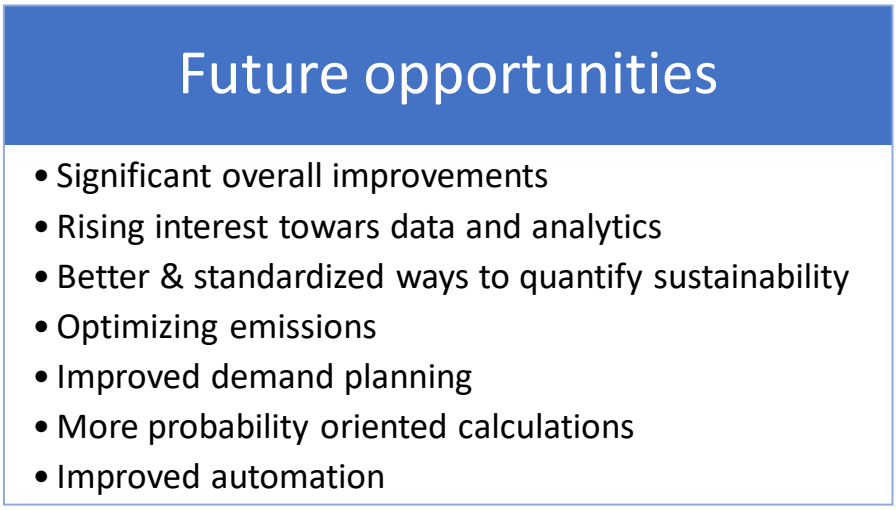

Figure 7. Opportunities of supply chain analytics

The empirical findings suggested that challenges related to data and data quality, such as lack of standardization and lack of data, will be resolved in the future. Most notable future direction identified in both empirical and theoretical part is the attitude towards supply chain analytics. Supply chain management in general is predicted to change towards more forward-thinking and thus, more data intensive. This requires increasing level of supply chain analytics usage in both operative and strategic levels.

7.2 Recommendations

The results of this study suggest that many industries haven't yet fully adopted supply chain analytics as part of their supply chain management processes, especially when it comes to sustainability. Both sustainability and supply chain analytics are however rising in importance and there is clear connection between the two. As it was found utilizing supply chain analytics to supply chain significant sustainability benefits can be achieved. Therefore, the most critical suggestion made based on this study is to start the process. Many companies may already use data and some form of analytical tools, but in order to gain sustainability benefits it crucial to develop tools and practices to collect and analyse sustainability data. As

it was found in this study sustainability issues often require different approach as the data may differ from for example financial data. This also relates to another suggestions concerning to data challenges. As data, and especially sustainability data, often causes challenges it is crucial for supply chain managers to evaluate the reliability of the current data and to consider alternative approaches to issues. For example, it was found that companies tend to struggle with emission data. If the quality of data poses challenges supply chain managers should consider alternative ways of measuring, at least until the issue can be fixed.

As the study indicates the roles of supply chain professionals and procedures used in supply chain management are changing due to digitalization and increasing amount of data. Therefore, adequate change management is required to successfully include supply chain analytics as part of sustainable supply chain management. Thus, this study suggest that supply chain managers make elaborate change management plans on how to develop required employee skills and how to change their employees' mindsets before the actual implementation or development actions. This study also suggest that special attention should be given to managing the change on different company levels. In practice this means that data-driven approach to sustainability should be used on both operational and strategic levels.

7.3 Limitation and suggestions for future research

Although this study addressed the defined research gap and provided new information on the issue, future research is still needed due to limitations of this study. This study was conducted as a qualitative study with relatively small sample of 5 different companies. Thus, the results are not generalizable outside of this study. The aim of this study however was not to provide generalizable results but rather to gain in-depth understanding of the issue for further research. Besides the limited number of studies, only one company for each industry was interviewed.

Therefore, the industry specific notions can't be verified as strictly industry specific but can also be considered as company specific.

Due to limitations of the study, next crucial step would be to conduct a larger study with bigger sample to confirm the results. It would be suggested that quantitative research method would be used to achieve generalizable results. Wider scope could be used to include companies from different industries to investigate industry specific issues more deeply. With bigger sample it the found industry specific differences found in this study could also be confirmed.

Besides investigating the application areas and relationship between supply chain analytics and sustainability also the concrete effects should be addressed. Sustainability is a complex issue and the sustainability effect caused by each supply chain action are multidimensional and interconnected. Therefore, further research should be conducted on the actual sustainability effects of for example demand planning. Demand planning affects supply chain in many ways and thus, can affect sustainability from multiple facets. Hence, one interesting future research objective could be to measure the actual changes for example in emissions caused by better demand planning. This also concerns other sustainability areas and dimensions such as transportation.

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