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Master Thesis

Thesis Master of Science

Supply Chain Risk Management in the construction industry: A case study of Statsbygg's Life Science Project in Oslo, Norway

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Abstract

Large-scale construction projects involve numerous contractors, actors, large investments and budgets. They often span over many years to complete and are known for high fragmentation, low productivity, conflicts and cost and time overruns (Bankvall et al., 2010; Fearne & Fowler, 2006). Consequently, SCRs are prominent in these projects due to the complexity, uncertainty and external influence. By focusing on SCR, SCRM and logistics, the industry can increase productivity, efficiency, resilience and robustness. There is much research on the RM field, but there is a lack of literature and empirical evidence on SCRM in large-scale construction projects, which this thesis will contribute. This thesis will further investigate the perception of SCM and SCRM in large-scale construction projects through a qualitative research method to provide an answer to the RQ: *How can actors in large-scale construction projects mitigate supply chain risks?* We have conducted an exploratory case study of the LSP in collaboration with SB to answer to the RQ and overall objective. Data were collected through semi-structured interviews and documentation provided from SB.

The findings from our study are how SCRM and mitigation strategies are deemed valuable to decrease SCR and complexity of a large-scale construction project. It was further discovered that mitigation strategies often need a combination of strategies to be successful. One of our main findings from the data collection was the impact of information, collaboration, labelling issues and that digitalization can create synergies improving project performance. Categorizing SCR provided an overview of the identified SCR and made it easier to see how the SCRs connect to each other, giving us in-depth knowledge about the identified SCRs. Mitigation strategies will decrease the probability and impact of SCRs occurring in large-scale construction projects, which will further amplify flexibility, transparency and collaboration in the CSC. This contributes large-scale construction projects to become more efficient and resilient with a CSC that works efficiently, with lower costs and better collaboration with the actors. Consequently, proper SCR identification and mitigation can reduce the disruptions in the LSP and large-scale construction project in general, making the goal of the five R's achievable.

List of abbreviations

CSC - Construction Supply Chain

GDPR - General Data Protection Regulation

GTIN - Global trade identification number

JIT - Just In Time

KHiB - Bergen Academy of Arts

LSP - Life Science Project

NSD - Norwegian centre for research data

OUS - Oslo University Hospital

UIO - Oslo of University

RFID - Radio Frequency Identification

RM - Risk management

RQ - Research Question

SB - Statsbygg

SC - Supply Chain

SCRM - Supply Chain Risk Management

SCR - Supply Chain Risk

SSB - Statistics Norway (Statistisk Sentralbyrå)

1.0 Introduction

In this master thesis we aim to add new insight into supply chain risk (SCR) and supply chain risk management (SCRM) in the construction industry, focusing on how SCRs can be mitigated in large-scale construction projects. To meet this ambition, we have executed an exploratory case study, where we explore SCRs in large-scale construction projects to identify and categorize SCRs and how to mitigate these through various mitigation strategies. Statsbygg (SB) has provided us with the research object: the Life Science Project (LSP) at Gaustad in Oslo. This paper will focus on the SCR and how different mitigation strategies may strengthen a CSC and project performance, as the construction industry serves as an industry with complex tasks and networks (Bankvall et al., 2010). It is worth mentioning that logistics in Norwegian also refers to SCM, which indicates that these terms will interact throughout the thesis. In the first chapter, we will elaborate on the background and motivation behind our choice of research area and topic. This will be followed by a discussion on the contribution and justification of our research. Then there will be a presentation of our research question RQ, and the empirical setting used to address the RQ. Lastly, we present an overview of the structure of this thesis.

1.1 Background and motivation

This master's thesis is about SCR and SCRM in large construction projects. Our interest and motivation for this thesis first and foremost originate from our major in our master programme at BI "Logistics, Operations and Supply Chain Management", and the election course we had in the autumn of 2020 “Supply Chain Risk Management in Project-Based Industries". The election courses provided us with insight in the value of RM and how the construction industry is far behind in productivity and innovation compared to other industries. After stating our interest in SCRM in construction, our supervisor at BI introduced us to SB, the Norwegian state’s key advisor in construction and property affairs, developer for state building projects, property manager and developer (Statsbygg, 2021). SB manages the construction of the new Life Science Building at Gaustad. It is one of the most significant construction projects in Oslo at this point. SB has stated their increased focus on SCM and RM in recent years, resulting in SCM

being one of the core activities in the LSP. This intrigued us to investigate the project and SCR that arise in large construction projects further.

Our motivation behind this study is that we wanted to investigate how an apparently old-fashioned and set industry meets with the increased pressure for optimizing and streamlining their projects. After several conversations with our contact person in SB, we concluded that the industry has the potential to increase productivity by focusing on SCR, SCRM and logistics. Moreover, there has been little focus on SCRM in the industry which can result from an industry embossed by fragmentation and the fact that the application of SCRM concepts in the construction industry has not yet been explored (Shojaei & Haeri, 2019). The lack of research in the area is also emphasized by Rudolf and Spinler (2018) and Thomé et al. (2016). The literature regarding the construction supply chain (CSC) focus on the concept from the manufacturing industry, which usually are permanent organizations, and how construction can learn from this (Shojaei & Haeri, 2019). London and Kenley (2001) point out how this creates issues, as there are some present differences between temporary and permanent organizations. This exemplifies the necessity to seek more control and insight in the CSC, to decrease underperformance, delays and cost overruns which has become characteristics in the industry (Rudolf & Spinler, 2018). As a result, the SC will be strengthened through robustness and flexibility (Thomé et al., 2016).

The construction industry is regarded as one of the most important sectors for social and economic development due to its contribution to the socio-economic infrastructure and is the second largest mainland industry based on turnover in Norway (Chaffey, 2017; Daoud et al., 2018; Øye, 2019). As illustrated in Figure 1, construction productivity is almost 30% lower than the total productivity on Mainland-Norway and has decreased its productivity by approximately 10% from 2000 until 2016 (Figure 1, Todesen, 2018). Bankvall et al. (2010) argue that the productivity growth to be much lower in the construction industry compared to other industries, and that construction projects suffer from poor performance.

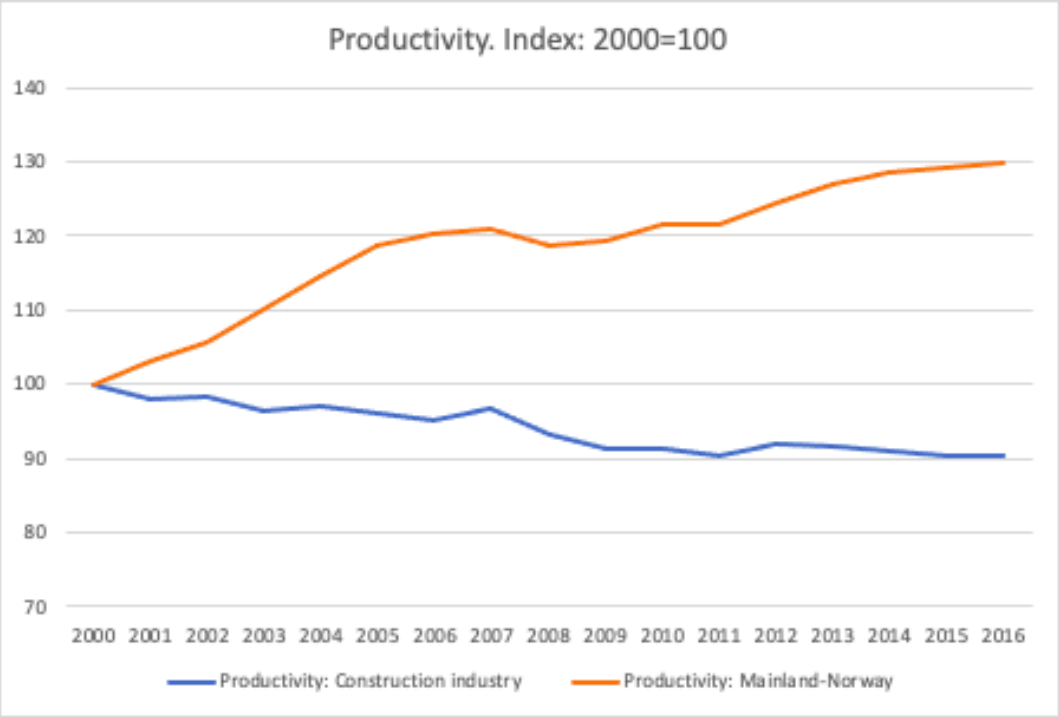

Figure 1: Productivity Index. (Todesen, 2018).

The low productivity can be connected to the independent mindset amongst the actors in a CSC, which can be further connected to SCRs (Min & Bjornsson, 2008; Vrijhoef & Koskela, 2000). Furthermore, the industry is viewed as one of the largest project-based industries where the need for external resources depends on each project and releases a great amount of waste (Hobday, 2000). A project is considered successful if the project is completed within the agreed time and quality with the developer, and within budget with the contractor and requires a high management quality to coordinate and oversee the complex SCs (Aloini et al., 2012). The most common method to measure and evaluate a project's success, is the iron triangle with the three main pillars: time, cost and quality (Chan & Chan, 2004). The industry, however, suffers from a poor reputation for coping with the effects of change, as many projects do not meet deadlines, quality and cost targets (Smith et al., 2014).

1.2. Research contribution and justification

There has been a considerable amount of negative publicity about productivity in the construction industry. There seems to be little to none research on SCR in large-scale construction projects and how to mitigate SCR (Rudolf & Spinler, 2018; Shojaei & Haeri, 2019; Thomé et al., 2016). This indicates a need to focus

on SCRM to facilitate a decline in negative outcomes of SCRs occurring in large-scale construction projects and establish a greater understanding of the importance of SCRM. The purpose of this thesis is to contribute the research field of SCRM in the construction industry by examining different views of SCR and challenges in the industry, and further provide suitable mitigation strategies on how actors in a large-scale construction project can handle SCR. This may contribute to better project performance in an industry suffering from low performance faced with extensive SCRs with various maturity amongst the actors within the CSC. Our research is of both practical and theoretical relevance as it challenges and reflects on the research area. The field of research will contemplate on several SCRs and challenges that are related to large-scale construction projects, with replenishment from the construction industry. Moreover, this thesis is innovative in the comparison of scientific literature as there is no known, as far as we know, empirical study of SCRM in large-scale projects.

For eight years in a row, Allianz Risk Barometer rates Business Interruptions, that includes SC disruptions, as the number one SCR affecting companies. This emphasizes the need for proper SCRM (Allianz, 2020). It is recognized that many organizations think they have mitigated SCRs, but have often neglected critical exposures in the SC (Jüttner et al., 2003). SCM is considered to be a critical factor to achieve successful project implementation in a construction project and to be a major contributor to improve a company's performance (Aloini et al., 2012; Gattorna & Day, 1986). This case study will contribute with empirical evidence from a real large-scale construction project and how different strategies can be used as mitigation to avoid disruptions in a CSC. Disruptions are referred to as all errors in delivery or delays, and can be more unexpected than delays, which is an already known SCR (Thomé et al. 2016).

1.3 Research question

The overall aim of this thesis is to add insight to the construction SCRM literature, which is identified to be mainly conceptual and descriptive (Aloini et al., 2012). This will be done by investigating and discussing the several aspects of the CSC, both in theory and practice. By investigating the CSC in the context of a real large-scale construction project, we aim to identify the most prominent SCRs

in these projects to find and develop suitable mitigation strategies. However, developing mitigation strategies can be challenging, and as all large-scale construction projects are unique and of great complexity, the formal structures are not always adequate. Therefore, it is necessary to identify and categorize SCRs to find suitable mitigation strategies and combine these into being value-adding activities. Based on this, we found it interesting to explore the perspective on SCM and what point of view the industry has on SCR. This makes it interesting to look further into how large-scale construction projects can mitigate these SCRs and how SCRM can increase a project's performance.

Having an exact RQ is necessary to recognize which data and literature are of importance in our research. It provides a guideline and overview of our research, and it helps to limit the area of research (Bell, Bryman & Harley, 2019). The RQ have been developed to understand how large-scale construction projects are focusing on SCM and how these projects can mitigate SCR. To make a thorough investigation of the research area, we have developed the following RQ:

RQ: How can actors in large-scale construction projects mitigate supply chain risks?

The RQ aims to reveal how actors in large-scale construction projects can mitigate SCR. In order to investigate this, a SCR identification and categorization will be necessary to prepare relevant mitigation strategies and get an overview of the identified SCR. SCM has been extensively researched in literature and SCRM theory will constitute the main concepts providing the theoretical framework in this thesis. Risk is a broad term which will be discussed and defined from the SCR theory perspective in the literature review. Consequently, we found it necessary to delimit the research area by using Thomé et al. (2016), Rudolf and Spinler (2018) and Sodhi and Tang (2012) as a basis for the discussion of SCR identification and categorization. There are several categorization frameworks and mitigation strategies, where one particular interesting is Thomé et al. (2016) who mention four dimensions to reach flexibility, redundancy, collaboration and agility. We was inspired by these key references, as further explained in the next chapter about the methodology.

1.4 Empirical setting

To study how SCR are prominent in large-scale construction projects and how this can be mitigated through identification, categorization and proper SCR mitigation strategies, SB has assisted with the empirical setting. The company has its roots back in Eidsvoll, 1814, when Norway got its constitution and is today Norway's main constructor of government buildings (Statsbygg, 2021). SB's goal is to be the best at "*Building with meaning*", which is the aim for all their projects. The company works with large construction projects and has over one hundred projects ongoing at any given time (Statsbygg, 2021). The ongoing execution of the LSP is the research object in this thesis. The LSP is a Norwegian initiative to develop a leading university environment in life science and to ensure Norway's international competitiveness in the area. The building will be a catalysator for Norwegian innovation and be the largest university building in the country. Oslo University Hospital (OUS) with the clinic for laboratory medicine (KLM), will be stationed in the building. The building is located at the bottom of Gaustadbekken and will consist of 66,710 sqm, divided on nine floors.

The vision for the LSP is "*An even better project*" where logistics and mitigation of SCR is an important part. However, there have been several postponements due to problems with the ground conditions and further financing resulting from this. The project is ongoing and still on a conceptual level regarding SCRM, consequently, we can therefore not conclude on the effect of suggested mitigation strategies in this thesis. Nevertheless, the LSP will be used as a research object to explore SCRM empirically in large-scale projects because of their explicit focus on SCRM, which our contact persons in the project states is not well established.

One of SB's previous project, the construction of the KHiB, is an important contextual factor for understanding SCR and the project implementation of the LSP. The project is based on the learnings and experiences from the development of the KHiB (see Appendix 4). The KHiB was supposed to be conducted differently from previous projects with a focus on logistics and lean methodology implemented in every part of the CSC, to reduce time loss, disruptions and create a flow in the project. SB's mantra in KHiB was "*Right information to the right time*". However, this did not achieve what they aspired, where the success of the lean methodology implementation became absent. The failure was due to the lack

of communication along with the different levels of maturity and the view of logistics amongst the involved suppliers. This has made us get a comprehensive understanding of the implementation of a large-scale project, as the LSP will be completed in 2024 at the earliest. To transfer knowledge and experience gained in previous projects, many from the KHiB project are currently participating in the LSP.

Moreover, to handle the uniqueness of the LSP and the construction site's design, SB has developed and improved a logistics concept that they are aiming to implement based on the experiences and knowledge gained from previous projects, especially the KHiB. The concept is implemented to get better results and performance. Consequently, this makes the project even more unique as the aim is to create more stability and efficiency. SB tries to facilitate for the actors involved in the project to work as *one* team, having *one* common project and having *one* common culture. Yet, the LSP is actually two projects; construction and equipment which are being controlled as one common project. This exemplifies the complexity of the project, with more than 1000 technical systems. In this thesis, we have limited the research to the construction and the CSC.

1.5 Structure of the paper

The thesis is divided into seven chapters, with the introduction as the first. The introduction is followed by the research methodology, where there is a review of the research strategy, design, data collection and quality of the study. Moreover, in chapter three, the literature review is presented to provide insight to the applicable case. There is a review of large-scale projects, SCR and SCRM, identification and categorization of SCR and relevant mitigation strategies, followed by a summary of the theory. The literature review is followed by the empirical setting, where our empirical findings are gathered. Chapter five constitutes the discussion of the empirical findings and the literature in the structure of the RQ. The final two chapters are the conclusion and research limitations and suggestions for further research.

2.0 Research methodology

Through this chapter, there will be presented a thorough justification and description of the research method and approach in our research. This study is designed in a combination of data and theory interacting through an abductive approach. Moreover, the RQ aims to provide an understanding of SCR faced in large-scale projects within the construction industry and how these can be mitigated through suitable strategies. This indicates that a combination of theory and data is essential to create value to the research field. From this, an abductive approach seems most suitable to answer the RQ, as it may discover new findings, like other variables and relationships (Bell et al., 2019). This approach is emphasized by Dubois and Gadde (2002) to discover new combinations with theory and new concepts arising from the confrontation of reality in the industry.

In this chapter the research strategy is first presented with approach and methods, followed by the research design. Then the data collection methods are elaborated, followed by the data analysis. In the last part there will be a presentation of the research quality.

2.1 Research strategy

Research strategies are defined by Bell et al. (2019) to be a general orientation on how to conduct a business research. According to (Seawright & Gerring, 2008), the research strategy is the overall approach in a research project and researchers are to choose the most appropriate strategy, which is distinguished by quantitative and qualitative approach. The general differences separating these two, is that quantitative research employs measurements and analysis of identified numbers, while qualitative research focuses on the non-numerical data (Bell et al., 2019). The overall aim of our thesis is to discover the prominent SCRs in large-scale construction projects and how actors in the industry deal with SCR, resulting in a developed framework based on our findings. The research is based on a qualitative research strategy to get an in-depth understanding of the research area by interviewing different actors within the industry. Considering that SCM efforts and SCRM is nearly impossible to exclusively measure and that the LSP is still ongoing, and does not have any data points on performance, it would not be possible to make a quantitative research study in this thesis. Thus, we have

conducted an exploratory case study of the LSP in collaboration with SB, to provide an answer to the RQ and overall objective.

2.1.1 Scientific approach

Research strategy addresses how the researchers conduct their reasoning. In scientific research, it is traditionally distinguished between two theoretical approaches, which is commonly known as deductive and inductive methods. Having a deductive approach is to base the method on numeric data, aiming to generate propositions and hypotheses based on what is known through the theoretical foundation, and from this design a strategy with the aim to test these hypotheses in the real world (Bell et al., 2019). The inductive approach is an opposite direction of the deductive, which systematically generates new theories emerging from data in the empirical research (Bell et al., 2019).

In addition to inductive and deductive reasoning, an abductive research approach is suggested to be a third way of approaching a study. An abductive research approach is a mixture of inductive and deductive and is most suitable to support qualitative research. The approach includes what the two others ignore, which is motives, interpretation, meaning and intention from everyday life (Locke, 2008). Abductive reasoning is motivated by an observation of phenomena, seeking to develop explanations for them. It is done by working iteratively between theory and data, providing a back-and-forth method for collecting and interpreting data where the research steps are non-linear. The method is to systematically combine theory and research, where the aim is to incorporate the two approaches, deductive and inductive (Dubois & Gadde, 2002). The systematic combining approach is illustrated in appendix 1, and shows how the framework, empiricism, theory and the case interact. However, unlike inductive and deductive reasoning, it is possible to discover problems that have not yet been explored by researchers (Bell et al., 2019). The systematic combining is referred to as an abductive approach and is aiming to fill the gaps that are associated with the deductive and inductive approach. Moreover, it is a process method that entails going back and forth in between the theoretical framework, the empiricism and the various research activities, which will develop simultaneously together with the case analysis (Dubois & Gadde, 2002). Dubois and Gadde (2002) further argue that by

having this approach, the researchers can expand their knowledge and understanding of both the empirical and theoretical data and are acknowledged to be particularly useful in the development of new theories. Consequently, a systematic combining method is considered to be suitable for our thesis, as it allows a continuous interplay between established theory and empirical findings through the research process. As a result of this approach, it is possible to refine existing theories based on findings from our research, and it will then allow us to contribute to the theoretical knowledge and understanding of large-scale construction projects and their SCRs.

2.1.2 Method

Research strategy can be distinguished between quantitative and qualitative research methods. The two research methods are specifying how the data is collected and analysed, based on the choice of the researcher's case (Bell et al., 2019). Quantitative research has a deductive approach and is based on numeric data and quantification of the findings, as well as focusing on what is measurable. Qualitative research, on the other hand, is based on written or spoken words, interviews and images, and has an inductive approach. The strategy emphasizes words and can explain phenomena, which are not possible to quantify, and is referred to as exploring the meanings, definitions, concept and descriptions in combination with others (Berg & Lune, 2017). This method is frequently used in case studies to investigate business relations and non-numerical connections between actors. However, the qualitative method has been criticized for being too subjective, difficult to replicate and too generalizing (Bell et al., 2019). When taking the RQ into consideration, the qualitative research method will provide us with an understanding and allows us to gain in-depth knowledge of how actors in large-scale construction projects handle SCR, how these occur, and which are most frequently occurring.

In this thesis we will use an integration of qualitative analysis, as this method applies a more open-ended research strategy, connecting key concepts in literature with the research objective and is more complex than quantitative research methods (Bell et al., 2019). By doing this, we believe our readers will be provided with a deeper and more complete understanding of our research. As this thesis

aims to discover and explore new knowledge and findings on SCR in large, complex construction projects, it is important to gain knowledge from people's experience, beliefs, ideas and plans, as it is not a fully discovered topic. Collecting qualitative data will help to support the findings from current and future situations, and the method makes it possible to provide different answers on scientific questions which would not be possible through a quantitative approach (Sale & Thielke, 2018).

An abductive approach and qualitative research strategy are most applicable in this research, making it possible to get a comprehensive understanding of the SC, SCRs and interdependencies within the industry. The approach allows us to have continuous interplay between established theory and empirical findings through the research process (Dubois & Gadde, 2002). Given the nature of our study, a qualitative method in the data collection has been emphasised. This method provides us with in-depth knowledge on the research area and makes it possible to ask questions on how, why and what to get a better understanding of the topic.

2.2 Research design: A case study

A research design is to provide a framework to enable the collection and analysis of data which relates to the criteria used to evaluate the quality of the research (Bell et al., 2019). The research design is determining how the execution of research is performed, and how the research method and analysis of data is conducted. Based on our chosen research area and the empirical need for using data, a real case seemed most relevant in our business research, making a qualitative case study design applicable. Yin (2003) defines a case study as " ...an empirical inquiry must examine a contemporary phenomenon in its real-life context, especially when the boundaries between phenomenon and context are not clearly evident..." (p. 88). A case study design provides unique means to develop theory through in-depth insight of empirical phenomena (Dubois & Gadde, 2002).

Yin (2011) emphasises three main questions when a case study is performed; (1) when the problem statement starts with how or why, (2) when the researcher has little control over the event and (3) when there is something that happens right

now. It is further acknowledged by Bell et al. (2019) that a case study should be conducted when examining the detailed and thorough analysis of a case. According to research, a case study will provide a great foundation in several contextual aspects, like theory refinement and development, an extensive understanding of data and activities regarding the phenomenon of interest (Dubois & Salmi, 2016). It is emphasized by Eisenhardt and Graebner (2007) that case studies are rich, empirical descriptions of particular instances of the phenomena which are typically based on several data sources. In other words, each case is a distinct and unique experiment that stands alone as an analytical unit which emphasizes the real-word context where the phenomena occur.

Given the nature of this thesis and the fact that the LSP is an ongoing project, a case study deemed most applicable for our research. This gives us the opportunity to get a complete and detailed description of the case and allows us to enlighten the aspects of the phenomenon of SCRM in large-scale construction projects. To answer our RQ we have investigated the LSP managed by SB. This is a suitable object of research, as the project has a unique approach that emphasizes logistics, SCR and planning, when compared to previous projects executed by SB. The distinctiveness of the LSP and that the project still is in the conceptual phase, we have gotten input from the execution of the construction of the KHiB on how the SCR, planning and logistics were done, as well as interviews performed with others in the industry. This makes it possible for us to identify challenges and opportunities within large-scale construction projects that have a greater focus on logistics, as well as discovering normalities and abnormalities within the industry. Our research supports an exploratory case study approach, due to the given nature of this thesis, which has allows us to explore the various aspects of the phenomena of SCR and SCRM in the construction industry.

A case study can be conducted both as a single-case or as a multiple case study. Eisenhardt (1989) further emphasizes that a case study can involve multiple or single cases, with a numerous level of analysis. This study is a single case study as it investigates a single project and is a revelatory case study as it allows in-depth insight to gain knowledge (Dubois & Gadde, 2002). Furthermore, one of the advantages of a single case, is that is makes it possible to develop high quality theory and provide the researcher with in-depth knowledge and understanding of

the subject (Dyer & Wilkins, 1991; Yin, 2018). However, a single case does not generalize, as it only focuses on one specific subject or research area (Yin, 2018). The LSP is one of few projects large-scale construction projects performed in Norway with a strong focus on logistics, SCM and SCRM. In addition, the project is in the concept phase with no suitable projects to compare with. It is thus a suitable research object to investigate the integration of SCM, logistics and SCRM in a large-scale construction project.

2.3 Research process

The research process in this study is in line with an abductive approach, where we started with a literature review, and further looked into how the literature and empiricism got connected. By working back and forth with between literature and empirical data, we constantly ensured that we obtained relevant information. The literature review is a variety of literature from the SCR- and the construction industry field and serves as the theoretical basis in this thesis. Literature can be collected through either a structured search strategy or a chaining technique (Bell et al., 2019). The purpose behind the literature review is to establish a thorough theoretical foundation to provide a theoretical framework of the thesis to develop deeper knowledge and insight from the empirical research. It is identified a lack of research within the SCRM in construction and the literature review provided us greater insight in the lack of research, which we hope to contribute.

Furthermore, the existing literature could serve as an indicator of what kind of research methods that should be executed (Bell et al., 2019). In this paper we have collected the literature based on the chaining technique, and it should be called attention to the importance of literature in an abductive approach. The most significant keywords used in our research are “Supply chain risk”, “Construction”, “Supply chain risk management”, “logistics” and these references have been tracked to find other relevant articles have been used. The main articles used in this study are Thomé et al. (2016), Rudolf and Spinler (2018), Aloini et al. (2012) and Shojaei and Haeri (2019), as these provide a proper foundation for SCR and mitigation strategies in large-scale construction projects.

2.4 Data collection

Data collection is the essence and key point of any research. The appropriate way of collecting data depends on the RQ and the access of data available (Bell et al., 2019). Data can be collected quantitatively, qualitatively or both and according to Yin (2011), a case study does not have a specific data collection method. However, Eisenhardt (1989) emphasizes that a case study usually combines data collection methods. The data have been collected through the various data sources interviews, organizational documents retrieved from the interviewees and the literature review as a means of triangulation. In this research, the interviews constituted the primary data and internal documents where supplemented as secondary data (illustrated in figure 2). The validity of the data has been secured through a triangulation strategy by cross-examining the collected data, which is illustrated in figure 2 (Bell et al., 2019). The secondary data in the paper is characterized by organizational documents retrieved from project participants and other interviewees. Furthermore, the analysis of data has provided a mapping of existing SCR, the industry's perspective on these and how construction companies can mitigate these in a large-scale project.

To access relevant interviewees, there has been a purposive sampling for the research. Purposive sampling is a non-random sampling method with an intention to sample based on strategic reasons, so that the interviewees are relevant to the RQ (Bell et al., 2019; Teddlie & Yu, 2007). There are different approaches and techniques of purposive sampling, where sequential sampling is one. Sequential sampling is an evolving approach where the choice of units is based on relevance to the RQ, as data is collected (Teddlie & Yu, 2007). After the interviews, we gathered the data and discussed what information that was further needed to answer our RQ. Thus, we contacted our supervisor in SB who suggested people that could be of interest and relevance for us to contact and interview. Our supervisor from BI has also provided some relevant interview objects at our request, making it possible to develop a deeper understanding of the industry.

2.4.2 Secondary data

Secondary data is data that has already been collected by someone else (Bell et al., 2019). In this study, the secondary data consist of reports, organizational

documents and other contextual documents provided from SB. Reports have been provided from both the current LSP and the KHiB, along with other documents of relevance. Furthermore, some of the data is retrieved through documents released on the internet or in hard paper form and articles written by external sources (media, consultants, researchers).

2.4.2.1 Organizational documents

To supplement the primary data and look at details more in-depth, we received organizational documents from SB. We received project plans, concept descriptions and strategy documents from the LSP and the construction of the KHiB, as well as other construction logistics documents our supervisor in SB found interesting to us. It is worth mentioning that the construction of LSP started before this research started and will be finished several years after this thesis is completed. Hence, the documents provided from SB are from the period before the project start and documents that have been developed so far in the project. The type of document provided and who we got it from can be found in Table 1.

Organizational documents	Source	Content
Livsvitenskap Logistikkstrategi [Logistics strategies for the LSP]	Interviewee 1	Description of the logistics and SCM in the LSP.
Kort intro om prosjekt Livsvitenskap [Short intro about the Life Sciences project]	Interviewee 2	Short intro with key information about the LSP.
"Lean metodikk i praksis" [Lean methodology in practice] (Holm, Johansen, Van Veen & Werteback)	Interviewee 2	Book based on the conduction of the KHiB where they implemented Lean in the conduction of the project.
Konseptbeskrivelse Risikostyring logistikk [Concept description Risk management logistics]	Interviewee 1	Description of SB's identified SCRs that can have an impact on the SC and the performance of the LSP.

Table 1: Overview of organizational documents

2.4.2 Primary data

Primary data is data we collect through our research. In qualitative methods, primary data can be collected through depth interviews, group interviews, focus groups and non-participant observations (Askheim, 2008; Bell et al., 2019). Interviews are a commonly used method for collecting primary data, as it is a way to get sufficient and efficient explanations and knowledge with depth (Eisenhardt

& Graebner, 2007). According to Gillham (2005), semi-structured interviews are a good element in research as it is conducted in a structured way, which is important for the analysis. Due to the COVID-19 restriction, it was not possible to meet the interviewees physically, nor do observations on the construction site ourselves. This would have given us insight on how the logistics in a construction project work in practice. However, this will be elaborated further in chapter 7.0 Limitations and Recommendations for further Research.

2.4.2.1 Interviews

According to Yin (2011), interviews are considered important and useful in a case study and are preferred in a guided conversation rather than structured queries. Including interviews in the study can present the researchers with insight into certain topics and provide a thorough and in-depth understanding of factors and the project (Yin, 2011). Eisenhardt and Graebner (2007) emphasize that it is essential to ask the right questions to get valuable answers and select relevant informants with diverse perspectives on the addressed problem (Eisenhardt & Graebner, 2007).

Bell et al. (2019) suggests unstructured or semi-structured individual interviews within qualitative studies, as interviews are considered to be the most prominent data collection strategy. Semi-structured interviews are performed with an interview guide where a list of questions and topics are to be covered, and the questions are comparable along with the answers provided from the interviewees. Collecting data through semi-structured interviews provides flexibility through its structure and quality and enables the researchers to adjust the focus of the research accordingly to the data collection and explored findings (Bell et al., 2019). The agenda may not follow the given outline, where the researchers can ask additional and follow-up questions to get more insight of the given information (Bell et al., 2019). Structured interviews are further seen to be the most restricted way of data collection because the researchers are focusing on topics and challenges which are already predefined. Unstructured interviews are on the other hand embossed on the given topic, where the researchers guide the conversations and do not take control over the interview (Bell et al., 2019).

For our data collection, semi-structured interviews were the primary source of information. This made it possible for us to control the conversation with follow-up questions, get clarifications and have a conversation about the subject. The primary goal for the data collection was to gather information about the LSP and the SCR that have or will occur, as well as getting a deeper understanding of the construction industry and its SCRs and challenges. The interview guide was developed based on the findings and insights from our literature chapter and the first discussions with our supervisor from BI and SB, in accordance with the abductive approach. This guide was to ensure a flow in the interviews and that all topics of interest were covered. Doing so enabled us to get a greater and deeper understanding of terms and concepts in the industry that we did not know in advance.

We have conducted a total number of fourteen interviews with eight interviewees, where two of the interviewees were our main sources of information. The interviews lasted between half an hour and an hour and a half. In the two first meetings performed with SB, there were two interviewees present. Other than that, all the interviews were performed individually. The relevant information about the interviews performed is listed in Table 2. Our questions were formulated prior to the interviews. Most of the interviews were recorded and we took notes simultaneously. After each interview we gathered our perspectives to ensure that we had the same perception of the answers we had received. The participants from SB were pre-selected based on their roles, knowledge and involvement in the LSP. To provide a proper answer to our RQ it was necessary to interview people from the construction industry as well. The participants were experts from various parts of the construction industry, both contractors and clients, along with logistics providers and consultants. Some of these have been involved in the LSP, while the others were interviewed due to their general insight and knowledge from the construction and SC issues. The interviewees were chosen based on purposive sampling as defined in 2.3 Data Collection. We found it relevant to interview a variety of people from the industry to get different viewpoints and experiences on SCM and SCR mitigation in construction. These interviews had a vital part in the validation and understanding of how this is done and approached in today's practice. Having this approach made it possible for us to reveal information that could be misleading.

It is worth mentioning that the interviews were conducted in Norwegian, and the interview guides attached are in Norwegian (Appendix 2 and 3). It should be noted that the term "logistics" in Norwegian has several meanings and can be referred to as transport logistics, SCM and operations. In this thesis logistics is mainly associated with SCM.

To fulfil the requirements and regulations set regarding the General Data Protection Regulation (GDPR), the interviewee participant's names are anonymized. The interviewees are therefore numbered in statements and quotes throughout the thesis, where the information and quotation gotten through the interviews have been done carefully and with caution. In the following Table 2 there is an overview of the participants, which are respectively identified by numbers and workspace.

Number of interviewees	Type of company	Role of the interviewee	Number of interviews
1	Logistics providers	Logistics Manager working on the LSP	Four interviews
2	Client	Project manager of the LSP	Four interviews
3	Contractor	Project manager and purchaser	One interview
4	Logistics provider	Industry knowledge	One interview
5	Client	Project manager and purchaser	One interview
6	Contractor	Project manager and purchaser	One interview
7	Contractor	Industry knowledge	One interview
8	Logistics provider	Industry knowledge	One interview

Table 2: Overview of the interviewees.

2.5 Data analysis

Through this section the analytical process which is the baseline for the entire study is presented. Qualitative data is derived from interviews, observations or documents making the textual material unstructured and it is typically a large corpus that has been compromised (Bell et al., 2019). There are no clear rules in how to conduct a qualitative data analysis, and Miles (1979) describes it as an

"attractive nuisance" because the data is valued by qualitative researchers. As a result, it is essential for researchers to avoid being overly captivated in such a way that "they are unable to interpret the data's broader significance" (Bell et al., 2019, p. 518).

Analysing data as the foundation of building theories from case studies is seen as the most difficult and least codified part of the whole process of building theories (Eisenhardt, 1989). This process is a difficult part of the research process, and it is acknowledged by Bell et al. (2019) as in many cases the researchers rather end up describing the data than analysing it. However, being aware of this helped us in the research, as it made it easier to analyse the qualitative data and explain how the conductions were performed. It is further acknowledge that searching for patterns is a key strategy to provide validity and an explanation of the results from the study (Ellram, 1996). This is further being conducted through an abductive analysis and systematic combining that provides guidelines on the analytical part of this research.

Our research started with a development of a preliminary theoretical foundation on SCR theory and large-scale construction projects, which served as a basis in the data collection process. The main objective of the thesis is to provide empirical evidence to SCRM based on the LSP case and opinions and knowledge from the industry in general. Furthermore, the framework which was originally created, has been through several modifications and revised in the process. The reason behind the changes was new aspects and findings deriving from the empirical data, and as a result it led to an adaptation and expansion of our framework and theoretical foundation. This was discovered through identification and investigation of our RQ. Moreover, Bowen (2009) states the necessity of establishing a chain of evidence for cross verification in the research to establish validity. To establish this, multiple sources were used, and the data was collected through organizational documents and interviews.

Thematic analysis is one of the most common analyses to qualitative research, where the identification, analysis and interpretation of patterns of opinions are weighted (Bell et al., 2019). This method is used by researchers to closely examine the gathered data to identify common themes, which means that the

topics and patterns that are shown repeatedly. Themes identified are depending on the occurrence frequency and how many repetitions of words and phrases of a certain matter, following the course of coding (Bell et al., 2019). To analyse the collected data, a process of sorting, categorization, coding and conceptualizing were executed. According to Bell et al. (2019) repetition is emphasised as one of the most common criteria in the acknowledgment of patterns and whether the data warrants is considered to be a theme.

When searching for themes in this search process, we have used the recommendation from Grey and Russel (2003) to identify themes based on theory and similarities, analogies and contrasts from the interviewees discussion on a given topic. Having this approach made it possible for us to compare the different viewpoints from the participants interviewed, which supplemented this thesis discussion chapter. As a result, from using a thematic analysis, we have been able to test the coherency between our findings and our framework. It is illustrated in the following table which themes are covered, where it will be an inclusion of some quotations and statements conducted from our interviews with people in the construction industry. First theme focuses on which SCRs have occurred in a large-scale construction project like LSP, and how logistics are part of the project. Further, the difficulties and challenges in construction projects and how SCR is addressed in the industry. The identified themes are addressing the formal structures and informal conditions that are related to the case.

Theme	Question	Answers
SCR and management of risks	Which SCR are frequently occurring, connected to the SC? What are the biggest SCR or challenges?	"Problems with materials not being delivered JIT, creating difficulties for slot-times". "There are great issues in tracking the material and the lack of labeling"
Risk mitigation	What focus do you have on SCRM? Do many see the value of SCRM?	"Risk is always in focus" "General in the industry, it has been to standardize elements and that one can easily replace suppliers who cannot deliver. On the other hand, it is difficult to reward correct behaviour and easy to punish mistakes." "We work to implement a common communication platform that will make interaction and collaboration easier." "SCRM is acknowledge to be valuable, however, companies seeks to mitigate and not avoid these SCRs"
Digitalization	How is the digital development in the industry?	"The industry is working towards being more digital. However, the development is slow. It could have been faster, but at least they are working it". "The development is slow, and it is visible in the whole value chain that it isn't connected."
Transparency and trust	Is transparency and trust in entering into agreements in the industry?	"In general, there is not much transparency and trust in the industry. This is because the participants put themselves in focus, which is a result of a fragmented industry..." "The construction industry has a very "I, me and mine" way of thinking, which makes it difficult to focus on the whole SC."
Maturity	How is the maturity for logistics management and SCM in the construction industry?	"It is an immature industry if you compare it with the grocery industry". "I think it is strange that contractors haven't had a proper focus on logistics and the supply chain, as it is important with the right goods and assembly at the right time. The focus and attention have not been good enough"

Table 3: Extracted quotations from the interviews.

2.6 Quality of the research

To ensure the quality of the study and evaluate it, the trustworthiness and authenticity must be taken into consideration (Bell et al., 2019). Lincoln and Guba (1985) propose four criteria in the assessment of trustworthiness in a study: credibility, transferability, dependability and confirmability. According to Bell et.al (2019) credibility and transferability parallels internal and external validity, while dependability and confirmability are parallels with the reliability and objectivity aspects of the research. An evaluation of the research is critical, as the criteria will represent the scientific credibility of a case study and it is noted that it is important to establish the quality of a business research (Bell et al., 2019).

The more times the interviewer does an interview and gets the same result, the more trustworthy the findings are. Approaching different people from several companies with interviews, we got a comprehensive view of the research and industry, increasing the trustworthiness of the study.

2.6.1 Credibility

Credibility refers to the connection between researchers' observations and theoretical ideas from literature and is based on the trustworthiness in a study. This criterion has been argued to be the most important of the four when it comes to trustworthiness (Bell et al., 2019). Moreover, the criterion is developed to ensure that the research is conducted according to good practice and "submitting research findings to the members of the social world who were studied, for confirmation that the investigator has correctly understood that social world." (Bell et al., 2019, p. 363). A conjunction between observations and literature indicates strong internal validity according to Bell et al. (2019). It is further stated by Yin (2011) that the data collection process affects the validity of the research and the striving for credibility can be heightened through gathering relevant research and ensuring accuracy. Through the mapping of literature and empirical data, we discovered a match between the sources, which is reflected in the discussion.

Lincoln and Guba (1985) recommend triangulation as means to increase the credibility, and thereby the trustworthiness. To ensure high credibility in our

research, we used a triangulation technique. This was done by conducting interviews with different entities in the project, attending meetings and cross validating the information with secondary data, like reports and documents, that has been retrieved from the interviewees.

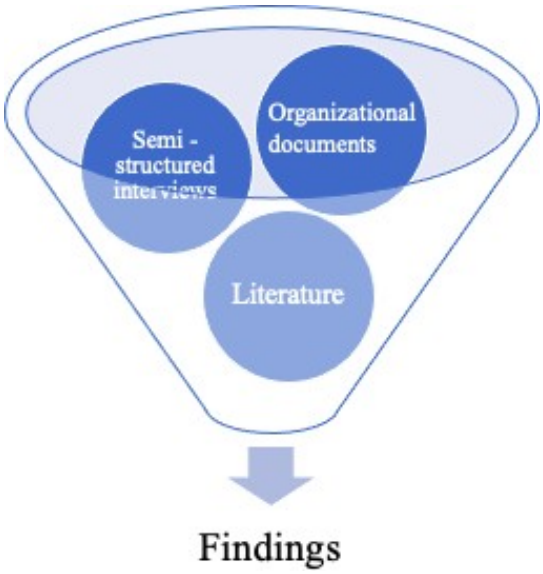

Figure 2: Illustration of the triangulation of our data collection.

2.6.2 Transferability

Transferability refers to the generalization of the study. According to Bell et al. (2019) it is dependent on whether the findings in the study can be transferred to other settings or companies. Geertz (1973) argues that the researchers should include thick description in qualitative research, which is rich accounts of the details of a culture. It is further stated by Guba and Lincoln that arranging a thick description provides others with a database where the individuals can make judgments regarding the transferability of the findings and to other environments (Bell et al., 2019).

In our thesis we have focused on the specific case study of the LSP, making it hard to conclude and apply our findings for other organizations. As a result, the transferability of our findings might not be adequate for other situations resulting from the uniqueness and complexity of the case (Bell et al., 2019). Some of our findings are firm-specific, and the results from the research might arguably only be suitable for similar projects performed by SB. However, it is suggested by Eisenhardt (2021) to strengthen external validity and improve generalizability by

involving cases and data with the same focal phenomenon in purposeful settings. In our research we have used the LSP as a foundation where we have further investigated how experts, contractors and consultants in the industry view SCR and mitigation of these. The intention is to provide a useful foundation for further research and discussions of how the findings might be applicable for other large-scale construction projects.

2.6.3 Dependability

Guba and Lincoln proposed the idea of dependability to demonstrate the trustworthiness of qualitative research. This involves adapting an approach which will ensure that records are completed at all stages in a research process (Bell et al., 2019). According to Bell et al. (2019) this consists of problem formulation, selection of research participants, interview transcripts, notes from the fieldwork, secondary data analysis, where all of these are stored in an accessible manner. This will make it easier for the researcher to present and elaborate the findings. Moreover, documenting the research process thoroughly can provide others who have the desire to do a similar study, a better starting point. In our research we started to apply for an approval to do interviews and record data following the regulations provided from The Norwegian Centre for Research Data (NSD) that complies with GDPR. To fulfil the GDPR and NSD requirements, it was necessary to store all data for our research on a password protected computer, because online services like Google or Dropbox do not fulfil the safety regulations. Consequently, some of our materials will not be published and accessible to others, which will limit the transparency and dependability of our research. However, the main interview questions are attached in appendix 2 and 3.

2.6.4 Confirmability

Confirmability reflects the objectivity the researchers have to the study and concerns with researchers being biased. It is further claimed that the study should be conducted in good faith from the researchers, meaning that they should not allow personal values or theoretical inclinations to angle the study in a particular direction (Bell et al., 2019). Confirmability is an important part of the thesis and has been emphasized through the process. Moreover, both researchers have

participated in the design of the interview guide, and we claim that none of the questions raised have been asked with an individual belief or hidden purpose. In all interviews conducted, both researchers were present and took individual notes to ensure that the interviews were unbiased. All the data collection and interviews were finished before the findings and discussion was prepared (Bell et al., 2019). Furthermore, it should be acknowledged that we do not have any personal gain to interpret the findings in a particular direction.

2.6.5 Authenticity

Lincoln and Guba (1985) propose a fifth criteria in addition to the four criteria presented above. Authenticity appraises the issues concerning the wider political and social impact of the research and is related to the researchers fairly representing different viewpoints. In terms of fairness, we have included all data provided from the various research participants. We formulated questions prior to the interviews, recorded the interview, took notes simultaneously and gathered our perspectives after each interview, to ensure that we had the same perception of the answers we had received. This made it possible to ensure authenticity. Lastly, we hope our research could have an impact on stakeholders and engage them to take actions in changing.

3.0 Literature review

This chapter will examine relevant literature for answering the RQ: *How can actors in large-scale construction projects mitigate supply chain risks?* A theoretical framework will be presented, setting the academic context and will work as a foundation for the analysis of the case.

The industry is exposed to different types of SCR, among other things, it consists of several actors and SCs, implicating a high complexity causing greater disruptions. Moreover, it is emphasized by Aloini et al. (2012) and Yeo and Ning (2006) that the projects in the construction industry are characterised with high fragmentation, low productivity, time and cost overruns, and conflicts. According to Christopher (2016), SCM is a wider concept than logistic. Logistics seeks to create a single plan for the flow of information and materials, while SCM is a newer concept and builds upon the framework of logistics. However, it is noted

that the definition of logistics is not unified and, in several environments, SCM and logistics are commonly acknowledged as one (Li, 2014).

RM in projects is a widely researched literature topic, but it is stated by Rudolf and Spinler (2018) and Thomé et al. (2016) that the SCRM literature is lacking. The greatest distinguisher between the two research areas is how SCRM focuses on risks in the SC and risks that can cause disruptions in the SC (Rudolf and Spinler, 2018; Thomé et al., 2016), while RM in projects is a research area where the focus is on how to handle risks in the project (Chapman, 2019). Consequently, relevant SCR theories provide a foundation of the construction industry's SCR profile. By investigating and exploring different theories and strategies, the SCR in large-scale construction projects can be identified and various mitigation strategies explored. Further, the literature provides the foundation for a framework to see how different types of SCR in construction projects can be mitigated and categorised (Rudolf & Spinler, 2018; Sodhi & Tang, 2012; Thomé et al., 2016).

3.1 Large-scale construction projects

Each construction project is unique in terms of size, location, different architects, engineers, contractors and subcontractors (Wegelius-Lehtonen, 2001). Since the 1980s, large-scale construction projects have gained attention in terms of its delivery model in the engineering and construction industry (Rudolf & Spinler, 2018). These projects are defined when it exceeds a budget of one billion dollars Capka (2004) and is characterized by "... a high number and diverse types of stakeholders (e.g., authorities, owners, designers and constructors)" (Rudolf & Spinler, 2018, p. 337). Large-scale construction projects involve numerous contractors, actors, large budgets and often take years to complete. As these projects often deal with several SCs simultaneously, make the industry complex to manage (Aloini et al., 2012).

Research has shown that only one in 1.000 large-scale projects is successful (Flyvbjerg, 2011). Yeo and Ning (2006) associate this with high fragmentation, low productivity, conflicts and cost and time overruns. Some researchers further claim that construction is the least integrated out of all industrial sectors, represented by adversarial and disjointed relationships (Bankvall et al., 2010;

Fearne & Fowler, 2006). Numerous researchers claim that the construction industry suffers from poor performance and that there is no interdependence within the individual SCs fitting the complexity presented in large-scale construction projects (Bankvall et al., 2010). The complexity and lack of coordination caused by interdependencies are considered a key reason for poor SC performance implicating a potential for improvements in mitigating SCR (Humphreys et al., 2003).

Large-scale projects are distinguished through their complexity, uncertainty, political and external influence (Floricel & Miller, 2001). Further, there are at least three factors that are highlighted in large-scale projects: a large sum of resources; high human, social and environmental impact; and great complexity (Capka, 2004; Flyvbjerg, Flyvbjerg, et al., 2003). Within the construction industry, these large-scale projects can be characterized as an engineering-to-order environment, where the performance is conducted through an environment with high complexity and high values related to supplies (Rudolf & Spinler, 2018).

3.1.1 Construction supply chains

Large-scale construction projects consist of a SC that has a great number of interactions between several actors and parties within various projects, making the SC complex and of temporary nature (Ekeskär & Rudberg, 2016). The actors in these SCs usually produce and implement physical products with little mobility, which means that the activities are often carried out and implemented on the site. These CSCs are operating under high uncertainties and interdependencies. It is called attention to the issues in how actors solve problems and distribute responsibilities regarding vulnerability, uncertainty and SCR in literature (Jones & Lichtenstein, 2008; Wang et al., 2017).

A CSC can be characterized as a converging SC that directs materials to the construction site, where the incoming materials are further assembled. The CSC is a typical make-to-order process as there will be a new product or prototype created in every project. Further, a CSC is of temporary duration, and will only last in the project's life span (Bakker, 2010; Chen et al., 2020). Grabher (2002) calls attention to actors in a CSC who usually have a limited task in a project and

will not be included in the whole process. Thus, the actors do not get the full perspective of the processes as the focus will only be on the task or activity that will be executed and may therefore miss valuable information and learning from the process. This can be a result of managers and contractors not continuously considering the SC, as there are difficulties with the interaction between the actors and the unstable nature of a CSC (Min & Bjornsson, 2008; Vrijhoef & Koskela, 2000). Egan and Williams (1998) reveal that there is inefficient linkage among the actors in the CSC, which contributes to the fragmented industry in terms of customer demand and expected efficiency. It is further supported by Chen et al. (2020) that the CSC faces significant problems because of inefficient coordination of information between the actors.

Vrijhoef & Koskela (2000) argue that the CSCs are broken down to three main conclusions; Firstly, the CSC is responsible for a significant amount of waste and problems. Secondly, problems are normally detected in a later stage than it was caused. Lastly, the difficulties regarding waste and challenges are mostly caused out-dated and blindness control of the CSC. There is a considerable amount of resource waste and delays of information in a CSC and having an efficient CSC through SCM provides improved performance in a large-scale project and reduces waste caused by lack of control and efficient management of materials (Bankvall et al., 2010; Chen et al., 2020; Wang et al., 2017).

3.2 Supply chain risk and supply chain risk management

The concept of RM has risen from companies' efforts to reduce vulnerability to risk and uncertainties (Rangel et al., 2015). As a result, this has increased the attention for finding applicable mitigation strategies to cope with risk and disruptions that might occur (Tang, 2006). There has been a significant development from previous literature and traditional viewpoints, where risk was undesirable. However, compared to today's society, firms have started to acknowledge that risk can cause advantages through proper SCR management (Rudolf & Spinler, 2018).

Risk is a broad term that has been discussed and defined in many ways within literature (Brindley, 2017). Heckmann et al. (2015) define risk as the "...

probability of occurrence of disruptive events" (p. 121). The definition is backed up by Mitchell (1995), expressing risk as the probability of loss and its significant impact on an organization. Many researchers define the negative consequences of uncertainties and positive consequences as opportunities (Hillson, 2002). Moreover, DeLoach (2000) defines risks in business as the "level of exposure to uncertainties that the enterprise must understand and effectively manage as it executes its strategies to achieve its business objectives and create value". SCR is further referred to by Aloini et al. (2012) to be an uncertain event or a condition that can have a negative impact on a project's objectives if it occurs, and a SC should aim to quickly and effectively respond to the occurred events. Regarding SCM, SCR has been associated with complexity, uncertainty and resilience when it comes to the concept of relational SCR in temporary multi-organisations (Thome et al., 2016). On the other hand, Jüttner et al. (2003) acknowledge that SCR is network-related, rather than being related to the product as in project RM literature. Jüttner et al. (2003) furthermore endorse that many organizations think they have mitigated SCR, but have actually often overlooked critical exposures in the SC.

Through extensive evidence there has been identified that the frequency of man-made disruptions and disasters has increased exponentially (Coleman, 2006; Tang, 2006). Consequently, this has increased the possibility of occurrence and impact on the CSC (Shojaei & Haeri, 2019). The identification of these SCRs is important, as the probability and impact are associated with individual SCR. Moreover, systematic interaction of SCR occurrence is not considered at the commencement stage in a project or in the project's life cycle (Qazi et al., 2016).

Higher degree of globalization and increased complexity has made SCR and SCRM gain momentum during recent years (Tang, 2006). This is because SCs are vulnerable to disruptions, which can cause unanticipated consequences and have impacted the performance of the companies in recent years (Ho et al., 2015). Sodhi and Tang (2012) acknowledges the necessity of SCRM, and Tang (2006) states that costs will increase by implementing RM strategies but provide additional selling points and retain apprehensive customers before and after major disruptions. Christopher (2016) supports the importance of SCRM and highlights

the importance of building a SCRM culture through the whole SC, which can result in less potential damages on the SC as a whole.

There is a common agreement amongst researchers of the importance of focusing on risk in SCs, as well as the importance of mitigating these properly and that the consequence of proper SCRM can improve SC performance (Aloini et al., 2012; Heckmann et al., 2015). Although risks appear in all kinds of SCs, there is a lack of a clear and coherent definition of SCR (Heckmann et al., 2015). Sodhi & Tang (2012) state that SCR are tied to the circumstances creating vulnerability for significant discrepancies between demand and supply. Thomé et al. (2016) further states that SCR can be connected to demand, product and information, and therefore suggests a categorization of the SCR in four categories: organizational, network, industry and environment. SCR can in simple terms be referred to as the possibility and effect of a mismatch between supply and demand (Jüttner et al., 2003). Christopher (2016) defines SCM to be "The management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole". SCRM is further identified as an implementation of strategies to handle everyday risk and unforeseen risks that might disrupt the SC (Kilubi, 2016).

Jüttner et al. (2003) suggest distinguishing four basic constructs in SCRM: SCR sources, consequences, drivers and mitigation strategies. SCR sources refers to the environmental, organizational or SC-related variables that impact the SC and cannot be predicted with certainty. The consequences of SCR are the SC outcome variables like quality and costs. SCR drivers are "calculated risks" that a company takes to improve their competitiveness, reduce costs and increase or maintain competitiveness (Svensson, 2002). SCR mitigation strategies are on the other hand strategic moves a company takes to mitigate uncertainties identified from the risk sources (Miller, 1992). In order to understand how to mitigate SCR efficiently in construction projects, it is crucial to get an understanding on how the SCR are generated and how they are influencing the firm's operations. SCR identification is the first step in a SCR assessment process and is necessary to provide suitable mitigation strategies (Ho et al., 2015).

3.2.1 Supply chain risk in construction projects

Construction projects often deal with several SCs simultaneously, which have made the industry more complex and exposed to SCR (Aloini et al., 2012). They are faced with numerous SCRs during its lifecycle, much due to their complexity and intricate relationships within the SC and with those involved in construction projects (Shojaei & Haeri, 2019). These SCRs can influence time causing delays and cost overruns, turning a project into a loss-making venture instead of a profitable investment. Within construction projects, the three primary targets that are most likely to be affected by the uncertainty and SCR are time, cost and quality (Smith et al., 2014). Moreover, SCR can cause great problems, like unanticipated changes in the flow due to delays or disruptions, and small delays or disruptions can cause a bullwhip effect (Chopra & Sodhi, 2004). The bullwhip effect is characterized as small fluctuations in demand which can cause great fluctuations in the SC (Lee et al., 1997). Hence, when a small disruption occurs, the order variability increases as the orders move upstream in the SC and therefore it will impact the project (Wang & Disney, 2016). Some researchers suggest that the domino effect caused by a disruption in a SC might have been aggravated in the last decade (Christopher & Lee, 2004; McGillivray, 2000).

In general, the main contractor often has several ongoing projects, indicating high complexity for construction companies, with interdependencies between tasks where the actors involved in the conduction need to be coordinated (Bankvall et al., 2010). Furthermore, complexity varies from each project and relates to the structural, dynamic elements and the interaction of these. These interactions are broad categories of technical, organisational and environmental domains (Qazi et al., 2016). The complexity in a construction project is caused by several contributing factors such as: components, tasks, financial aspects together with the funding, personnel, as well as a large number of sources creating SCR and the interaction of these (Kardes et al., 2013). From previous research, Van Marrewijk et al. (2008) highlight some factors leading to complexity; the large scale, great timespan, the multiplicity of technological disciplines, the number of participants, multi-nationality, the interests of stakeholders, sponsor interest, increasing costs over time, country risk, uncertainty and high levels of public attention or political interest.

Interdependencies within the individual SC may cause challenges and increased SCR in a project (Bankvall et al., 2010). The low performance in the construction industry can be connected to the lack of collaboration and integration of suppliers at an early stage in the planning process. Further, it is acknowledged by Rudolf and Spinler (2018) that SCRs are considerably underestimated at the beginning of the project and that the industry is lacking flexibility, visibility and transparency.

3.3 Identification and categorization of risks

In the beginning of a construction project, it is beneficial to identify SCRs regarding probability and impact, which tends to be an underestimated task. Consequently, it will be easier to develop a suitable plan to deal with possible occurring SCR (Rudolf & Spinler, 2018). By identifying and classifying SCR, one can assess and further look at the interrelated relationships between various SCR to get an overview of the consequences and likelihood it can pose a project. Berle et al. (2013) acknowledged that categorization of risks is necessary in the foundation for developing scenarios of vulnerability to establish mitigation strategies.

Rudolf and Spinler (2018) have identified the most typical SCR in large-scale engineering- and construction projects to be the environment, SC coordination and management, supplier behaviour and cooperation. In the environmental risks some sub-categories are prominent, like the economic risks, the social environment, following and being updated on laws and regulations and natural events. Within SC coordination and management, the most prominent sub-categories are SCM along with its configuration, changes in demand, logistics, planning and forecasting. Furthermore, the supplier risks focus on the performance and operations, the environment and market of the supplier, contractual terms and conditions, and the supplier's financial stability. Lastly, behaviour and cooperation are a risk with less frequent occurrences where the most prominent sub-category is collaboration and planning. These SCR are the ones with highest occurrence in large-scale construction projects. Within large-scale construction projects, some of the most significant challenges the industry is exposed to is lack of labelling and labelling errors. There are no set standards in this area, which have resulted in suppliers using different labelling of materials, making the sorting and storage

process difficult. These challenges expose the SC and may cause disruptions and exceed costs (Ginzburg et al., 2018).

Sodhi and Tang (2012) also suggest SCR categorization into four types: supply, demand, process and corporate level. Uncertainty relating to the customer and its demand is characterized as demand risk. Risk of getting the correct supply at the correct time and space is associated with supply risk, as well as supply cost and quality. The process risk covers internal risks within a SC and arises at a construction site, which concerns the design, manufacturing and distribution. Further, overall risks that may arise in relation to regulations, financial conditions and weather, among other things are associated with corporate-level risk. However, the main distinguisher between Thomé et al. (2016)'s and Sodhi and Tang (2012)'s framework is that Thomé et al. (2016) concerns temporary multi-organization projects, while Sodhi and Tang (2012) concern the SC as a whole. The SCR categorization in this section is based on the framework suggested by Thomé et al. (2016) due to large-scale construction projects being a temporary organization. Thomé et al. (2016) suggest four SCR categories: organizational, network, industry and environmental. These dimensions are based on previous literature and provide a review of the most important SCR faced in a project.

Categorizing SCR events makes it possible to accommodate the impact of the event for a particular SCR category and provide better knowledge and comprehension of the disruptions that might occur in an industry's SC (Sodhi & Tang, 2012). By categorizing SCRs provides a better understanding and management of those identified in a CSC. The categorization helps address the SCR that make the SC vulnerable in a structured and systematic way and is deemed to be of great importance as the impact of SCR can create huge consequences (Colicchia & Strozzi, 2012; Rangel et al., 2015). After the categorization of SCR, mitigation strategies can be developed and implemented.

Complexity and uncertainty drivers in SCM are being reviewed by Serdarasan (2013) and are further classified according to type. The first type is static or structural, which is the number of components and interactions in the SC. Secondly is the dynamic type that is connected to operations, and further relates to the uncertainty of time and coincidence. The third type is decision-making, which

is associated with the volume and the information required to make a decision. Further, these types of complexity (static, dynamic and decision-making) are cross-referenced with what is considered to be the origin of complexity. When cross-referenced with the origin of complexity it is the internal, external and supply/demand interface that are of importance. The internal origin is generated by the decision and internal factors in a SC, like products and processes. However, within the supply/demand interface it is the material and information flow with customers, suppliers and service providers that are in focus, while the external focuses more on market trends and regulations (Thomé et al. 2016). These origins and complexity types are further being connected to each other, providing a more extensive understanding of the categorization of SCRs.

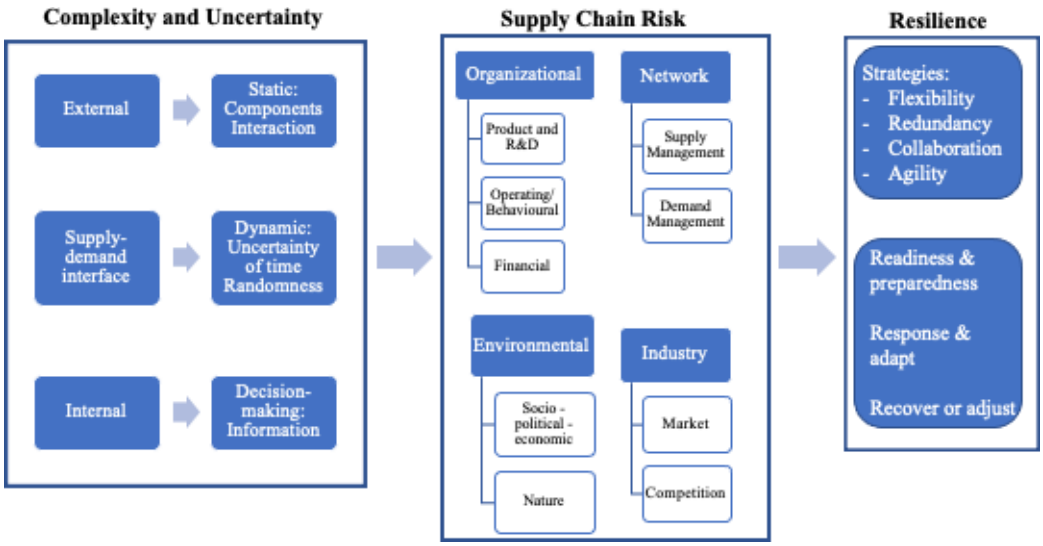

Figure 3: A synthesis framework for supply chain risk, (Thomé et al., 2016).

3.3.1 Organizational

Organizational risk is associated with the internal risks to the focal firm and is further divided into subcategories. The first is associated with SCR related to the product, such as the uncertainties connected to the launching, development of new products and liability risks with existing products. The operational and behavioural SCR categories are connected to labour, raw materials, IT and manufacturing technology, strikes and employees seeking their personal gain (Thomé et al., 2016). The financial risk aspect is another subcategory at the organizational level. This SCR is associated with the dependency of financing to execute assignments and complete the project within aimed quality, time frame

and budget (Harland et al., 2003). All these SCRs are prominent in the construction industry.

3.3.2 Network

Network risk is associated with supply and demand disruptions, such as seasonality, outbound logistics, product development and product life cycle threats (Thomé et al. 2016). The lack of ownership in the network creates unclear boundaries between buyers and suppliers. This may lead to uncertainties regarding responsibilities along with visibility, which can lead to a bullwhip effect in the SC (Ho et al., 2015).

3.3.3 Industry

The industry risks are associated with the market and competition regarding the quantity to produce and the timing of production as well as concerning the change in demand affecting the market. There are SCRs concerning how fast the market changes, especially in the construction industry, as new requirements and changes in demand from the end-customer may arise (Akintoye & MacLeod, 1997). Moreover, the competition poses SCR because firms no longer compete as firm against firm, but SC vs SC (Thomé et al., 2016). If a competitor has a better SC, with better visibility, their SC will be more efficient with less disruption and more accuracy.

3.3.4 Environmental

Lastly, the environmental risk includes socio-political changes and governmental regulatory actions, and man-made and natural disasters that can disrupt the SC and project development (Tang, 2006). Within this category, the most prominent SCR is the geotechnical risks, due to the huge effects a disruption in the environment will have on a construction project. It could cause delays, budget overruns, changes in material and uncertainty (Thomé et al., 2016).

3.4 Mitigation strategies

As previously mentioned, the construction industry is faced with numerous SCRs that can disrupt the SC. SCR identification provides the foundation for developing and establishing prevention efforts and mitigation strategies. Giezen (2012) and Lehtiranta (2011) refers to how structural and known uncertainties are avoidable by reducing the complexity of construction projects, while the unknown uncertainties are unpredictable and reveal the necessity for mitigation. To reduce the likelihood and consequence of the different SCRs in the construction industry, different mitigation strategies are decisive. Rudolf and Spinler (2018) affirms how companies have realized the competitive advantages after managing SCR properly. This implicates the importance of having sufficient mitigation strategies and by implementing these correctly, the likelihood and consequence of the SCR will be reduced.

Researchers agree on the importance of mitigating risks properly in SCs (Heckmann et al., 2015). Furthermore, SCRM is identified as an implementation of strategies to handle everyday SCR, as well as unforeseen events that might disrupt the SC (Kilubi, 2016). As both natural and man-made disasters have increased dramatically during recent years, it is more important than ever to implement mitigation strategies that can reduce potential negative outcomes (Tang, 2006). Mitigation of SCR and the aim of SCRM is a valuable approach to prioritize the most prominent and problematic issues in large-scale construction projects, making it possible to select adequate response actions (Aloini et al., 2012).

It is further acknowledged by Thome et al. (2016) that several of the mitigation strategies are connected and intertwined, creating synergies and establishing resilience in the SC. CSCs are faced with several SCRs and uncertainties, making them inefficient, and by implementing SCRM the projects will strengthen their ability to face the sources of SCRs (Chen et al., 2020; Kilubi, 2016). It is further stated by Jüttner et al. (2003) that known uncertainties serve as triggers for mitigation strategies, while the unknown uncertainties are the motivation towards resilience. To handle the disruptions in SC resilience, strategies can be conducted and Thomé et al. (2016) have supported resilience strategies to be categorized into four dimensions: flexibility, redundancy, collaboration and agility. Having

resilience strategies leads to preparedness and effectiveness to respond to unforeseen events. However, by implementing these strategies loops back to complexity, because by strengthening the resilience will often lead to networks becoming more complex (Bhamra et al., 2011; Colicchia & Strozzi, 2012; Hohenstein et al., 2015; Ponomarov & Holcomb, 2009).

Flexibility is the first strategy to work towards to establish resilience in the SC and to mitigate unknown and known SCR. It can be achieved through several strategies, like *JIT* and *digitalization*, which will be further discussed (Jüttner et al., 2003; Tjahjono et al., 2017; Yang & Yang, 2010). This is further supported by Rudolf and Spinler (2018) that large-scale construction projects lack flexibility, visibility and transparency, making it important to mitigate. The next category is to handle the *redundancy* in order to spare capacity and inventory to mitigate disruptions, like sparing stocks, having multiple suppliers and extra facilities. It is suggested by Tukamihabwa et al. (2015) to reduce waste and improve coordination, which can be achieved through a *lean strategy*, and it is acknowledged that large-scale construction projects are aiming to reduce the waste through the SC (Tortorella et al., 2017). The third strategy is to enhance collaboration. A *collaborative strategy* is thereby necessary as it refers to the ability of working efficiently with other entities and *share information and knowledge*. Being collaborative results in mutual benefits within forecasting, *postponement* and sharing of SCR. Moreover, it is emphasized that choosing the right supplier is crucial to be successful with collaboration in a SC (Bresnen, 2009; Jaskowski et al., 2010; Tukamuhabwa et al., 2015). Lastly is the dimension of agility, where the ability to respond rapidly to unforeseen events in demand or supply is considered necessary and important. Being agile is seen as creating visibility and velocity in the SC which will help to detect disruptions at an early stage. Identifying vulnerable suppliers and implementing tools will decrease the potential failures (Jüttner & Maklan, 2011; Tukamuhabwa et al., 2015). This indicates *supplier selection* and digitalization as initiatives to create a more agile SC (Aćimović & Stajić, 2019).

Based on this, it seems appropriate to further explore the mentioned mitigation strategies; *lean, JIT, postponement, digitalization, collaborative strategy, supplier selection, information and knowledge sharing*. The consequence of focusing on

these four dimensions in a SC of temporary nature is to become in a constant state of preparedness and readiness, making it possible to respond rapidly to unforeseen events and adaptation to changes, making it possible to recover or adjust to the disruptions (Thomé et al., 2016).

3.4.1 Lean construction

By implementing lean as a mitigation strategy may help cut costs and improve the SC coordination, improving redundancy (Thomé et al., 2016; Tukamuhabwa et al., 2015). Lean arose as a philosophy from the automobile industry to manage supply resources better. It rapidly increased and developed when it expanded to other industries and broader contexts (Hines et al., 2004). The philosophy is applicable in various industries and provides the foundation for waste reduction and value growth. Lean principles involve continuously working towards identifying and eliminating waste, in terms of time and material, to achieve only value-adding activities in the value stream and maximize value and profit (Rother & Shook, 2003). There is a misconception that the main purpose of lean is to reduce costs, while the main goal of lean is to increase capacity by designing a system that optimally meets customers demand (Womack & Jones, 2003). The philosophy works to establish an efficient and high performing SC (Tortorella et al., 2017). Moreover, lean is a strategy that works towards cost minimization and waste elimination making it a suitable strategy to reduce SCRs (Cabral et al., 2012; Tukamuhabwa et al., 2015).

Lean philosophy in the construction industry has developed further into the concept, Lean construction. This has evolved to become one of the most prominent means to improve construction performance over the past years (Bygballe et al., 2018). Lean construction is referring to the adaptation and application of the underlying principles and concepts from the Toyota Production System, into the construction industry (Sacks et al., 2010). However, the adaptation of lean into SCM is a difficult process. It is, among other things, easier to identify waste on the floor level rather than in a SC, and processes can be controlled through top management while SCM requires involvement from the entire SC (Tortorella et al., 2017). In lean construction there are some of the same principles, where the focus is to reduce waste, increase value and seek continuous

improvements (Sacks et al., 2010). “The creation of value in building and construction projects has a particularly strong place in the lean construction philosophy that lean is based upon” (Koskela et al., 2002). Lean construction is the adaptation of the underlying concepts and principles to outline this, which are the transformation, flow and value. Working lean means to integrate these three principles into the SC (Koskela et al., 2002; R. Sacks et al., 2009).

According to Issa (2013) lean construction strategy can serve as a tool to decrease variability risks, improve flow reliability, eliminate waste, remove complexity in operations and implement benchmarking. The three principles transformation, flow and value are essential in the implementation of a lean construction to mitigate potential SCR. In the transformation view, which originates from the value chain theory proposed by Porter (1985), is one approach embodying the transformation principle (Koskela et al., 2002). The principle provides an overview of which tasks are needed in the SC and how to get these realized, and through this principle the SC can seek continuous improvements (Koskela et al., 2002; Sacks et al., 2010). The flow principle of production was first introduced by Gilbreth and Gilbreth (1922) and has been the basis for lean and JIT production. The goal with the principle is to eliminate or reduce redundant waste from the flow process and prominent concepts is to reduce lead time and variability, as well as promoting simplifications. In the third principle, the focus is on value generation (Sacks et al., 2010). This principle aims to create the best value from the customer’s point of view and is associated with the quality (Cook, 1997; Koskela et al., 2002).

These three principles can be connected to how the SC is modelled, structured and controlled, and that they combined can improve the SC. Lean construction is still “a work in progress” and often lacks information sharing between contractors, which is a crucial part of the philosophy and will be further discussed in 3.4.6 (Sharma et al., 2011). Moreover, lean construction is based on a better theory than conventional construction and by implementing lean in the SC makes processes more efficient than the conventional point of view (Koskela et al., 2002). These concepts and principles can be used as ways to manage SCR and working lean will simplify the SCR and establish high efficiency (Issa, 2013).

3.4.2 Just in time and postponement

JIT has its origin from the manufacturing sector where it supports handling materials efficiently and providing the right materials with the right quantity and quality "just in time" for production (Pheng & Chuan, 2001). The concept was developed to do operations and planning more efficiently and create greater quality in production. In general it is acknowledged that JIT improves quality, motivation and morale amongst the employees, along with worker involvement, commitment and decreasing inventory, as well as decreasing lead time, setup time, defects, preventive maintenance and costs (Akintoye, 1995). By implementing JIT ensures that a supplier delivers the product or production to reduce inventory and consequently reduce production costs, along with inventory cost and delays (Shin et al., 2011). Hence, JIT is emphasized to create collaboration between actors in the SC because of the requirements following an implementation. These requirements are set to establish trade-offs against the benefits, leading to a strong network that could facilitate a rapid and efficient response if the CSC is disrupted (Thomé et al., 2016; Tukamuhabwa et al., 2015). Important factors that are relevant in the construction industry are the implications for construction output and quantities, supplier relationships and material sourcing. Moreover, the concepts of addressing complex communication and coordination, along with waste minimizing, is JIT (Akintoye, 1995).

In today's construction industry buildings are getting larger, taller and even more complex as new technology is developed. This has resulted in higher difficulty to secure the stockyard for material (Shin et al., 2011). The industry requires active movement of materials from suppliers to the production area or the construction site. A JIT system can make sure that materials can be delivered to site just before use and preferably on the day of use (Lim & Low, 1992). It has been more common to use prefabricated modules, such as precast concrete components are usually big, bulky and heavy, which requires expensive cranes for hoisting. It is therefore important to minimize handling of the components through good logistics management (Pheng & Chuan, 2001). Pheng and Chuan (2001) refers to the 3S for buildable design underpinned by the three principles of standardization, simplicity and single integrated elements. Standardized prefabricated modules makes the production of the modules and assembly on site easier. Simplicity is identified as uncomplicated building construction systems and installation

processes, making assembly and installation more efficiently. Combining several single integrated elements to form a single element may help to save time on site. Pre-installed window frames and wall tiles reduce operations and time on site. The 3S principles in design have a positive effect on buildability and may increase productivity and effectiveness. As all components are promptly delivered and received, JIT is time sensitive. Factors such as poor coordination and SCM, inadequate space for storage and traffic congestion at the worksite can interfere with the deliveries, causing additional expenses (Pheng & Chuan, 2001).

Flexibility is highly valued in business, which can be achieved through various strategies. One of these is postponement, which is a strategy extracted from JIT. The strategy is based on the principle of delaying the decision to make, configure, label or ship products to a particular destination or until order information becomes available (Jüttner et al., 2003; Yang & Yang, 2010). This reduces the dependencies on forecasts and increases the company's ability to respond to variability and disruptions in demand (Jüttner et al., 2003). A postponement strategy becomes increasingly valuable when the degree of external components increases in the final product (Manuj & Mentzer, 2008). In construction, postponement may be valuable as it delays the assembly of the different components which increases flexibility and reduces assembly time on site.

3.4.3 Digitalization

Digitalization is a significant part of today's- and future businesses and is essential to keep up with demand in the market and economic growth. Moreover, digitalization creates greater robustness in the SC, and can be used as a SCR mitigation strategy (Ivanov et al., 2019). Through a more robust and resilient SC, creates better flexibility to adapt to the fast-changing environment and disruptions that occur in a large-scale construction project with little time and effort (Thomé et al., 2016; Tjahjono et al., 2017; Tukamuhabwa et al., 2015). The SC will always be affected by changes and developments. In a world with unique, outstanding complexity and opportunities, the SC is now faced with radical changes making it even more complex and intricate the past decade than before. These extensive changes are executed to respond to the increasing challenge to improve performance, flexibility and response time (Tjahjono et al., 2017).

Through digital disruption and pressure on the information flow and the physical flow in the SC, firms have been pushed to become more innovative in their way of doing business.

The construction industry has been slow in the adoption within digitalization compared to other industries when it comes to technological innovations and processes (Agarwal et al., 2016). Eling and Lehmann (2018) acknowledges how digitalization helps industries in the grasp of operational excellence, how it changes SCs to become more automated and how it increases efficiency of physical tasks and planning, which also becomes automated (McKinsey & Company, 2016). Lugert et al. (2018) emphasise digitalization as it helps the value stream mapping the suppliers correctly in real-time, making it easier to detect faults and react quickly to volatility. However, the construction industry has not been able to keep up with technological developments to the same extent as other industries. High degree of on-site interaction, low commitment to digital technology among workers and fragmented relationships may be some reasons for the low digitalization in the industry (Friedrich et al., 2011).

It is acknowledged by Aćimović and Stajić (2019) that digitalization can be used as a tool to develop from the traditional trade-off between speed and price, to the pursuit of creating an agile SC. Even though globalization has increased the length of SCs, the implementation of digitalization as a strategy will shorten the informational lengths. This has resulted in informational lead time in a SC to shrink significantly, and is often close to zero, even though the material flow lead time has increased and become longer in several cases (Mak & Shen, 2021). Implementing digitization in a construction project can serve as a mitigation of SCR, as it could enhance the SC by the use of information technology establishing real-time sharing of information. Agarwal et al. (2016) states that this will ensure transparency and collaboration, quality control and from this create better and more reliable outcomes. By doing so will increase the SC resilience through increased flexibility (Thomé et al., 2016).

3.4.3.1 Integrated systems

The implementation of digitalization in the construction industry is regarded as a key strategic response to mitigate low productivity, quality and to get value for

money (Linderoth, 2017). It is shown that only 1% of revenues is invested in information technology and research and development (Agarwal et al., 2016). Incorporating integrated systems in a project will improve information sharing, collaborative value creation through new ways of interaction and transparency between stakeholders (Tezel et al., 2020). Furthermore, it is acknowledged by (Liu & Chua, 2016) that information sharing is the key to success in a CSC, and by having integrated systems or platforms will enhance the information flow. However, this implies a change in the SC design and greater integration of suppliers (Ivanov et al., 2019). The industry has not yet made major investments in digital technologies that can provide significant long-term benefits. This can be because contracts do not include incentives for SCR sharing and innovation, and SC practices are still unsophisticated to the industry (Agarwal et al., 2016).

Well integrated systems like RFID (Radio Frequency Identification) and EID (Electronic Data Interchange) connected through the same platforms and system could reduce the lead time and faults in the SC (Radley Corporation, 2017). Further, these systems are practical, and firms have become more receptive to use these to stay competitive and efficient (Ivanov et al., 2019). Integrated digital systems may be an essential factor in a complex SC, as it creates greater visibility and transparency between the parties. Consequently, digitalization implies a change in the SC design and greater integration of suppliers (Ivanov et al., 2019).

3.4.4 Supplier selection

Supplier selection is suggested as a mitigation strategy as it facilitates a more agile and responsive CSC (Tukamihabwa et al., 2015). It is further acknowledged to be a key issue in SCM how to manage the suppliers given that the cost of component parts and raw materials are representing the primary cost of a product (Yoon et al., 2018). Actors in a SC are purchasing an increasing amount of both labour and material, and consequently the main contractors have become increasingly dependent on the other actors within a CSC (Vrijhoef & Koskela, 2000). This also arises from the SC's structure, as it has become extended, more complicated and globalised making the firms in the SC increasingly dependent on their suppliers (Yoon et al., 2018). To handle these SCRs, a coordination between the actors and suppliers is considered a necessary factor for improving the SC profitability and

supplier selection could be helpful to find the right suppliers to coordinate with each other (Chen et al., 2018).

Supplier selection is considered to be the process of selecting the most suitable supplier to deliver to the project's expectations, to ensure the goal of best value for the money (Singh & Tiong, 2005). It is argued that supplier selection is an essential factor in the partnering, which results in several positive effects like better project performance. This is with regards to the triangulated time, cost and quality, with improved collaboration between client and contractor (Bresnen, 2009). Jaskowski et al. (2010) acknowledge that an inappropriate contractor or supplier will increase the SCR regarding cost overruns, delays, disputes or even bankruptcy. This is supported by Weele (2014), who specifies that many problems related to quality and delivery from a supplier, are traced back to either the supplier selection process or wrong contract model applied, where there have been insufficient specification and requirements.

The supplier selection process can serve as a mitigation strategy as choosing the right supplier can reduce the presence of SC disruptions and delays (Sawik, 2017). A careful supplier selection process will be ensured through two stages, increasing the probability of choosing the right one. First stage would be to pre-select and pre-qualify the suppliers. Doing so will ensure the financial stability of the firms, decreasing the risk of bankruptcy of the supplier. The second stage is to select the best offer from the pre-selected suppliers and subcontractors (Weele, 2014).

Sourcing from one or few suppliers will enable projects to reduce cost, however, it could create difficulties if delays, demand fluctuations or major disruptions occur and makes the SC vulnerable to disruptions (Tang, 2006). To cope with this, Kamalahmadi and Mellat-Parast (2016) emphasize a selection of right suppliers and appropriate demand allocation among them would significantly reduce the associated costs and risks of disruptions in the SC. When choosing a supplier, it was discovered in a study of construction logistics that purchasing price was the dominant criteria in the selection of supplier (Vrijhoef & Koskela, 2000). It is further emphasised that the price criterion is a prominent criterion for the subcontractors, and that these are predominantly selecting suppliers based on the price. It is further emphasised that suppliers should be selected in the construction

industry based on their willingness to adopt the project's strategy (Aziz & Hafez, 2013). Lastly, mitigation of SCR and creating maximized value can only be realized through collaboration and all parties involved in the SC working together effectively, and to do so supplier selection is of great value (Weele, 2014).

3.4.5 Collaborative strategy

Van Wassenhove (2006) argues that a closer collaboration within the SC and between organizations creates a more effective and efficient SC responding to the growing complexity which is further supported by Tukamihabwa et al. (2015) and Chen et al. (2020). Several researchers claim that SC integration and collaboration are initiatives with great improvement potential to reduce SCR (Bankvall et al., 2010a; Geraint, 2014). Risk and benefit sharing will vary according to the type of collaboration and the ownership (Harland et al., 2003). It is shown that early involvement of internal and external entities will decrease SCR in terms of for example faulty design of different components. This will further improve good communication and collaboration within the SC throughout the project, which in turn will improve the project performance. However, having close relationships or trust in construction projects seems to be challenging, as the actors are often engaged in projects that are having the characteristics of uncertainty, SCR, and high complexity (Laan et al., 2011). On the other hand, it is emphasized by (Naoum & Egbu, 2015) that increased collaboration is vital in the construction industry, to achieve future goals and establish improvements in the delivery of the clients aim of the triangular, time, cost and quality.

Communication, collaboration and transparency makes it easier to detect disagreements and defaults at an early stage in the process, which will minimize exceeded budgets. However, to get parties in a SC to collaborate requires some sort of formal agreements (Harland et al., 2003). Agreements that could be used ensuring this can be obligation contracting, property right sharing, ownership control or provide incentive systems to motivate the parties to collaborate (Grandori & Soda, 1995). One prominent SCR in collaboration is the less formal types as there may not be a clear division of responsibilities and risk and benefit sharing. As a result of this, it is important to establish an agreement that ensures long-term commitment, making it easier to share sensitive information (Harland et

al., 2003). Moreover, these long-term agreements can be drawn in comparison to Toyota's Production System success, which were mentioned in the lean construction chapter, where they formed contracts with the suppliers to share risks and benefits (Wolf, 1991). Collaboration is further distinguished to be a strategy that enhances flexibility in the SC and provides a more coordinated response, which can be connected to Toyota's collaboration with their suppliers (Tukamuhabwa et al., 2015).

By having collaboration and communication will also increase the visibility across the complex SC in the construction industry. Having visibility throughout the SC is essential to provide well established prevention efforts, as it will increase the visibility of risk that the SC is exposed to (Harland et al., 2003). Lack of visibility can be connected to unclear distribution of roles, responsibility and tasks, which in turn can lead to entities establishing inventory without the knowledge of what others have already acquired (Ho et al., 2015). This, in addition to poor forecasting of demand throughout the SC can result in incorrect inventory, by either lacking or having excessive inventory (Rangel et al., 2015). Indeed, lacking visibility can cause lack of inventory as the various entities have the belief of a common depot within the SC. Furthermore, it can cause an excessive inventory if all entities gather their own depot because of bad communication among entities. According to Francis (2008) poor visibility slows down responsiveness. Some of the benefits arising from collaboration and communication in the SC, is joint product and service design, process design and SC innovation, better forecasting of demand and distribution of roles. However, it is essential to have an open dialogue between the involved parties to assess SCR and benefits in the activities, making it possible to agree on SCRs and uncertainties that could arise across the SC (Harland et al., 2003).

Relationships affect the outcome of decisions and actions done by actors, which are sources to efficiency and effectiveness (Gadde et al., 2003). By building relationships and making actors more aware of the benefits can cause better utilisation of resources beyond the boundaries of firms (Dubois & Gadde, 2000). Having greater collaboration with the actors and looking at the actors as a contribution to the project's value could result in fewer mistakes and mitigation of SCR.

3.4.6 Information and knowledge sharing in supply chains

"The construction business network is generally seen as conservative and non-innovative" (Håkansson and Ingemansson, 2013, p. 40). Information and knowledge sharing is one of the most prominent mitigation strategies to enhance collaboration, as it can reduce uncertainty, increase the transparency and facilitate for reducing SCR (Tukamuhabwa et al., 2015). Lack of knowledge sharing, adaptation and innovation within the construction industry is acknowledged by Dubois and Gadde (2000). The current focus on the effectiveness of individual projects is one of the main reasons for the absence of adaptation to a comprehensive understanding of the complexity in each project. The industry is further characterized by little collaboration between entities and projects (Dubois & Gadde, 2000). Collaboration is however important in sharing knowledge and competence (Harland et al., 2003). Håkansson and Ingemansson (2013) delegate the problem to the inter-organizational setting within the industry, which is not suited for innovation and industrial renewal. Engwall (2003) and Sydow and Braun (2018) acknowledge the importance of not only focusing on one individual project, but bringing well functional structures and procedures from previous projects further into new ones.

Lack of knowledge and experience transfer from project to project has been an issue throughout the construction industry, and the industry will miss out valuable learning if workers do not bring back knowledge to their originating company. As knowledge is seldom transferred between the different companies, each project functions as an "island" (Engwall, 2003). Hence, the temporary organization, like large-scale construction projects, must consider other previous, similar projects to gain important knowledge enhancing their efficiency and performance (Dubois & Gadde, 2000). Ho et al. (2015) endorse that knowledge sharing and learning enhances the robustness and resilience in SC through improved visibility, flexibility, velocity and collaboration. Knowledge is embedded within people and systems in an organization, and when properly executed, knowledge sharing can result in competitive advantages and create a more sustainable SC (Afiouni, 2007). This is because knowledge in a SC is valuable, rare, inimitable, and non-

substitutable (Casimir et al., 2012). Moreover, SCR is more effectively and efficiently managed by transferring knowledge (Ho et al., 2015).

3.5 Summary of the theory

Through this section the most prominent insight from previous research will be presented to get a better understanding and knowledge of SCRM in large-scale construction projects. The theories used are taken from several different research areas to make it possible to cover the underlying aspect of our research. Based on the literature review, we can see the potential SCRM has in large-scale construction projects. It is emphasized in the literature that SCRM is gaining momentum, and where SCR was previously undesirable, firms in the CSC are starting to realize that SCRs can cause significant advantages through proper SCRM (Rudolf & Spinler, 2018). SCR is prominent in large-scale construction projects due to the complexity, uncertainty and external influence, and the fact that a CSC consists of a great number of actors interacting in various projects (Ekeskär & Rudberg, 2016; Ho et al., 2015).

The literature has further highlighted SCRM to be valuable, as it refers to how structural and known uncertainties are avoidable by reducing the complexity of construction projects, while the unknown uncertainties are the ones that bring unpredictability and the necessity for SCR mitigation (Giezen, 2012; Lehtiranta, 2011). It is crucial to understand how SCRs are generated and how these are influencing the SC in a construction project before enhancing any mitigation strategies (Ho et al., 2015). The complexity is brought by several contributing factors such as components, tasks, financial aspects together with the funding, personnel, as well as a large number of sources creating SCR and the interaction of these (Kardes et al., 2013).

To deal with these often-unforeseen events, it is essential to develop mitigation strategies and prevention efforts. Making the strategies work, the SCR must be identified and categorized at an early stage. There are many categorisations, but the review by Thomé et al. (2016) illustrate that there are four types of SCR categorisations that are suitable for a temporary multi-organization: organizational, network, industry and environment. As Thomé et al. (2016)'s

framework covers the aspects of a temporary multi-organization, we found this framework most suitable as a foundation for our study due to the lack of proper categories and focus on CSC in Sodhi and Tang (2012)'s framework. By doing this will make it possible to implement suitable mitigation strategies as response, and it is a valuable approach as it provides an overview of the most prominent and problematic issues in large-scale construction projects (Aloini et al., 2012; Lehtiranta, 2011). Scholars claim that SCRM and mitigation strategies are of great importance to manage known and unknown disruptions in the CSC, and by implementing proper strategies can reduce potential negative outcomes (Heckmann et al., 2015; Kilubi, 2016; Tang, 2006). It is further acknowledged in the literature that by managing SCR properly can create competitive advantages, and the likelihood and consequence of the SCR will be reduced (Rudolf & Spinler, 2018).

From the literature there have been suggested several mitigation strategies, but the most prominent strategies in context to large-scale construction projects are the six strategies: *Lean construction, JIT, Digitalization, Supplier Selection, Collaborative Strategy and Information and Knowledge Sharing*.

3.5.1 Theoretical framework

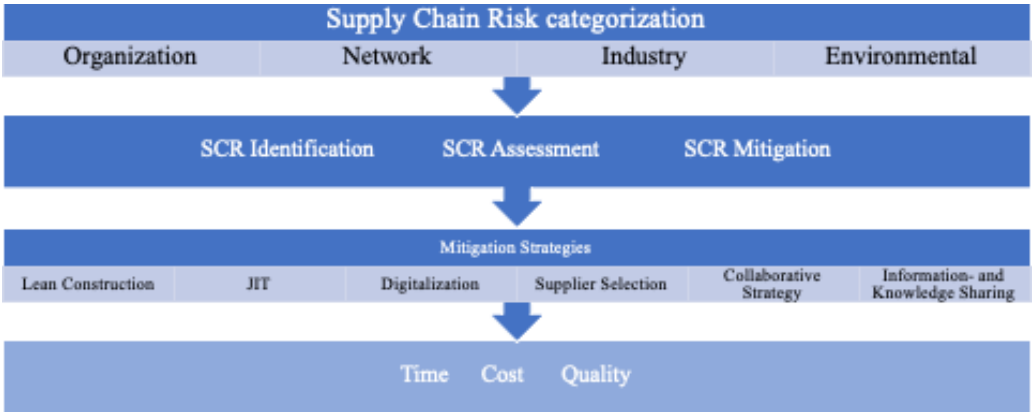

Figure 4: Theoretical framework.

The theoretical framework (Figure 4) has worked as a basis for our study, where we have structured our findings through the framework. A framework can be suitable as the researchers can go back and ask questions regarding the material (Malterud, 2001). Using the framework properly can ensure that the researchers

are connected to the validity of the research. Moreover, this framework illustrates the main findings from the literature where the respect has been to discover the correct way of handling SCR in large-scale construction projects, how to identify these and how to mitigate them to establish a more robust CSC.

4.0 Empirical findings and analysis

In this chapter we will present the combination of the empirical findings and analysis, which were performed in our research. The results of our exploratory case study of the LSP will prepare the research for further discussion and our framework will be used in the presentation of our results. Further, we will apply quotes provided through the preformed interviews and refer to the secondary data. The aim of this thesis is to investigate the various SCRs occurring in large-scale construction projects, and how these can be mitigated through different strategies. We have performed an exploratory case study of the LSP to get a comprehensive understanding of our RQ. The first part of the chapter will present the empirical setting with an introduction of the case. The second part will elaborate the empirical findings.

4.1 Introduction of the case study

The LSP is a project executed by SB, who is leading several of the largest and most complex construction projects in Norway. SB works towards a seamless project implementation with lean and systematic completion, among other things. The LSP is the first large-scale construction project SB has SCM as core activities, making this a suitable choice of research object in the thesis. The Life Science building will be the largest university building in Norway with a GBA over 80.000 sqm, divided on nine floors. The building will be a catalyst for new Norwegian innovation and contribute to a commitment to increase Norway's competitiveness in the construction market. Four effect goals have been formulated within research, education, innovation and infrastructure which the building will contribute.

The project implementation will be performed as industrial construction with "lean extreme", primarily to reduce costs. By having this approach there will be a flow in the processes that will optimize cost, quality and time which is defined as

the performance targets. Continuous improvement with strong and continuous uncertainty management will be in focus throughout the project implementation. The project is carefully planned with the use of BIM and efficient implementation. Further the number of components is being reduced and standardized to decrease complexity and costs.

"*Due to the small space at the construction site, it will be more like an assembly site than a construction site*" (Interviewee #1).

There will be as few working hours as possible on the construction site, parallel production and prefabrication, as well as good logistics performance, automation and robots, will enable this. The LSP has developed from some of the principles extracted from the construction of the KHiB. This can further be associated with Engwall (2003)'s statement that "No project is an island", as the KHiB has been an important project in the development of the LSP and indicates that there has been a learning process. Many of the same project participants from the KHiB were further assigned to the construction of the LSP. This enhanced the project planning and made the project managers already knew the need and benefits for proper SCM.

To ensure a good customer experience, SB are focusing on processes with predictability and careful decisions, relationships with trust and communication with the various actors, and the right product delivered to the right project with the right quality. SB has further defined seven points, provided from the organizational document, see table 1, that are connected to the lean principles which apply to all the participants in the LSP. To succeed with their project goals, the participants should seek to avoid:

- Overproduction
- Waiting
- Transportation
- Unnecessary movements
- Creation/Deviation
- Storing
- Unnecessary processing

These points are developed to reduce the waste of time and resources in the project. They have origins from the system that are going to be developed to provide continuous feedback and follow ups. This is going to be executed to avoid bottlenecks, strive for continuous improvements and at the same time maintain and improve the project's processes. The system is supposed to ensure JIT deliveries of materials to the construction site according to the plan.

Even though the LSP has been postponed and stopped several times, the project is keeping up with their plan and schedule. As a result of SB's incentives in the supplier contracts, the contractors are on standby and ready to start their activities when given a "go". The reason behind the several postponements is, first and foremost, challenging ground conditions that were discovered in the fall 2020, where the costs increased considerably and there was a need for new financing. As a result, OUS has been allocated a separate wing on the west side of the building. This has increased the size of the building, complexity and workload. Additionally, SB was initially going to build and hand over the building to Oslo University (UIO), but in the spring of 2020 it was decided that they will also operate and maintain the building after handover. SB must thus plan and prepare accordingly. We will however not focus on that aspect of the project in our thesis. SB has developed four strategies to improve development and growth in the project, which will be further elaborated in 4.2.1.

4.1.1 Contractors and budget

The turnkey contractors for the project are Hent, AF-gruppen, GK, Schneider Electric, Oneco and Braathens Landskapsentreprenør, which are large contractors in Norway who have been involved in the construction of a great number of large buildings. In 2018, the Parliament approved a state grant for construction projects outside the rent scheme, initiating construction projects to 45 BNOK. The building is budgeted with a cost framework of 5,677 BNOK, a control framework of 4,965 BNOK and user equipment to 1,141 BNOK. The project has been paused several times due to greater problems with the ground conditions than first thought. As a result, there has been a need for more financing before the project can continue with the outlined project plan (Kvandal, 2021).

4.1.2 Contract strategy

As SB is a state-owned company, all supplier agreements must be obtained through a tender, giving all actors in the market the opportunity to obtain a larger contract. The LSP has seven large interaction contracts with the contractors. To access the benefits of interaction contracts, it is important that the involved parties understand what it means to interact and how to create a win-win situation through collaboration throughout the whole project execution. In the context of logistics, this is about enabling collaboration throughout the value chain and making basic data available for information logistics at the time of contract signing. Provisions regulating the logistics of the project must be included and be in accordance with the dealer's principles. Moreover, the contract must regulate systematic interaction, ownership, costs and responsibilities between the client and the contractor, and SB wants to facilitate as much transparency with and between the entities as possible through the contracts and collaborations. SB strives towards the goal of having *one* common project, working as *one* team and to have *one* common culture.

4.2 Empirical findings and analysis of the case study

Through this chapter we will present a combination of our empirical findings and the analysis of the case study. In our thesis we aim to investigate and explore various SCR and SCR mitigation strategies that can be conducted in large-scale construction projects. Experience and knowledge from project participants of the LSP and other actors in the industry has been included to establish associations to the LSP and large-scale construction projects, as the LSP is in the first stages. It should be noted that there are several drives and root causes for complexity and SCR that characterizes the construction industry. This will, however, not be a main focus through the thesis and rather be handled subsequently.

The structure of our empirical findings will be introduced by first presenting the logistics strategy in the LSP to get an overview of the project and to create a base for the identified SCRs. Further, there will be an elaboration on SCRs in the construction industry with the preliminary occurring SCRs in the LSP and SB’s SCR identification, assessment and current mitigation strategies. Next, the perceived SCR in the industry are elaborated. Then there will be an exploration of

the perspectives on SCM in both the LSP and the industry in general. We have made this division to highlight the SCR in the LSP, which is the main objective of the thesis. It may be necessary to mention that general perspectives on SCM in the industry also influence the perspectives on SCM in the LSP. To highlight the differences between the industry and the LSP, we have divided the perspectives into two subcategories, as LSP has had a greater focus on the issues. Lastly there will be a summary of the empirical findings.

4.2.1 Logistic strategy in the LSP

The logistics strategy for the LSP extends throughout the whole building process from planning until the building is handed over and reflects the project's vision and goal which is "*An even better project*". Incorporating SCM will influence all actors in the project and support SB's vision of being "*Best in building, with meaning*". It is specified in the project plan that logistics will include the whole value chain, including all flow of goods, materials, equipment and resources from the manufacturer or supplier to, from and on the construction site as well as return logistics of residual waste from the site. The logistic strategy has been implemented in the LSP as a core activity to increase project performance and as a tool to achieve the primary goals of project success.

Four strategies have been developed by SB where the aim is to contribute to the project's development and growth. These strategies are presented in documents provided from SB, see table 1. The combination of strategies will provide synergies, contributing to a seamless project implementation without defects and faults, making the strategies of significant value.

1. Lean strategy: established to monitor continuous improvements where the entities involved should continuously search for bottlenecks and take care of and improve their own processes.
2. Systematic Completion: implemented to avoid doing things over again and multiple times. The testing is simplified, as there is a structure in the work, making it easier to detect errors and omissions.
3. Digitalization: tools helping in the planning and improving the SC's information logistics.

4. Logistics: how to get all the materials to the construction site safely and efficiently.

All the listed strategies are seeking to support the project's realization of the iron triangle, time, cost and quality. These strategies are further aiming to establish flow in the process which will optimize the cost, quality and time, where the primary goal is to reduce the costs without compromising the quality or time. Even though the strategies interact, the logistic strategy will be working as the interface towards the others. The strategies have been developed from the construction of the KHiB with adjustments based on the mistakes that were performed in that project.

"The project shall evolve through interaction. This time the project is closely planned with Lean and systematic completion being prominent" (Interview #2).

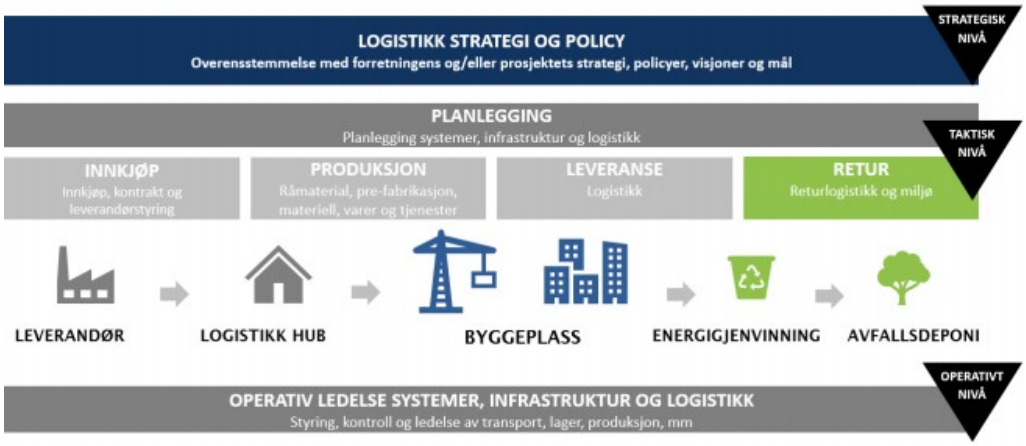

Figure 5: Logistic strategy and policy in the LSP. Retrieved from organizational document, see table 1.

SB are going to establish hubs in the area surrounding Oslo as a part of the developed logistics strategy which will consolidate the deliveries and reduce the number of transportations required to the construction site. The components will be partially built and assembled at this off-site storage and further be transported to the construction site for the last assembly. The desire of pre-fabricating as many components as possible and storing it off-site made this solution most beneficial in the LSP. The hub will facilitate the JIT- and Lean principles, ensuring the five R's: right materials, to the right time, right quality, right price and to be at the right place. However, it is still yet to be decided how many hubs

will serve the LSP. This will depend on the possibilities of combining hubs with other on-going projects or if they need to establish their own. The hub will mainly serve as an intermediate storage to facade elements and small and medium sized deliveries. There will be established a system and control function for the logistical flow between the producer, supplier and construction site. All information regarding the logistics and the SC are being assembled and controlled through an "Control tower", which is a common logistics service monitoring transport logistics and material flow. The primary aim of the control tower is to reduce the amount of incoming materials, traffic and to establish coordination between activities that are performed, as well as incorporation collaboration between the different actors. Consequently, the implementation will facilitate greater reliability in deliveries associated with the purchasing and preparation routine. The common logistics service is a digital solution that creates more CSC visibility and transparency of data and information. To ensure the control of transparency and visibility of data and information, the control tower's function will be to observe the SC and processes, at the same time facilitating for the five R's. Digital integration and collaboration between SB and its suppliers are fundamental to increase CSC performance. As there will be significantly more people on the construction site, the LSP has arranged for materials for a specific activity to arrive at the same time to the site. To do so, there has been established a common agreement between the main contractors where all involved parties in the LSP have accepted the terms of working efficiently and avoid being in the way for each other.

One of the requirements set from SB to the contractor, is the transparency of data and information in the CSC, which also may serve as a mitigation strategy. This applies to all parties involved, from producer to installer. It is required to make all necessary information accessible, which applies to all suppliers and sub-suppliers, to ensure visibility and control through the whole SC in the LSP. By establishing transparency and collaboration, SB aims to ensure deliveries and have less waste using digital interaction. Through proper use of digital systems, the LSP aims to establish a more efficient and effective SC making it easier to communicate with the parties involved in the project. This will further provide greater flexibility and responsiveness in the value chain.

4.2.2 Statsbygg's supply chain risk identification, assessment and mitigation plan

The general SCRs that are associated with time, cost and quality in the CSC and the supply flow to the construction site, have been elaborated in an individual SCR analysis for the activities. Thus, this section is based on information from the documents provided from SB about the LSP, see Table 1. Furthermore, the SCRs identified, assessed and suggested mitigation strategies, are based on SB's evaluation, identification and development. All processes, activities and events that may go wrong or could have an impact on the project, have been reviewed to identify errors, disruptions, delays or deviations. SB's identified SCRs in the LSP are assessed regarding their probability and consequence, where it is given a quantitative and qualitative assessment of each individual risk. This is illustrated in a heatmap (see figure 6), that is based on the identification and assessment from SB on the LSP and provides a proper understanding of the SCR that frequently occur in large-scale projects.

The heatmap illustrates the importance of the different SCRs represented by the colours red, yellow and green. Measures must be found for SCRs that are classified on a red level, i.e., critical factors that have high priority and must be handled immediately. For SCRs that are classified at a yellow level, a case-by-case assessment is made to consider whether measures should be established, as there may be a need for administration or change over time. The yellow levelled SCRs are considered a medium priority. SCRs that are considered to be acceptable are the ones that have less need for change and thus have low priority are at a green level. As a consequence of the identified SCRs, SB has developed a contingency plan that will contain a risk register, -plan and a -picture when all suppliers are known, and specific solutions have been chosen in the project. The register will be frequently updated by the purchaser at all times ensuring supply to the construction site, and the system will be a foundation for competitive tendering of common logistics services to the construction site.

SB have divided the already identified risk in the LSP into internal and external risks, provided from an organizational document, see table 1. Internal risk is considered to be the SCR in the LSP and contractor's value chain, and is identified by SB to be delivery security, contract, supplier and availability of raw materials. External risks in the LSP are associated with the financial, reputation,

CSR and personnel risks. This will however not be covered in this research, as we focus on the SC and logistic risks, and will thereby not be mentioned any further in this thesis. Moreover, SB has developed strategies in the LSP that will serve as mitigation of the identified SCRs. Measures to mitigate SCR are going to be monitored and reviewed systematically by all involved contractors. Furthermore, there have been several initiatives proposed as mitigation of SCR in the LSP; changed planning, alternative suppliers, established emergency plans and safety stock, among other things.

The first SCR in the LSP mentioned by SB is the product, and the *nature of the product* being a risk in itself, as it can be difficult to detect whether a product is damaged during delivery. This SCR is at a green level, meaning it will not be devoted much time and is not considered as crucial. The measures that have been implemented to prevent this are training of contractors and subcontractors. The previously mentioned *lack of labelling* of materials is a known source of error in the industry. However, as the first identified risk, this is a SCR at a green level and is considered acceptable. To prevent this, there has been developed routines and procedures, and currently work is being conducted on a common logistics service to help prevent possible errors. Another mitigation strategy introduced is a sanction regime which has been established in the cooperation agreements with the contractors. Next SCR identified is the *delivery security*, which is linked to planning and routines. Jointly developed project routines shall be used, covered by a sanction regime in the cooperation agreements. This is also considered at green level and has low priority. The probability is medium, and the consequence is small. *Supplier networks* are further treated as acceptable with low priority. The measures suggested are collaboration, training and project specific routines. *Availability of raw materials* is ranked at a red level and is a critical factor that must be treated immediately. To mitigate this SCR, SB will use part of the same strategy as in supplier networks that can be applied such as follow-up, collaboration, training and common project-specific routines. The last internal SCR that has been assessed in the heatmap is the *service agreement for the logistics service*, which among other things applies to deliveries that are exposed to the risk of human error. This is because the LSP is influenced by several agreements with various complexity between the parties and the construction site is a complex production line. This SCR is ranked at a yellow level, and the case

must be monitored, and the work has a medium priority. Measures are the preparation of a cooperation agreement between the contractors, SB and the logistics partner to regulate cooperation. Based on this information provided from SB's organizational documents of the LSP, see table 1, we have developed a heatmap which is illustrated in figure 6.

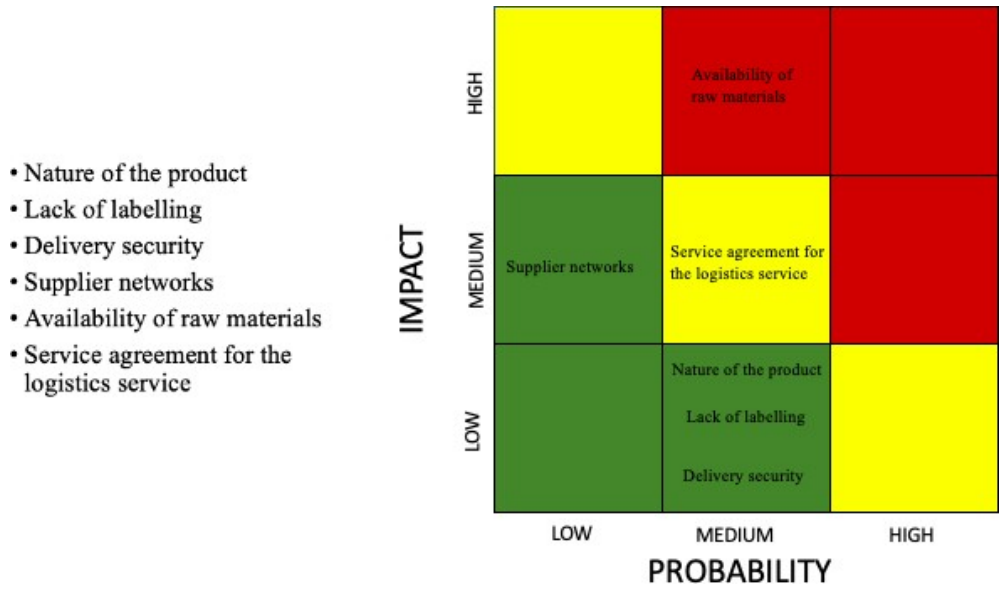

Figure 6: Heatmap of identified supply chain risks by SB in the LSP.

4.2.3 Occurred supply chain risks in the LSP

The LSP is still in its early stages, and many of the identified SCR from the project planning phase have therefore not occurred yet. However, at the beginning of the project they were faced with a greater environmental challenge than first expected. This is a consequence of the life sciences building being built on top of a former landfill consisting of quick clay. They knew from the start of the project planning that the lot has poor ground conditions, and several tests were performed to test the foundation. However, it has later come forward that the ground conditions were worse than expected and have been a challenge in the project from the beginning. This has further led to large budget overruns and postponements in the project as they have been dependent on more funding to cover the costs to fix the ground conditions. To raise capital, several departments have been added to the building, resulting in an even larger project with significant complexity.

The uniqueness of the project contributes to increased complexity, especially regarding the logistical challenges associated with the site. Firstly, it is a cramped lot with limited space for handling material, which also limits the installation area for work barracks and parking. Secondly, the construction site has the same entrance and exit as Rikshospitalet from the heavily trafficked road Ring 3. This means that they cannot close the entrance as there must always be free passage. Simultaneously as the LSP is to take place, there will be several other large construction projects performed close to the life sciences centre. This will create enormous pressure on a small area and traffic as many of the projects need the same roads to transport materials to their individual construction sites. Furthermore, the LSP construction site is close to residential areas, commercial buildings and hospitals. Hence, this limits the logistical activity, in addition to the risk regarding weather and driving conditions must be considered. The location of the building can thus create great and many challenges for the implementation.

4.2.4 Supply chain risks in general construction projects

"There are a great number of risks occurring in large construction projects..." (Interviewee #3).

SCRs are always present in construction projects, however, it is acknowledged by several of the interviewees that when a project evolves to become a large-scale project, these SCRs become more prominent. This is a consequence of the complexity growth in a project, and the intricate relationships in the CSC, where participants often are involved in several different SCs. It is supported by several of the interviewees that risks associated with the CSC tend to be underestimated in a construction project.

Several of the interviewees states that the most prominent SCR in the construction industry is the lack of information and information flow. Interviewee #6 emphasizes the impact of deficient information and information flow. Lack of incentives for handling the information correctly may be a reason for this, as well as lack of competence, knowledge sharing and quality assurance in a temporary SC. The consequences of a slow information flow can be huge, and it is

challenging to ensure the right information to the right actors in a temporary SC. This can further lead to huge disruptions in the CSC.

Lack of correct information flow may cause damages to materials, activities must be done multiple times and causes waiting, which was acknowledged by several of the interviewees. To reduce errors and waiting, the interviewees state that the companies wish to implement JIT. However, there are often lacking incentives for the sub-suppliers to be collaborative and communicate, making JIT implementation difficult and often result in deliveries or activities being conducted in the wrong order. Interviewee #8 mentioned that some orders are done verbally, not digitally, which creates uncertainty regarding accuracy of the order and difficulty in the tracking.

Another SCR mentioned by the interviewees, which creates problems for the information flow and difficulties to achieve successful logistics, is the lack and challenges of labelling products and materials. Several of the interviewees stated the need for a common labelling- and information system. The consequence of this SCR is materials disappearing or being placed at the wrong place at the wrong time. This further leads to delays and higher costs. Moreover, it has been stated by several of the interviewees that some prominent challenges and SCRs are not knowing how much time activities or production takes. The greatest difference in the impact between small or large-scale projects, is that the impact in the large-scale project will be much greater in the aspect of time, budget and quality.

"In general, there is not much transparency and trust in the industry. This is because the participants put themselves in focus, which is a result of a fragmented industry..." (Interviewee #3).

Trust and transparency are acknowledged by several of the interviewees to be difficult to establish in construction projects, as well as being a root cause and driver for other SCRs. Temporary SCs involve actors who usually work on several projects at the same time, meaning that the focus amongst the participants will differ. It was also acknowledged that actors in a CSC are careful with their information sharing and do not share more information than necessary. Lack of information sharing may also lead to difficulties in a project, as it is crucial that

the project participants know when and where to carry out their activity. A functional communication system is therefore needed to inform other actors about the continuity in the project. Another SCR highlighted by the interviewees in large-scale construction projects, are the ground conditions. This is a SCR that is difficult to predict as one cannot know exactly how the site will be until the first ground break. The identified SCRs are extracted from the general perception of SCR in construction projects by the interviewees, which can be seen in Table 4.

Perceived Identified Supply Chain Risk in construction projects
Ground conditions
Availability of raw materials
Information flow
Transparency and trust
Contracts
Products/Materials
Supplier selection
Supply disruptions
Interdependency
Various maturity
Lack of knowledge sharing
Lack of competence
Ordering
Information sharing
Market

Table 4: Overview of identified supply chain risk in construction projects, based on the interviews.

4.2.5 Perspectives on supply chain management in the LSP

Our RQ are aiming to reveal what types of mitigation strategies are suitable to reduce the SCR in large-scale construction projects and the perspective on SCRM. Consequently, our study is further aiming to reveal the motivation behind the use of SCM in the LSP. We want to discover whether the use of mitigation strategies in large-scale construction projects are value-adding activities that will reduce disruptions and budget overruns, making a successful project. This constitutes the

basis for SB's motivation and their actual perspective for incorporating a logistic strategy and better SCRM in their projects. It is again worth mentioning that logistics in Norwegian also refers to SCM, so when the interviewees talk about logistics, this also refers to SCM.

The LSP is going to be used as a leading experiment to test the use of logistics as one of the main strategies running throughout the project. This section will present our findings regarding the motivation and perception of SCM. Firstly, we will present an examination of the perspectives of logistics within the industry, and further the perspectives on logistics in the LSP.

The LSP is a large-scale construction project with significant complexity. Logistics are being used as a tool to improve core activities and enable the construction of the LSP on a limited construction site with challenging infrastructure. To develop the logistics strategy, SB extracted their experience and knowledge from the construction of the KHiB into the LSP, intending to learn from previous mistakes and failures. After the construction of the KHiB they saw the need for change, especially considering logistics and to implement better and more well-planned project plans in a complex project as the LSP.

"We did try logistics management in previous projects, like KHiB, but we did not succeed..." (Interviewee #2).

The same project team from the construction of the KHiB was retrieved to work on the LSP. This has made it easier to draw knowledge and experiences from the previous project to the current LSP. They saw the need for change in the KHiB and used that experience to implement a better and more well-planned project with the LSP, especially considering the logistics. One of the foremost differences between the two projects is how the implementation was and will be performed. The aim in the LSP is to perform activities simultaneously and follow a strict time schedule where the activities are performed through systematic completion. In the KHiB, however, the activities were performed through an equivalent sequential, streamlined implementation which was possible in a smaller and less complex project.

SCRM has been conducted based on continuous SCR assessment aiming to reduce the SC's vulnerability and ensure deliveries in the LSP. For the project to be well-executed, the five R's must be present, which SCRM can contribute to ensure. In addition to the reduced number of articles going into the project, with more standardized and prefabricated components, the most significant SCRM strategies SB has implemented are the four strategies: Lean, digitalization, systematic completion and logistics.

"I do not think Statsbygg has ever executed a project with this kind of focus on logistics..." (Interviewee #2).

After the approval of the LSP and involvement of a fourth-party logistics company, it became clear that they had to rethink their logistics strategy, as there have not been any previous projects with this significant focus on logistics and complexity. The site's location and form indicate that logistics must be a big part of the project implementation, as elaborated in 4.2.3 Occurred supply chain risks in the LSP.

"We have a reception that receives goods for the upcoming week. This reception will be open to receive from Monday until Thursday and repacked on the reception area on Thursday and Friday" (Interviewee #2).

Materials are moved as much as seven times on average on a construction site, which implies considerably wasted time and resources. In the LSP the logistic strategy aims to minimize the movement of materials and tries to move things only once. Due to the space issues, SB facilitates for JIT with the reception area for materials. Accordingly, the days of delivery of material is set to be Monday until Thursday to provide themselves with some days with slack, and the distribution is from Friday to Sunday. To make the repacking easier, TMF (Interdisciplinary labelling system) is used. This system is developed by SB and is a mandatory tool in all of SB's construction projects (ITB-guiden, 2021). The system makes it possible to classify the different product categories and makes it easier to collect the right components. However, the lack of common labelling standards in the industry makes the process complicated. SB has therefore made a new kind of procedure to the LSP, based on the same system the grocery industry

is based on, called Logistic conditions for LSP, retrieved from documents provided from SB, see table 1. The system is developed from previously gained knowledge and experiences, where much material has been incorrectly marked and been a great source of error in the past.

According to several of the interviewees, there is a lot of waste followed by materials arriving at a construction site and is considered a significant challenge in construction projects. Furthermore, the LSP aims to decrease the amount of packaging from the materials going into the site. The more you take in, the more you have to take out. By decreasing the amount of packaging and waste will provide less pressure on the transportation and storage capacity on the site. SB are going to repackage and assemble components in hubs around Oslo, which will release space in the limited area. Interviewee #2 notes that construction sites usually look quite messy and unstructured, and consequently an indication of the implementation of logistics in the project plan has provided a site that is neat and tidy. This is the current case for the LSP, see Figure 7.

Figure 7: Image of the construction site of the LSP. Retrieved from organizational document, see table 1.

"The requirements set by SB in the project have to be differentiated due to various maturity in the industry" (Interviewee #2).

Furthermore, it is essential to get the delivery of the right products at the right time. Accordingly, SB has established five principles from Lean philosophy, the

five R's: Right time, place, quality, quantity and price. Materials and work with the right quality must therefore be at the right place, with the right quantity, at the right price at the right time. SB underlines the significant differences of the maturity in the industry and how they have focused on mapping this. Through this focus they have matured together with the participants and reached an understanding on how to collaborate and communicate in a large-scale construction project. However, it is recognized by the interviewees that the actors in the industry are careful about what information they share and will not share more information than necessary when entering into agreements.

The LSP is aiming to enhance the SC through digitalization of information logistics. All contractors involved in the project are going to have system solutions and a digital infrastructure that makes it possible for them to realize the project's strategy. The logistics in the project are connected vertically, which means they work according to a Takt planning principle. They are also working towards being one week ahead with the delivery of material. It has resulted in optimization and positivity between the participants, as it has increased quality and reduced costs. The interviewees argue that they can already see the effect of the logistics and the focus on proper conduction is already showing off, which means that the well-executed project plan has resulted in the LSP not surpassed on time of any of the executions. Interviewee #2 also addresses that the project has so far gone "embarrassingly well" considering the logistics and that they have nearly no invoiced hours of waiting from the suppliers, as it has been in previous projects. Following the project's postponement at the end of 2020 and the resumption, it is clear that the developed strategy works and adds value to the implementation. It is further acknowledged by interviewee #2 that this project has better project implementation than previous projects.

4.2.6 Perspectives on supply chain management in the construction industry

"Logistics is seen as a new concept in the construction industry" (Interviewee #1).

SCM in construction has emerged and changed much over the last couple of years. Interviewee #1 informs that he conducted a market dialogue to examine the

demand for logistics management in the construction industry which received low interest in 2018. Indeed, there was an increased interest in 2021. It has been established several companies focusing on logistics in the construction industry, whereas the Swedish company MyLoc has become an established actor in the market. MyLoc offers cloud-based logistics solutions customized for construction companies wanting to work more efficiently in their projects. These are systems developed to mitigate challenges faced in the industry through integrated systems that enhance the visibility in the projects. It aims to reduce the risk of errors in deliveries and enable a more seamless handling of goods.

It is recognized by the interviewees that it requires time and resources in choosing the right SCR mitigation strategies in a project. Several of the interviewees acknowledge that there are different views regarding the value of SCRM and developing mitigation strategies is not prioritized amongst several of the participants in construction projects. It is also informed that the industry is embossed by old habits, and many of the actors have been in industry for a long time, which have further influenced the industry to not mature in accordance with other industries. It is, however, deemed as important by the ones interviewed, because having proper mitigation strategies makes it possible to look ahead and be prepared for uncertain events.

"There are a lot of components and people going into a construction project, making it important to discover the supply chain risks associated with all products" (Interviewee #1).

Several of the interviewees refer to how much of the logistics is based on common sense in the industry. It is further being acknowledged that the industry is very set and constant, as well as being seen as bureaucratic and hierarchical. However, lack of tradition and the fact that people are not familiar working with logistics has made actors choose to avoid the possible changes and benefits it may entail. They further acknowledge that something needs to be done, but do not know how to develop or change in the right direction.

"It is an immature industry if you compare it with the grocery industry" (Interviewee #7).

"I think it is strange that contractors haven't had a proper focus on logistics and the supply chain, as it is important with the right goods and assembly at the right time. The focus and attention have not been good enough" (Interviewee #8).

As the industry is faced with growing complexity and more intricate SCs, there is a need for a shift in the industry to try to catch up on digital development to decrease delays and budget overruns. Resulting from the lack of willingness of renewal and development, the industry has fallen behind on innovation and digitalization. The background for this may be the self-centred attitude when it comes to events beyond their own project or activities. It is further acknowledged by several of the participants interviewed that the industry is lacking maturity and is not focusing on the SC as a whole or logistics. However, interviewee #4 thinks that the industry is facing a shift to more digitized operations in the coming years.

"The construction industry has a very "I, me and mine" way of thinking, which makes it difficult to focus on the whole SC." (Interviewee #2).

Contractors that are not good at planning and ordering make it difficult for the supplier market and the project to plan deliveries. According to interviewee #1, it often happens that suppliers receive orders of up to 5% of the annual volume to be delivered in 1-2 weeks. This illustrates that there is a variety of maturity for planning and logistics in the industry, which can be significantly improved to reduce costs and predictability for suppliers. Further he adds that many builders order all the materials at once to get a quantum discount. This creates problems on the construction site, as the materials must be moved several times, leading to waste of both time and resources. Several of the interviewed are acknowledging that it is easy to lose control and overview of the materials, making it difficult to know where the materials are when needed. The material flow in a construction project is vital to keep up with the project plan, as deviations could create delays and increased costs.

"We have no control on materials that lack labelling" (Interviewee #6).

One significant challenge in the industry is the lack of labelling standards. This is a known source of error in the industry, resulting in a lot of unnecessary movement of materials and materials that are broken because they are stored incorrectly. However, interviewee #8 informs that there is a growing demand for tracking systems of materials, because it will ensure a flow in production and can be associated with quality assurance. Many companies have developed their own types of labelling, which has resulted in many different systems and standards. This makes it difficult to coordinate the inbound logistics at a site. However, the Norwegian construction industry works towards implementing one labelling standard using the barcode Global trade identification number (GTIN), but this is still a work in progress. It is further stated by several interviewees that not all materials are labelled, which results in loss of control over the materials. Lack of labelling standards is considered a major problem in the industry, which indicates a major potential to streamline time and resources with a common labelling system. However, it was called attention to by interviewee #7 that Norway is far ahead when it comes to labelling and barcoding in comparison to other countries, but still, it is a major source of error and has a long way to go.

"Good relations, competence and quality are going hand in hand.." (Interviewee #6).

Interviewee #6 acknowledges the value of SCM, choosing the right suppliers and establishing long term relationships, which consequently results in closer collaboration with suppliers and actors in the CSC. By having close collaboration and communication can create better execution of tasks and establish an interaction arena. Their experience is that an involvement of suppliers makes them put the project's goals in focus generating trust, commitment and collaboration.

"Measures are first taken when the "fire" occurs, and there is often not good preparedness" (Interviewee #7).

One of our main empirical findings is that SCRM is considered less important and that the actors often act when the accident has already occurred. However, interviewee #6 points out that SCRs should be mitigated, not avoided, and that these are not only negative, but creates opportunities as well. Interviewee #4

acknowledges that SCR mitigation strategies make it possible to optimize the working hours, avoid unnecessary deliveries and bottlenecks.

4.3 Summary of the empirical findings

From our empirical findings we discovered several prominent SCRs and the different views and perspectives on logistics in the industry. Logistics and SCRM are still are considered less important, as actors do not take actions before an accident has already occurred. However, the industry is starting to acknowledge the necessity to handle and mitigate SCR in large-scale construction projects and in the CSC. The SCR are collected in an overview presented in 5.1 Discussion, see table 5.

5.0 Discussion

In this chapter we will elaborate and discuss the empirical findings and analysis from chapter 4, where we will draw comparisons and relations to the theoretical background that was presented in chapter 3. We combine the different areas of our findings in a thorough comparison with the relevant issues from the literature and our empirical findings. Further, we have developed a framework merging our empirical findings and literature. The framework illustrates how characteristics impact a large scale project, and how SCR sources can be categorized into four different categories. Mitigation strategies are then extracted to increase performance and enhance the five R's.

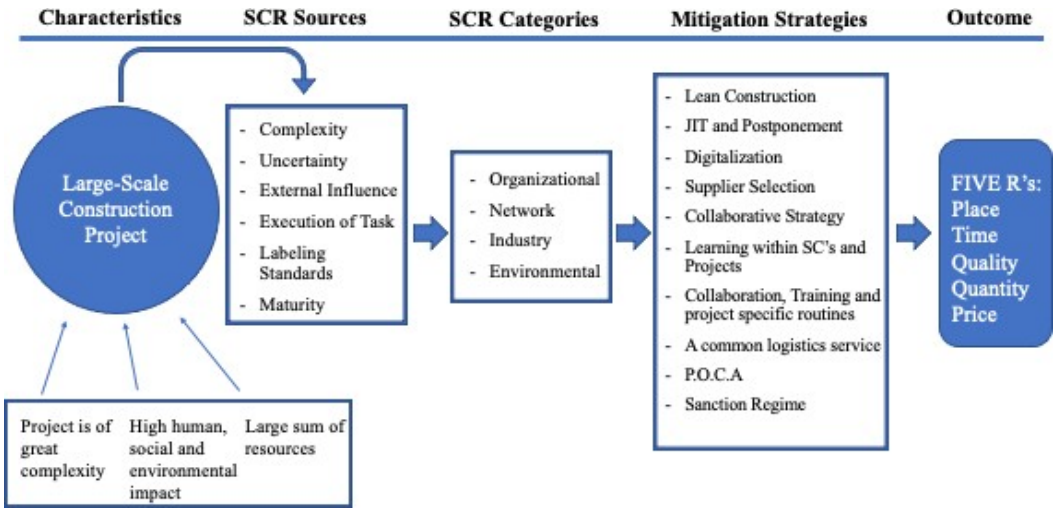

Figure 8: Revised framework: Supply chain risk in large-scale construction projects.

As there are several aspects that are of interest from the theoretical background and our findings, we have extracted the most relevant and greatest findings to answer the RQ. Because of the LSP not coming as far as with the project implementation as planned at this point, and is still in the conceptual phase, the SCR identification will include the SCRs we have discovered from the study and not the actual SCRs occurred. The discussion will be based on the SCRs identified in the construction industry, the LSP and in the literature. We discovered that SCR occurring in construction projects are likely to occur in large-scale construction projects as well. The impact, however, will be greater as the size of the project increases.

The discussion will be based on our RQ: *How can actors in large-scale construction projects mitigate supply chain risks?* We find it necessary to identify and categorize the SCRs to extract suitable SCR mitigation strategies. Therefore, this section of the thesis will start with a discussion regarding the identified SCRs and whether they belong to a SCR category, see table 5 for an overview of identified SCR. Accordingly, there will be a discussion of different SCR mitigation strategies actors in a CSC can implement to reduce the probability and impact of SCRs occurring. This will serve as a basis for the main conclusion and a final conclusion will be taken in 6.0 Conclusion and provide an answer to our question.

SCM has over the past years been used as a tool to establish efficiency and productivity in core activities in several industries (Aloini et al., 2012; Bankvall et al., 2010; Yeo and Ning, 2006). However, the construction industry does not have any industry standards on how to cope with logistics in a construction project and is considered to be far behind in technological development compared to other industries. A finding from the study, is the common knowledge of the importance of proper SCRM, and how this can reduce potential negative outcomes and create a competitive advantage (Rudolf & Spinler, 2018; Shojaei & Haeri, 2019; Thomé et al., 2016). Even though this is commonly known, SCRM is still underestimated (Shojaei & Haeri, 2019). In the LSP, the focus has shifted, and they are aware of the lacking focus in SCM and consequently the management in the project has acknowledged the importance of logistics and SCRM. Moreover, it is

acknowledged in literature and by the interviewees that the industry is embossed by old habits and how a large number of actors have been in the industry for a long time (Bankvall et al., 2010; Fearne & Fowler, 2006). This has further influenced the industry to not mature in accordance with other industries, making them less updated on SCM and have created more difficulties in the management of a CSC. SCM is further deemed to be a new concept in large-scale construction projects, and to succeed with the logistics, SCRM is of great importance. There are different views and opinions on the importance of logistics and SCRM in the construction industry, and on how this might improve the industry (Bankvall et al., 2010; Geraint, 2014; Humphreys et al., 2003). Consequently, large-scale construction projects, and the industry in general, does not focus on the risks associated with the SC, where the choice of suppliers are considered less important. SCM and SCRM is, however, deemed important by the ones interviewed, because having proper mitigation strategies makes it possible to look ahead and be prepared for uncertain events.

5.1 Supply chain risk identification and categorization

From a combined insight from our study and literature review, we have identified several prominent SCRs in large-scale construction projects that can cause disruptions in a CSC. These SCRs are originating from both the literature review and the empirical findings, where some are the same. Construction projects are in general exposed to a large number of SCRs and when the project size increases, so are the SCRs (Rudolf & Spinler, 2018). These have been listed in Table 5 to provide an overview of the SCRs that have been identified in this research. It is further emphasized in the literature that the SCR identification process could help to decrease the costs, delays and ensure quality, and it is deemed essential by several researchers to categorize and develop mitigation strategies, for the actors in a CSC to deal with SCR (Berle et al., 2013; Colicchia & Strozzi, 2012; Ho et al., 2015; Rangel et al., 2015; Sodhi & Tang, 2012).

Perceived Identified SCRs in Construction Projects	Perceived Identified SCRs in LSP	Identified SCRs in the Literature
Ground Conditions	Nature of the Product	Supplier Networks
Availability of raw materials	Lack of Labelling	Environment
Lack of Labelling	Delivery Security	Supply Chain Coordination and Management
Information Flow	Supplier Networks	Supplier
Transparency and Trust	Availability of raw materials	Behaviour and Cooperation
Contracts	Service agreements for the Logistics Service	Lack of Labelling
Product/Materials	Financing	Financing
Supplier	Ground Condition	Contracts
Supply Disruption	Materials	Availability of raw materials
Interdependency	Various Maturity	Lack of Ownership
Various Maturity	Information Sharing	Supply Disruption
Knowledge Sharing	Lack of Visibility	Interdependency
Lack of Competence	Construction Site	Technology
Ordering	Environment	Competition
Information Sharing		
Market		

Table 5: Identified supply chain risks from the findings.

From the literature, it is acknowledged that the identified SCRs should be categorized, which is supported by the empirical findings as well (Berle et al., 2013). A heatmap has been developed by SB for the LSP to illustrate the probability and impact of the identified SCRs. However, a framework has not been used that specifies the categories and the risks associated with the CSC in the LSP. It is supported by several researchers and interviewees that a SCR categorization framework is necessary to establish better mitigation strategies, clarification of various SCR and a foundation for develop scenarios of vulnerability (Berle et al., 2013; Colicchia & Strozzi, 2012; Rudolf & Spinler, 2018; Sodhi & Tang, 2012; Thomé et al., 2016). By categorizing the SCR provides a proper understanding and management of these in a CSC and helps address those who make the SC vulnerable in a structured and systematic way.

Furthermore, it makes it possible to accommodate the impact of the event for a particular SCR category (Colicchia & Strozzi, 2012; Rangel et al., 2015; Sodhi & Tang, 2012).

From our literature review we identified that Thomé et al. (2016)'s framework of SCR categorization covers most of the aspects within a CSC. Sodhi and Tang (2012)'s framework is another framework for categorizing SCRs, but this focuses on the SC in general, not on temporary multi-organization SC, like the LSP. Consequently, we found it more suitable to use the categorization from Thomé et al. (2016) as a foundation in our discussion. From the research, 22 SCRs have been identified that are most frequently occurring in large-scale and general construction projects. Several of these are associated or connected to each other in some way, meaning that if one risk occurs, another may occur as well (Sodhi & Tang, 2012; Thomé et al., 2016). The identified SCRs will be elaborated below and divided into the overall SCRs connected to Information, Digitalization and technology, Supply, Product, Construction industry and Ground conditions.

5.1.1 Information

Information was frequently identified in our research and is a relevant theme from our empirical study. It should however be mentioned that this is of great interest and that there is not much research in the context of SCRM. From our research we identified information- and knowledge sharing to be prominent SCR, which is supported by both the theory and interviewees to be of great importance. These SCR are associated with actors in a CSC who are only willing to share information that is necessary, making it hard to get information flow in the chain. It often lacks information sharing between actors in a CSC working on a large-scale construction project, which further impacts the knowledge sharing between actors in different projects (Sharma et al., 2011). In a large-scale project this can create difficulties as information and communication is required to know when activities start and when they are done. A challenge identified is how communication, openness, collaboration and information- and knowledge sharing are difficult in a large-scale project, like the LSP, making interaction in the CSC challenging. From the interviewees it is stated that this becomes a challenge when projects surpass 1 BNOK. It is emphasized in the literature that when a project

surpasses one billion dollars, it becomes a large-scale project, where the complexity increases drastically and operations with collaboration and communication are harder to implement (Capka. 2004). These are SCRs that can be connected to the "organizational" category suggested by Thomé et al. (2016) which includes SCR associated with the product, operations and behavioural and financial SCR aspects. This is because the information- and knowledge sharing is associated with the organisation and seems more suitable than Sodhi and Tang (2012)'s framework due to the complexity in temporary multi-organization projects.

The next SCR called attention to in our research is the information flow. It is supported by several researchers and the interviewees that disruptions in the flow of information, may lead to delays and cost overruns in a large-scale construction project (Christopher, 2016; Jüttner et al., 2003; Thomé et al., 2016). This will further have consequences on the material flow, as it may cause damages to materials and delays in deliveries, activities that must be done several times and waiting. The mentioned SCR, information flow, can further serve as an amplifier to the SCR regarding the lack of competence in the CSC. As it often lacks incentives for handling the information properly, this can provide disruptions in the information flow, which is emphasized in our research. These SCRs can be related to Thomé et al. (2016)'s "Network" category, as disruptions in a CSC and the uncertainty regarding deliveries and responsibility, can create a bullwhip effect that can impact the construction project (Ho et al., 2015). This is further associated with the SCR regarding supply coordination and management, as it will create difficulties to coordinate the in-bound logistics in a project if there is lacking communication and information between actors in the CSC. As a consequence, the suppliers in a CSC do not feel involved in the project, which further can be a result of the lack of ownership. Supply coordination and management can be categorized in Sodhi and Tangs (2012)'s category of "Supply" risk, as it comes to getting the correct supply at the right time and place. However, this SCR can also be put in the category suggested by Thomé et al. (2012) "Network", as it focuses on supply management. Meaning, the impact of this SCR can lead to disruptions in the CSC, less visibility and uncertainty regarding responsibility, which can further lead to a bullwhip effect in the CSC (Ho et al., 2015; Thomé et al., 2016). This leads to the next identified SCR, which

is the challenges regarding interdependencies. In line with Bankvall et al. (2010) we have identified that there is no interdependence within the individual SCs that fit into the complexity that are present in a large-scale construction project. It is further deemed as a SCR due to how CSC are operating under high uncertainties and interdependencies (Jones & Lichtenstein, 2008; Wang et al., 2017). Consequently, interdependencies can serve as an amplifier for other SCRs. This could be connected to Sodhi and Tang (2012)'s risk category "Process", but as it closely relates to the network in a CSC, it seems more suitable to attach it to the "Network" category suggested by Thomé et al. (2016).

The lack of information has been considered in our research to lead to the second most frequently mentioned SCR, the lack of labelling. Lack of labelling is considered as one of the most prominent findings from our analysis and literature, which exposes construction projects for disruptions, cost overruns and change in quality (Ginzburg et al., 2018). This has been acknowledged by interviewees to be a result of bad communication, information sharing and the various maturity in the industry, and the complexity of large-scale construction project's CSC. Moreover, it was identified by the interviewees that the lack of and incorrect labelling of materials is a major source of error creating unnecessary use of time and resources. When materials lack labelling, there is a loss of visibility and control, which can be connected to the material flow in a CSC since proper labelling enhances the flow of materials. Moreover, due to the lack of digital ordering, communication and various maturity in the construction industry along with the lack of common labelling standards in the industry, this is a SCR frequently occurring in a CSC (Ginzburg et al., 2018; Wang et al., 2017). Lack of labelling can therefore result in materials being delivered to the wrong place, delaying activities and resulting in a lot of unnecessary movement of materials and materials that are broken because they are stored incorrectly. This indicates that the SCR category "Network" is suitable, as it is directly connected to the impact of materials lacking labelling (Thomé et al., 2016). A consequence of labelling lacking is how the SCR can result in lack of visibility in a CSC, which is supported by the empirical findings and Rudolf and Spinler (2018). Lack of visibility is further associated with unclear distribution of roles, responsibility and tasks, which in turn can lead to entities establishing inventory without the knowledge of what others have already acquired. This is supported in the

empirical findings and by Ho et al. (2015) and Rangel et al. (2015). The lack of visibility is therefore arguably associated with the "Network" risk (Thomé et al., 2016).

5.1.2 Digitalization and technology

In line with extant research, our study showed that digitalization is a prominent challenge in the industry. The interviewees acknowledge how digitalization is a SCR associated with the organization and operations that are performed in a project, as the projects in today's construction industry are getting larger, taller and even more complex with new technology (Shin et al., 2011; Van Marrewijk et al., 2008). The construction industry has been slow in the adoption within digitalization compared to other industries in terms of technological innovations and processes, this has exposed the industry to more disruptions and SCR (Agarwal et al., 2016). It is further identified that there is a high degree of on-site interaction, low commitment to digital technology among workers and fragmented relationships, which may be some of the reasons for the low digitalization in the industry and the influence it has on the actors in a CSC (Friedrich et al., 2011). The digital and technological SCR concerns the organization and behaviour in evolving and developing processes, which is a sub-category within Thomé et al. (2016)'s "Organizational" risk category. Digitalization is a proper example on how SCR in an industry are connected, as digitalization is a tool that is frequently used to enhance information- and knowledge sharing which are prominent SCRs in large-scale construction projects. Hence, this SCR increases the probability of disruptions associated with information- and knowledge sharing.

5.1.3 Supply

Our research further identified how disruption in the supply can create difficulties for a project with a complexity like the LSP. A large-scale construction project often has several contractors and suppliers, who further have their own suppliers, with complex tasks and networks, which is characteristic for the industry (Aloini et al., 2012; Bankvall et al., 2010). The SCR is connected to supplier networks where the maturity of the sub-suppliers can create challenges and difficulties in the work towards an efficient CSC with less disruptions. Supplier networks are supported to be a source to SCR by Jüttner et al. (2003) as poor supplier networks

decrease the efficiency and response in the CSC (Thomé et al., 2016; Tukamuhabwa et al., 2015). Having poor supply networks leads to unclear boundaries in the network, and the SCR can be connected to Thomé et al. (2016)'s "Network" category due to the uncertainties regarding responsibility in the CSC (Ho et al., 2015).

Contracts and service agreements for the logistics service are identified as a SCR in the LSP (see 4.2.2.2 and table 5) and SB has pointed out the SCRs associated with the service agreement in the LSP, applies to deliveries that are exposed to the risk of human error. Large-scale construction projects are influenced by several agreements with various complexity between the parties, where one of the challenges is, according to our findings, the various opinions regarding how to cope with logistics. Moreover, Weele (2014) specifies that many problems related to quality and delivery from suppliers are traced back to the supplier selection process or it has been applied to a wrong contract model with insufficient specification and requirements. It is further identified that contractual terms are an exposed SCR in the CSC, as the contracts often lack incentives for risk sharing and innovation (Agarwal et al., 2016). These SCRs can be connected to Thomé et al. (2016)'s "Network" category, as they address the supply and demand challenges in large-scale construction projects.

5.1.4 Product

In large-scale construction projects there are several SCR occurring, and one of the SCR that have been discovered in our research, is the nature of the product or material. The nature of the product is a SCR itself, as it is difficult to detect whether products or materials arriving at a construction site are damaged and the product can be of great complexity. Thomé et al. (2016) states that risks in the SC can be connected to the product, and in large-scale construction projects, the CSC is a make-to-order process and there will be a new product or prototype created in every project, enhancing the probability of the product's nature (Bakker, 2010; Vrijhoef & Koskela, 2000). The product risk can be connected to Thomé et al. (2016)'s risk category "Organizational", which concerns the product risk. Consequently, SCR associated with the nature of the product can be further connected to the availability of raw materials, which is a prominent SCR in the

construction industry and in large-scale projects. Through our research there has been attention to this, as it is deemed important in a project of the size and complexity like the LSP to have access to materials at the right time to avoid disruptions and delays. It is further emphasised by interviewees and research that projects will stop and delay if there is no access to materials (Thomé et al., 2016). This further leads to the SCR of financing and is the greatest threat in a large-scale construction project, due to the nature of these projects tending to have huge cost overruns. This SCR is prominent from the research because without financing, the project will stop (Kardes et al., 2013; Shojaei & Haeri, 2019; Smith et al., 2014). Having financing is in other words necessary to execute assignments and complete the project within the aimed quality, time frame and budget (Harland et al., 2003). Hence, the dependency of financing can be placed in Thomé et al. (2016)'s risk category "Organizational" as this is one of the sub-categories.

5.1.5 Key characteristics in the construction industry

One of the discoveries from our research is that the construction industry is vulnerable when it comes to competition, which is supported by Akintoye and MacLeod (1997). It is further stated by Thomé et al. (2016) that the competition is an increasing SCR as today's firms are not competing firm against firm, but SC against SC. This implies that the competitor with a better SC, that can transfer this into a CSC with less disruption and more accuracy, will become more competitive and efficient, and take a great number of projects. However, we have identified the supplier and ordering of materials to be prominent SCRs due to the ordered quantity and timing of production, which is in line with Rudolf and Spinler (2018). The supplier risks are associated with the performance and operations, the environment and market of the supplier, contractual terms and conditions, and the supplier's financial stability. Furthermore, we identified delivery security to be another SCR connected to the supplier, as it is linked to the planning and routines. It is of great importance to get the right delivery of products at the right time in large-scale construction projects to avoid huge delays. In the LSP there is a great focus on the delivery security, as the materials are going to be delivered to the hubs one week ahead of the delivery of materials to the construction site. The SCR regarding delivery security, ordering, market and supplier can be connected to the industry in general. Consequently, the SCR can be categorized into Thomé

et al. (2016)'s "Industry" category, which is associated with the market and competition in a temporary multi-organisation, like the LSP and other construction projects.

5.1.6 Ground conditions

It was acknowledged by the interviewees participating on the LSP, that the construction site itself and the access to it may pose great SCR. There is limited capacity in the location of the LSP and consequently it is required more planning for the logistical activity. The construction site is problematic, as it has nearly no room for storing materials and barracks. Moreover, poor ground conditions are a risk itself, as the foundation of a building is crucial for the project implementation. The poor ground conditions in the project have caused great budget and time overruns as well as it is seen as a logistic challenge by the interviewees working on the LSP. This has resulted in greater complexity in the project's CSC where it needs more involvement of the suppliers and contractors, which have influenced the costs and time. These SCRs are in line with Thomé et al. (2016)'s risk categorization "Environmental" concerning the geotechnical risks. This is because it is challenging to map the ground conditions before the first ground break, which is acknowledged by the interviewees who work on large-scale construction projects. The consequence of impact can be large budget overruns and postponements, as they are dependent on funding to cover the costs to fix the ground conditions.

5.2 Summary of the identified supply chain risks

From our research we discovered several SCRs that can cause disruptions in a large-scale construction project, where the most prominent from our research were extracted and discussed. Through the discussion of the categorization of the identified SCRs, we found it appropriate to divide them into an extended framework of Thomé et al. (2016) risk categorization. We further discovered that several of the SCRs are connected to each other, meaning if one occurs, the possibility for this to initiate another increases. Consequences, or impact, of identified SCR increases with the project's complexity and size. Moreover, the SCR categorization has served as a tool for us to further investigate how to reduce and mitigate the identified SCR, which helps us answer our RQ. The discussed

SCR are allocated to the four different types Organizational, Network, Industry and Environmental in table 6 below. This will further constitute as the basis for suggesting and discussing the SCR mitigation strategies in 5.2.

Organizational	Network	Industry	Environmental
Nature of the Product	Information Flow	Delivery Security	Construction Site
Availability of raw Materials	Lack of Competence	Ordering	Ground condition
Technology	Lack of Ownership	Market	
Financing	Various Maturity	Supplier	
Material	Contracts		
Information Sharing	Supply Coordination and Management		
Knowledge Sharing	Supplier Networks		
	Service agreement for the Logistics Service		
	Lack of Labeling		
	Interdependency		
	Lack of Visibility		

Table 6: Categorization of identified supply chain risk.

5.3 How can actors in large-scale construction projects mitigate supply chain risks?

The construction industry is faced with a shift in the next few years, and it is acknowledged by several of the interviewees that digitalization will be the main change in large-scale construction projects. In order to achieve the potential opportunities to increase efficiency and to decrease costs, significant investments will be necessary to establish the necessary measures. It will require time, resources and a common understanding that this is something needed in the industry among the actors. This is also acknowledged by Tang (2006) stating that implementing mitigation strategies will cost but provide additional selling points retaining apprehensive customers before and after disruptions.

In this section we will focus on the prominent mitigation strategies we have discovered from the study. SB has already developed suitable mitigation strategies

for the identified SCR as elaborated in 4.2.2 Statsbygg's supply chain risk identification, assessment and mitigation plan, in addition to the four strategies; Lean, digitalization, systematic completion and logistics. However, in this section we will discuss different strategies that can be implemented in a large-scale construction project based on the identified SCR. As a large-scale construction project is embossed by significant complexity with a great number of SCR, it is deemed important to establish some SCR mitigation strategies. As previously mentioned, the construction industry is the least integrated of all industries, which is a poor starting point for the actors focusing on SCRM (Bankvall et al., 2010; Fearne & Fowler, 2006).

One of the main findings from our research is how CSC risks are first mitigated when it occurs, which is in line with Rudolf and Spinler (2018), stating that SCRs tend to be underestimated. In the LSP, SCRM is going to be performed based on continuous SCR assessment with the aim to reduce the CSC's vulnerability and ensure deliveries and has an aim to achieve the five R's. It is acknowledged by several researchers and interviewees in this study that mitigation strategies are deemed important to properly deal with the risks in a CSC (Heckmann et al., 2015; Kilubi, 2016; Lehtiranta, 2014; Rudolf & Spinler, 2018). SB aims to respond to the five R's in the LSP, making it essential to provide proper mitigation strategies. Therefore, we aim to suggest strategies that will contribute to ensure the five R's based on the categorization, see table 6.

5.3.1 Mitigation of the organizational supply chain risk

The SCR in the organizational category are associated with the product, operating and behavioural and the financial aspects. To handle the SCR from the *nature of the product*, the measures that can be implemented, is training of contractors and subcontractors. The consequences of this could be the reduction of complexity, and contractors being aware of the requirements set by the product. Moreover, this SCR can be associated with the *availability of raw materials*, where the SCR of lacking materials is handled. According to our empirical findings, follow-ups, training and common project-specific routines are strategies that are implemented in the LSP to secure availability of raw materials. This can lead to greater visibility, which has been lacking in large-scale construction projects. By

implementing a collaborative strategy, it will be possible to forecast the demand in the CSC, avoiding incorrect inventory, where their inventory is often either lacking or excessive (Ho et al., 2015; Rangel et al., 2015). This is in line with Shin et al. (2011) who propose a JIT strategy to secure a stockyard for materials, however, this is challenging in large-scale construction projects due to its size, complexity and technology. Consequently, the SCR regarding *technology and digitalization* is next to be discussed. The low commitment to digital technology among workers and the fact that the construction industry is fragmented may be a reason for the low digital commitment. It is acknowledged in the findings and in the literature study that digitalization is a strategy that can help projects to perform better by implementing changes in the CSC and making it more automated to further increase efficiency of physical tasks and planning (Eling & Lehmann, 2018; Friedrich et al., 2011; McKinsey & Company, 2016). Digitalization can provide flexibility to the CSC, as well as making it more resilient and robust (Jüttner et al., 2003; Tjahjono et al., 2017; Yang & Yang, 2010). However, if a large-scale construction project is to succeed with the implementation of the digitalization strategy, information sharing is needed.

Sharing of information is considered to be one of the main findings in this research, as there is a low degree of trust and transparency in a CSC. This has left its mark on large-scale projects like the LSP. It is discovered that digitalization can establish real-time sharing of information which will increase the transparency and collaboration, quality control and from this create better and more reliable outcomes (Agarwal et al., 2016; Tezel et al., 2020). To succeed with this, it is emphasized in both the literature and the empirical findings that collaboration and communication is needed. The LSP have incorporated contract agreements with requirements to their contractors to ensure collaboration throughout the value chain and making basic data available. This is in line with the research conducted by Harland et al. (2003), which makes it easier to share sensitive information. This exemplifies how SCR are interacted, as information sharing is a requirement to succeed with a digitalization strategy. Furthermore, the SCR regarding information sharing is closely related to the SCR of *knowledge sharing*. A collaborative strategy can enhance sharing between participants, and by having the same actors or participants involved in one or more projects make the knowledge and innovation gaps smaller than in projects with high turnover of

participants. It is further discovered in our research that by implementing a strategy of information- and knowledge sharing within the CSC, enhances the robustness and resilience in SC through improved visibility, flexibility, velocity and collaboration (Casimir et al., 2012; Dubois & Gadde, 2000; Ho et al., 2015). Consequently, the efficiency in a CSC will increase by managing transference of knowledge, which further results in a better prepared large-scale construction project.

The last SCR in the organizational category is *financing*. This is a SCR that is difficult to mitigate, as large-scale construction projects in general have major cost overruns due to unpredictable events or poor preparation. However, by doing a careful supplier selection process can ensure the financial stability of the firms, decreasing the SCR of bankruptcy of the supplier (Weele, 2014). It is further discovered that several of the SCRs can evoke this, meaning that the mitigation of other SCR must be present to decrease the financial risks in a large-scale construction project, as it may have fundamental impacts.

5.3.2 Mitigation of the network supply chain risk

This is the category most exposed to SCRs, where several mitigation strategies are applicable. One of the most prominent SCR from our research is the *information flow*. The lack of incentives for handling the information correctly and competence, knowledge sharing and quality assurance in CSC can be deemed as the reason, due to their temporary multi-organization. Moreover, the mitigation of this SCR is of great importance in large-scale construction projects as slow information flow can cause great disruptions in a CSC. To mitigate this, it is suggested to implement a digitalization strategy, as it is stated by Tjahjono et al. (2017) that the result of this strategy will improve performance, flexibility and response time. It is further identified in the empirical findings that JIT is a mitigation strategy several large-scale construction projects want to implement to increase the information flow, to get the materials to the construction site at the right time, which are in line with Lim and Low (1992). Moreover, the strategy reduces inventory and consequently reduces production costs, along with inventory cost and delays, which are in line with the five R's presented earlier in the section. However, according to Akintoye (1995) to succeed with this strategy,

it is essential to have communication and coordination, connected to information flow, which is also supported by Pheng and Chuan (2001). The information flow is closely associated with the *supply coordination and management*, making it important to mitigate the SCR as supply to a large-scale construction project is essential and critical to be managed and coordinated, and the occurrence of this SCR is high. This is because there is a lack of coordination in such complex projects. To mitigate this SCR, a collaborative strategy by having information sharing, proper supplier selection and a JIT strategy, the supplies arriving at the construction site will arrive at the right time and improve the CSC profitability (Chen et al., 2018). This strategy is suggested in line with the primary goals in the LSP to achieve the five R's. Moreover, the JIT strategy is addressing complex communication and coordination, along with waste minimizing and as stated by Pheng and Chuan (2001) the strategy can create, if implemented right, a better SCM and coordination with materials at the right time and place (Akintoye, 1995; Shin et al., 2011).

The interdependency are related to the coordination between suppliers and actors and need to be mitigated as there are interdependencies between the tasks in the LSP and it is acknowledged by Bankvall et al. (2010) that proper mitigation of this SCR leads to improved coordination. Mitigating this SCR can further lead to improved performance in the CSC, which is supported by Bankvall et al. (2010) and Humphreys et al. (2003). To deal with this SCR it can be facilitated for information- and knowledge sharing to create more ownership to the project, which have been used in the LSP and identified in the findings where SB used knowledge from the KHiB to establish better logistic preparedness and learnings for the LSP. This is in line with Dubois & Gadde (2000) where it is suggested that large-scale construction projects should consider previous projects to gain important knowledge enhancing the CSC efficiency and performance.

Another SCR identified in large-scale construction projects, which creates challenges for the information flow and difficulties to achieve successful SCM and reach the five R's, is the *lack of labelling* on materials arriving at the construction site. In the LSP there has been developed a strategy of sanction regime with the contractors, with routines and procedures that have been established in the cooperation agreements to ensure the delivery of materials.

Furthermore, it is acknowledged by several interviewees that a common logistics service strategy, with a labelling standard all participants in a CSC must follow, would decrease the number of lacking labels and errors. This is in line with Ginzburg et al. (2018) who states that the mitigation of this SCR can reduce the challenges exposed in the CSC and decrease delays and costs. However, to fulfil the aim of the five R's, the labelling can be handled through JIT and postponement strategy, as there will be a delay in the labelling until the order information becomes available (Jüttner et al., 2003; Yang & Yang, 2010). This can be valuable for a large-scale construction project due to the flexibility the strategy provides. It emerged from the literature chapter that integrated digital systems will improve information sharing, increase collaboration through new approaches of interacting and increase transparency between stakeholders and participants, which will result in better visibility in the CSC (Ivanov et al., 2019; Liu & Chua, 2016; Tezel et al., 2020).

Large-scale construction projects suffer from the *lack of ownership*, and it is stated by Ho et al. (2015) that by mitigating the SCR can reduce the bullwhip-effect that can occur through the CSC. A collaborative strategy can be used through closer communication with the suppliers and contractors, and Laan et al. (2011) support how an early involvement of the internal and external entities can create an improved project performance. However, the project performance is exposed to the *various maturity* in the industry, and to handle this SCR it seems suitable to implement a strategy that facilitates information- and knowledge sharing. Engwall (2003) and Sydow and Braun (2018) acknowledge the importance of not only focusing on one individual project but bringing well functional structures and procedures from previous projects into the next project. The mitigation strategy is in line with Ho et al. (2015) who state that knowledge sharing, and learning can improve visibility, flexibility, velocity and collaboration.

The next SCR connected to the network and that is embossed by the various maturity, is *supplier networks*. It is suggested by SB to incorporate collaboration, training and project specific routines in the LSP, and it is emphasised in the literature by Bankvall et al. (2010) and Geraint (2014) that CSC integration and collaboration are initiatives that can be implemented to reduce SCR.

Communication, collaboration and transparency makes it easier to detect disagreements and defaults at an early stage in the process, which will minimize exceeded budgets. To succeed with this, it is required some sort of formal agreement to get the parties in a CSC to collaborate (Harland et al., 2003). Consequently, the SCR associated with this is the contracts. Moreover, in our empirical findings, *contracts* were identified as a SCR due to the contractual terms and conditions. To mitigate this SCR in the LSP, there have been incorporated contract agreements with requirements as contracts and regulate systematic interaction, ownership, costs and responsibilities between the client and the contractor. The SCR can further be mitigated through a proper supplier selection as it is emphasized in both literature and findings that price is often predominantly when selecting suppliers, and it is suggested by Aziz and Hafez (2013) that suppliers should be selected based on their willingness to adopt the project's strategy. This strategy can be combined with the collaborative strategy to create maximized value through collaboration and all parties involved in a large-scale construction project working together effectively (Wassenhove, 2006; Weele, 2014). The SCR regarding contracts are connected to the *service agreement for the logistics service* that has been identified in the LSP. The mitigation strategy is to prepare for cooperation agreements making it easier for the actors to share information and collaborate, which is further supported by Rudolf and Spinler (2018) as collaboration and planning are needed to succeed with this strategy.

5.3.3 Mitigation of the industry supply chain risk

From our research we identified that it is crucial for construction actors to keep up with the market development and evolution to stay competitive, even though the industry is far behind other industries. However, to be competitive, they must establish the necessary strategies to make a seamless and efficient CSC. Supplier selection is arguably the first and most important factor ensuring *delivery security* and can be a crucial factor in a project's success, as choosing the wrong supplier may result in fatal consequences for the project (Jaskowski et al., 2010; Weele, 2014). By mitigating delivery security, the project will ensure the right quantity delivered to the right time and makes it possible for large-scale construction projects to achieve the aim of the five R's. However, it is considered a difficult task, as the construction industry consists of many actors, and the contractor

cannot know whether the supplier is able to answer every order. It can thus be advantageous to develop relationships and collaborations with suppliers through a collaborative strategy, which is shown to increase the performance between the actors involved (Naoum & Egbu, 2015). However, as stated by Rudolf and Spinler (2018), the industry is lacking flexibility, visibility and transparency, which may complicate a collaborative strategy. Considering SB being a state-owned company and must thereby use tenders in their supplier collection, complicates the possibility for a collaborative strategy. However, the tenders make it possible for them to establish good and competitive agreements in large-scale construction projects.

Collaboration will arguably be necessary to establish other strategies further, such as JIT, lean construction and a common integrated system. To secure *orders* and keep track of *suppliers* the digital system is necessary to ensure the details in the agreements and traceability of materials. Moreover, to handle the SCR regarding orders, a strategy could be to implement a lean construction and JIT with integrated systems as it is essential for a project with the complexity and size like the LSP, to get the right ordered quantity to keep within the time frame and reduce amount of waste into the construction site (Koskela et al., 2002; Rafael Sacks et al., 2010; Tortorella et al., 2017). This is further supported by the JIT strategy, which is why the strategies can be used in a combination and it is emphasized by several researchers that using a Lean construction strategy can improve the CSC performance. By combining integrated systems, it is easier to gain visibility in the CSC and reduce inventory and consequently reduce production costs, along with inventory cost and delays (Shin et al., 2011; Tezel et al., 2020; Tjahjono et al., 2017). The mitigation of *ordering* and *supplier* can be linked to the mitigation of lacking labelling and by mitigation one of these may result in handling the other as well. This is another example that reveals how SCRs are connected to each other. In the LSP it is the turnkey project contractors that relates to all suppliers and sub-suppliers. It would require a completely different staffing in SB than they have today, if they were to do this themselves. SB is careful about transparency and traceability in its agreements, and it is therefore important that all agreements are made digitally. Many of the requirements SB places on their contractors are passed on to the contractors' suppliers and subcontractors, and SB's requirements are thus met.

5.3.4 Mitigation of the environmental supply chain risk

The *ground condition*s are considered a huge SCR in construction projects (Thomé et al., 2016). Poor ground conditions can make a project a loss-making project before construction has even begun. To map and plan for the work delegated to the ground conditions, there must be thorough testing of the grounds. As previously mentioned, the project managers in the LSP knew that the ground conditions at the site were problematic, but not to the extent it actually was. It is impossible to avoid problems with the ground conditions, as the site is constant. The construction must therefore be handled according to the site's conditions in the best possible way.

The SCRs concerning the *construction site* can be mitigated through lean construction, a collaborative strategy and a common digital logistics service. Lean construction, which has become one of the most prominent means to improve construction performance over the past years can be implemented to deal with the difficulties the construction site poses to the project implementation (Bygballe et al., 2018). As the LSP aims to have as little transportation to the construction site as possible and researchers suggest implementing this strategy to decrease variability SCRs, improve flow reliability, eliminate waste, remove complexity in operations and implement benchmarking (Issa, 2013; Koskela et al., 2002; Rafael Sacks et al., 2010). However, to succeed with this strategy, it is necessary to combine it with a collaborative strategy and a common digital logistics service. This is emphasised by Sharma et al. (2011) and supported by Laan et al. (2011) as close relationships and trust in large-scale construction projects is a challenge. Namoun and Egbu (2015) further state that collaboration is vital in the construction industry, to achieve future goals and establish improvements in the delivery of the clients aim of the triangular, cost, time and quality. Moreover, combining lean with the digital service makes it possible for the workers to have a more seamless implementation of the logistical activities on the site. This also facilitates a collaborative strategy amongst the project participants. Hence, by implementing these mitigation strategies in a large-scale construction project will ensure less waste at the construction site, delays in deliveries and remove complexity by having less traffic into the construction site.

5.4 Summary of the supply chain risks and mitigation strategies

Resulting from our discussion on the several prominent findings from the research, it is reasonable to conclude that SCR mitigation is a value adding activity in large-scale construction projects like the LSP. Mitigation strategies are deemed as valuable and decrease the SCRs and complexity of a large-scale construction project, however it further discovered that mitigation strategies often need a combination of strategies to be successful. It is further discovered in this section that several of the strategies need some degree of collaboration and communication, which means that these strategies are of great importance. Furthermore, it should become an improved focus on logistics and SCRM and the benefits it can bring into a large-scale construction project. Having better collaboration between actors through a digital platform can be essential to succeed with a better and more cost-efficient project implementation.

Supply Chain Risk	Category	Mitigation Strategy
Nature of the Product	Organizational	Training of contractors and subcontractors
Availability of raw Materials	Organizational	Follow-up, Collaborative Strategy, training and common project-specific routines, JIT
Technology	Organizational	Digitalization, Collaborative
Information Sharing	Organizational	Digitalization (Integrated Systems), Collaborative Strategy
Knowledge Sharing	Organizational	Learning within SC's and projects, Collaborative Strategy
Financing	Organizational	Supplier Selection
Delivery Security	Industry	Supplier Selection, Collaborative Strategy, JIT
Ordering	Industry	Lean Construction, Integrated Systems, JIT, Collaborative Strategy
Market	Industry	JIT, Lean Construction, Collaborative Strategy
Supplier	Industry	Supplier Selection, Lean Construction, Collaborative Strategy
Construction Site	Environmental	Lean Construction, Collaborative Strategy, Common digital logistics service
Ground condition	Environmental	Thorough testing of the ground conditions
Information Flow	Network	Digitalization, JIT
Lack of Labelling	Network	JIT and Postponement, Development of a common logistics service, sanction regime with

		the contractors, routines and procedures, Digitalization
Lack of Ownership	Network	Collaborative Strategy
Various Maturity	Network	Learning within SCs and projects
Contracts	Network	Digitalization, Supplier Selection, Collaborative Strategy
Supply Coordination and Management	Network	Collaborative strategy, supplier selection, JIT
Interdependence	Network	Learning within SCs and projects
Service agreement for the Logistics Service	Network	Preparation of a cooperation agreement
Supplier Networks	Network	Collaborative Strategy, Training and project specific routines
Nature of the Product	Organizational	Training of contractors and subcontractors

Table 7: Identified supply chain risks with the associated mitigation strategies.

6.0 Conclusion

The overall objective of this study has been to investigate how SCR identification and mitigation strategies can reduce the SCRs in large-scale construction projects. Based on the overall objective, we will answer our developed RQ: *How can actors in large-scale construction projects mitigate supply chain risks?* We have based our thesis on an exploratory case study to answer the RQ. Consequently, this has made it possible for us to get an in-depth understanding of SCRs that are considered most prominent in large-scale construction projects, with the LSP as the research object. This has been performed by interviewing participants from eight different firms related to the construction industry, where the development of the LSP has been used as a foundation for the interview questions. In the interviews, it was given special attention to SCR identification, sources of SCR, mitigation strategies and maturity in the industry. Moreover, we discovered that it is challenging to exclusively measure the effect of SCM in a construction project, as there are a significant number of variables affecting the final result. The empirical findings were then further discussed in comparison with the findings in our literature study.

We discovered that some SCRs are more prominent than others in the LSP and large-scale construction projects with its size, uniqueness and complexity. One of our main findings from the interviews and organizational documents was the

impact of information, collaboration and labelling issues. These SCRs have been some of the primary reasons for poor performance in the construction industry, where the CSCs are particularly exposed to disruptions. Thomé et al. (2016)'s SCR categorization was emphasized to be suitable in the discussion. Categorizing the SCRs provided us with an overview and made it easier to see how the various SCRs connect, and provide an in-depth understanding of the identified SCRs. Furthermore, the categorization served as a tool for finding suitable mitigation strategies. Research showed that mitigation strategies can be implemented to create a more robust CSC and increase project performance. Moreover, in both the theory and empirical findings, we discovered that the industry is embossed by the lack of digitalization and renewal, with insufficient collaboration, transparency and trust. Digitalization is located to be a strategy that can serve as an enhancer for collaboration and establish a foundation for trust and transparency. This is because digitalization creates visibility and enables a collaborative strategy, better tracking of materials and provides better information flow. Consequently, this leads to a more agile CSC with better coordination. It is discovered through our discussion that it is not possible to allocate which strategies fit into the different categories, as several of these connect or associate with one another. SCR identification and categorization makes it possible to develop specific mitigation strategies or a combination of different strategies to handle the SCRs, which will decrease the probability and impact of SCRs occurring in the LSP and large-scale construction projects in general.

The contribution of our research is that it supplements the literature with empirical evidence from a large-scale construction project. Consequently, we have developed a revised framework (see figure 8) from a coalition of different theories, gathering theoretical and empirical findings from our research. To answer our RQ, we located the SCR sources and characteristics of large-scale construction projects. The complexity of large-scale projects must be considered when reviewing and developing mitigation strategies, with its large sum of resources, high human social and environmental impact, and overall complexity of projects. The SCR sources were acknowledged in both the literature and the empirical findings, as they are considered challenges in the LSP and large-scale construction projects. It was, therefore, beneficial to explore the most prominent SCRs in the industry and the LSP.

Our study revealed key issues faced in the industry, and there has been developed suggestions for suitable mitigation strategies that can be implemented in the LSP for handling SCR causing disruptions. We discovered that mitigation strategies could be conducted to create a more robust CSC and increase the project's performance. It is, however, difficult to conclude with an overall combination of strategies to deal with SCR due to the uniqueness and complexity of each construction project and the fact that SCRs are connected and influence each other.

Our research has further located interesting, practical implications for organizations and managers regarding the digitization of processes. There has been identified a need for digitalization and performance improvements in large-scale construction projects, along with the importance of SCR mitigation at an early stage. Our study discovered that a collaborative strategy is repetitive and acknowledged to be a foundation for almost every SCR identified in the LSP and several large-scale construction projects. To succeed with a collaborative strategy, which is repetitive from the study, implementing the digitalization strategy will be necessary. This enhances communication and collaboration within the CSC and may create synergies of managing disruptions and enable better project performance. The theoretical and empirical research has shown that there should be a more general view on SCM in the construction industry, where SCRM and the perspective of SCM in the CSC have been underestimated. As we discovered in our study, SCM and SCRM can decrease disruptions, enhance project performance and establish a more robust and resilient CSC (Humphreys et al., 2003; Pheng & Chuan, 2001; Rudolf & Spinler, 2018; Weele, 2014). It is also emphasized that mitigating SCR properly can amplify flexibility, transparency and collaboration in the CSC. This will make it possible for a project to establish a better planning and decision-making process.

The study indicates that the mitigation strategies could lead to better project performance in the LSP, as the CSC will become more robust with better visibility through digitalization and common communication platforms. A combination of strategies can serve as an amplifier to achieve the five R’s discovered in this research, which is a development from the iron triangle that focuses on cost, time

and quality. Furthermore, each project must be evaluated individually to find the combination of suitable mitigation strategies to deal with SCR. It influences a large-scale construction project to become more efficient and resilient with a CSC that works efficiently, with lower costs and better collaboration with the actors. Our research supports the consequences of how proper SCR identification, categorization, and mitigation can reduce the SCRs in the LSP and in large-scale construction projects, making the five R's achievable.

7.0 Limitations and recommendations for further research

The paper identifies several aspects of the SCRs in the CSC and provides a holistic view of the SCRs posed in a large-scale construction project. However, our study was limited due to several reasons. Firstly, it was not possible to visit the construction site or meet with SB in person, due to the restrictions resulting from the COVID-19 pandemic. Furthermore, the project extends over several years after we have delivered the thesis, which means that we cannot assess the finished product and compare the implementation of the LSP to another large-scale project not focusing on logistics to the same extent. The project is still at an early phase and has been postponed several times in the process. This means that there has not been as much logistics activity on the site as there really should have been at this time. Moreover, the number of interviewees was limited due to the time aspect of the data collection, which means that we could not interview every actor or participants involved in the LSP or other actors in the industry. However, we believe that we have provided a holistic view of the research areas, even though the study could be more general if we had conducted more interviewees from both the project and the industry. Consequently, the scope of a master thesis restricted the research on both time and resources.

We believe that our limitations and restrictions could highlight areas of interest for future research. As the LSP were at the first stages when this research was conducted, it would be interesting to look at the complete implementation of the project and see the effect of proper SCM regarding costs and completion. This study discovered that identifying SCRs and combining mitigation strategies can result in better project performance. For further research, we recommend studying whether other disruptions occurred in the LSP and what consequences they had. As we found our framework to be of value in this research, we recommend our

framework as a basis for future research as it is applicable in other construction projects and research in SCRM. It could also be interesting to make a quantitative study of the productivity of different project implementations and link the degree of SCM and project success. Furthermore, we have discovered that it would be interesting to investigate how the networks in a project-based industry influence the SC performance and learning aspects and how knowledge- and experience sharing may improve the SC performance.

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Appendix

Appendix 1 - Systematic combining model

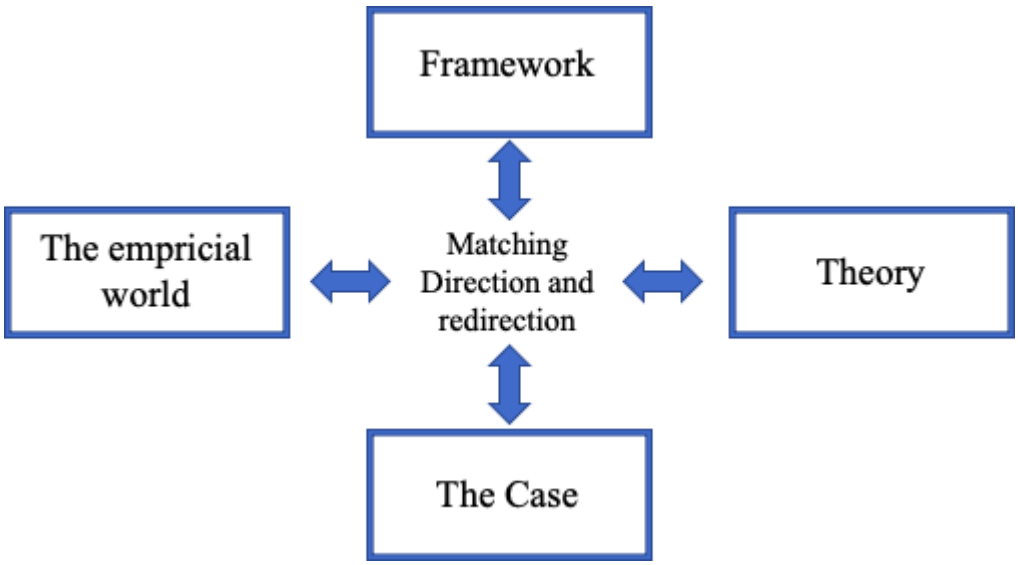

Figure 9: The systematic combining approach by (Dubois & Gadde, 2002).

Appendix 2: Interview guide actors working on the LSP.

Hvordan går prosjektet i dag?
Et enda bedre prosjekt: hva gjør dere til forskjell nå fra tidligere prosjekt?
Ligger dere etter planen? Har det kommet noen uforutsette hendelser den siste tiden?
Hvordan går logistikken til/fra og på byggeplassen?
Hvordan velger dere leverandørene deres? Fri konkurranse, anbud eller annet?
Hvilke problemer har dere/har dere hatt med leverandørene?
Hvordan har inkluderingen og samarbeidet mellom aktørene vært?
Hvordan foregår kommunikasjonen på et såpass stort prosjekt? Har dere en felles kommunikasjonsplattform?
Har dere hatt fokus på risikohåndtering?
Hvilke risikoer ser du med prosjektet? Er det noen risikoer knyttet til supply chainen og logistikk som er fremtredende i såpass store prosjekter?
Hva har dere gjort for å minske risiko i et såpass stort prosjekt?
Har det oppstått andre risikoer enn de dere identifiserte i starten av prosjektet? • Hvordan håndterer dere risiko?

Er det noen spesielle utfordringer du ser byggebransjen står overfor?
Hvordan er perspektivet på logistikk generelt i bransjen?
Bruker dere tid i planleggingsfasen å kartlegge mulige risikoer og utvikle risiko håndteringsstrategier dersom de oppstår?
Hvordan er den digitale utviklingen i bransjen?

Appendix 3: Interview guide other actors in the construction industry.

Hvilken rolle har du i bransjen og i prosjekter?
Hvordan er konkurranseutviklingen i bransjen?
Hvordan er modenheten for logistikkhåndtering og SCM i byggebransjen?
Er det noen spesielle utfordringer du ser byggebransjen står overfor?
Hvordan fungerer merkesystemene som finnes i dag?
Hva er de største konsekvensene av manglende merking på materiale?
Hvilke risikoer/utfordringer knyttet til forsyningskjeden oppstår ofte i byggebransjen og prosjekter?
Hvordan er fokuset på risikohåndtering?
Er det mange som ser verdien av risk management, eller er mer sett på som et tiltak hos arbeiderne?
Er det noen spesielle risiko håndteringsstrategier som ofte blir brukt?
Hvordan har den digitale utviklingen i bransjen vært?
Hva slags erfaringer har du om åpenhet for innovasjon og nye løsninger, nye måter å gjøre ting på som kan effektivisere driften? Er de som jobber fysisk med dette åpne for noe sånt eller trives de med sånn det er?
Er åpenhet og tillit ved avtaleinngåelser i bransjen?
Vil aktørene dele på informasjon eller holder de ting tilbake?

Appendix 4: Kunsthøgskolen i Bergen (KHiB)

Logistics and the benefits it can bring has first been acknowledged and gotten attention by SB in recent years. The KHiB is an example of their attempt to integrate a greater focus on logistics. In 2013 they were given funding to accomplish the construction of the KHiB with the intention to implement a lean methodology (Holm et al., 2018). The project was supposed to be conducted

differently from previous projects with a focus on logistics and lean methodology implemented in every part of the SC, aiming to reduce time loss, delays and create a flow in the project. SB's mantra in KHiB was to provide a common goal for the involved parties: "*Right information to the right time*". However, this did not go as planned and the success of the lean methodology implementation became absent. The failure was caused by the lack of communication along with the different levels of maturity in the digital development and view of logistics amongst the suppliers involved. The actors were too focused on personal gain rather than creating a common plan, which all parts involved would benefit from. In other words, logistics and scheduling were given lower priority. This was the first project with a structured lean methodology for several of the parties involved and became too much for everyone to get acquainted with (Holm et al., 2018).

SB have spent time establishing one common culture in their projects. This was viewed as a success in KHiB, as there were few contractors and companies involved in the project. The head entrepreneur, Snøhetta, used time to include all the participants and created ownership to the project. Consequently, SB wants to proceed with the same success in the LSP, but due to the complexity of the project, the many postponements and home-office restrictions followed by COVID-19, they have not succeeded this time.

The gained knowledge from the KHiB project have been taken into the LSP with the aim to create better logistic preparedness and learnings for this project. The same project team from the construction of the KHiB was recruited to work on the LSP, which makes it easier to draw knowledge and experiences to this project. SB has also brought in logistics expertise from Dynabyte Consulting that specializes in logistics and SCM, to be better prepared in this project. This indicates that a greater focus has been placed on the importance of logistics and the benefits this may entail.