CHALMERS
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Factors that drive efficiency of construction logistics

Master's Thesis in the Master's Programme
Production Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Vocabulary

Checkpoint	A road-barrier to control incoming and outgoing deliveries to a construction site.
Consolidation	Smaller deliveries of material from different suppliers are loaded together in one truck and then transported to the place of use.
Delivery point	The place of delivery at the construction site. The delivery points are specific marked areas at the construction site and the entrepreneurs can chose to which delivery point they want the material delivered.
Milk-runs	A transportation tour where material pickups and deliveries are executed in a pre-decided sequence to utilize the space of the transport means.
Unloading zone	The place where trucks deliver and unload material before it is carried in and delivered at one of the delivery points.

Acronyms

3PL	Third-party logistics
CCC	Construction Consolidation Center
CCC tent	Construction Consolidation Center outdoor storage
CCC warehouse	Construction Consolidation Center indoor storage
CLS	Construction Logistics Solution
HATS	Handling, Administrative, Transportation and Storage
JIT	Just-in-Time
NUS	Norrland’s University hospital
RQ	Research Question
TPS	Toyota Production Systems
VSM	Value Stream Mapping

Abstract

Title	Factors that drive efficiency of construction logistics
Introduction	ÅF is a design and engineering company that has developed a construction logistics solution (CLS) for large construction projects that include a construction consolidation center, an IT-system for coordination and planning, and a third-party logistics provider that handles all operational logistics activities at the logistics center and at the construction site. To be able to reach the full potential of the construction logistics solution, an evaluation of the logistical setup and the material flow hava to be performed. To be able to implement the construction logistics solution in other construction projects, it is necessary to gain knowledge about what factors that make it successful.
Purpose	Identify potential improvements in the construction logistics solution and increase knowledge about factors that drive efficiency of this solution.
Research questions	RQ1: What are the materials handling activities that exist in the material flow of the construction logistics solution? RQ2: What are value-adding, non-value-adding and necessary activities in the material flow in the construction logistics solution and how can non-value-adding activities be eliminated? RQ3: What different factors affect the materials handling activities in the construction logistics solution?
Methodology	A Value Stream Mapping (VSM) process has been performed to be able to map the material and information flow in the current state of the case study. Lean production principles have been used to categorize activities according to value-adding, non-value-adding and necessary work and to find areas of improvement to increase efficiency of the current construction logistics solution. This master thesis is a qualitative study and the methodological path that has been followed is a triangular approach with a literature review, an interview-series and a case study to increase knowledge about factors that drive efficiency of this solution.

Result and Conclusion

Three different delivery planning approaches have been analyzed and all activities in the material flow and the information flow have been categorized according to a HATS analysis (Handling, Administration, Transportation and Storage analysis) and divided into value-adding, non-value-adding and necessary work. It is the administrative activities that vary the most depending on which delivery planning approach that is being used. Most of the activities in the construction logistics solution have been categorized as non-value-adding and necessary work. Areas of improvement include elimination of non-value-adding activities, ergonomics, storage policies, planning and coordination, development of work process standards and communication between actors. Most of the factors presented in this thesis were identified both in literature and for the studied case. Factors identified in the case study are mostly connected to administrative activities.

It is not enough to just look at one factor to decide if the CLS is efficient to use in a construction project or not. It is not the impact from one single factor that is critical, it is the combination and correlation between different factors. The CLS needs to be adapted to the specific case and maintain some flexibility during the production phase to be able to tackle impact from uncontrollable factors.

Keywords

Construction Logistics Solution, Construction Consolidation Center, Third-party logistics, Value Stream Mapping, Lean construction, Factors affecting construction logistics, Efficiency factors for logistics

Acknowledgement

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Magdalena Bogren and Johanna Sigvardsson
Gothenburg, June 2019

Table of Contents

List of Figures

List of Tables

1. Introduction

This chapter shortly introduces this master thesis project by presenting the construction logistics solution that has been studied in the project, the purpose and the research questions examined, and the scope and delimitations of this study.

The cost of construction in Sweden has increased in recent years (Ekeskär and Rudberg, 2016) and the construction industry is suffering from low productivity and rising production costs (Koskela and Vrijhoef, 2000). Figure 1 shows how the construction prices have risen in Sweden between 1969 until 2017.

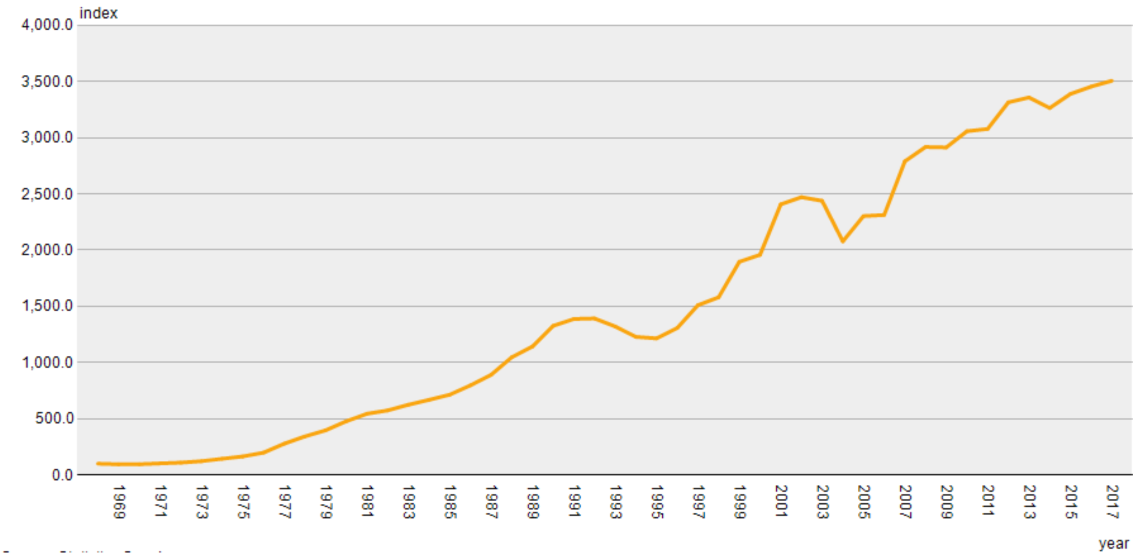

Figure 1: Building price index for dwellings in Sweden from 1968 to 2017 with index 1968=100 (Statistics Sweden, 2018).

Josephson and Saukkoriipi (2005) made an investigation of productivity in construction projects and found that 33,4 percent of the total working time is spent on unnecessary activities that can be eliminated without having any effect on the final product. Supply of material into the construction site is a common problem in construction projects (Thunberg, 2016).

1.1 Introduction to the studied construction logistic solution

ÅF is a design and engineering company that has developed a logistic solution for large construction projects to ensure an efficient material flow into the construction site. The goal of the construction logistic solution (CLS) is to coordinate different material flows and create conditions for an efficient production process. Figure 2 shows a visualization of the current CLS that ÅF has developed.

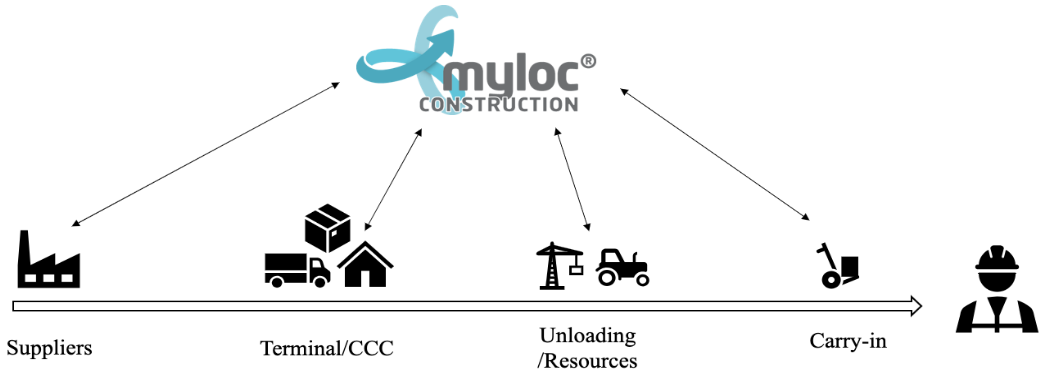

Figure 2: Visualization of the current logistics solution, with the different functions that are included.

The CLS includes all operational materials handling activities at the construction consolidation center (CCC), transportation between the CCC and the construction site, unloading at the construction site and carry-in services to the delivery point. ÅF has the overall responsibility for the material flow from the point when the material arrives at the construction consolidation center to the point when the material reaches the construction workers (entrepreneurs) at the construction site. Myloc is the IT-system that is used for communication between different actors and the platform that is used for planning and bookings of material deliveries. ÅF has connected some material suppliers to Myloc and this means that the information flow extends from the point when the order is initiated at the supplier to when the material reaches the entrepreneurs. Three different delivery planning approaches can be handled by the logistics personnel in the CLS:

- *No delivery planning,* suppliers are not connected to Myloc.
- *Light delivery planning,* suppliers add a booking number from Myloc to all parcels.
- *Full delivery planning,* suppliers are connected to Myloc and use labels from Myloc on all parcels.

At the CCC, full pallets are consolidated, and then transported by truck to the construction site. The deliveries from the CCC should be consolidated to the highest extent possible to reduce unnecessary transportation, as long as it does not cause late deliveries. The aim is to decrease traffic and number of transports into the construction area. The entrepreneurs must book in advance at what time the material needs to be delivered and to what location at the construction site.

To increase efficiency and to be able to reach the full potential of the CLS, continuous improvements are crucial. The current state needs to be analyzed to see if the right product is delivered at the right time, in the right amount and to the right place and it is necessary to investigate how non-value-adding activities in the materials handling processes can be eliminated. To be able to implement the CLS in other construction projects, it is necessary to gain knowledge about factors that affect the efficiency in the CLS.

1.2 Purpose and research questions

The purpose of this thesis is to identify potential improvements in the CLS and increase knowledge about factors that drive efficiency in this solution.

To attain the purpose, three main research questions will be addressed. By identifying materials handling activities that exist in the CLS, knowledge will increase about the different parts of the CLS and it will be possible to find areas of improvements. By identifying activities that exist, it is possible to understand how the activities are connected to factors that affect the construction logistics.

RQ 1: What are the materials handling activities that exist in the material flow of the CLS?

By classifying the materials handling activities into value-adding, non-value-adding, and necessary work, it will be possible to give suggestions about how non-value-adding activities can be eliminated. If the current CLS can be improved, the efficiency of the solution will increase, which will lead to that the CLS can be used on a wider range of construction projects. By understanding why some activities are necessary to perform it will help to identify factors that affects the CLS.

RQ 2: What is value-adding, non-value-adding and necessary activities in the material flow in the CLS and how can non-value-adding activities be eliminated?

When the activities have been categorized into value-adding, non-value-adding and necessary work, it will be possible to examine factors of the construction site that cause the categorization. By understanding which factors that contribute to the categorization, it will be possible to draw conclusions about factors that drive efficiency in the CLS.

RQ 3: What factors affect the materials handling activities in the CLS?

1.3 Scope and delimitations

The scope of the thesis involves the material and informational flow. The study is limited to the ingoing material flow to the construction site, from the point when the material is delivered to the CCC or directly to the construction site (dependent on what type of delivery it is) to the point when the material reaches the delivery point that it is ordered to by the entrepreneurs. The thesis will include examination of the CCC, the delivery of material to the right place at the construction site and the use of the IT system. These parts forms what will be referred to as the CLS in this thesis. The thesis will not include the outgoing material flow nor the work of the entrepreneurs. Implementation of suggested improvements will not be performed in the thesis.

2. Theoretical framework

This chapter provides the theoretical framework needed to understand the work procedure, the results, the analysis and the recommendations of this study. This chapter covers four main areas: construction industry, construction logistics, lean production and Value Stream Mapping. Factors affecting construction logistics that has been identified in the theoretical framework, are summarized in a final section.

Table 1 presents a summary of the literature used to develop each section of the theoretical framework.

Table 1: Summary of literature used in the theoretical framework

Research areas	**References**
Construction industry	Koskela and Vrijhoef, 2000; Bellgran and Säfsten, 2010; Josephson and Björkman, 2011; Byggkommissionen, 2002; Ekeskär and Rudberg, 2016; Xue et al., 2007; Janné, 2018; Dubois and Gadde, 2000; Josephson and Saukkoriipi, 2005; Thunberg, 2016; González et al., 2014; Chua and Kog, 1999; Faniran et al., 1998; AlSehaimi and Koskela, 2008; Frödell et al., 2008; Arbetsmiljöverket, 2017; Arbetsmiljöverket, n.d., AFS 1999:3; AFS 2012:2; Council Directive 92/57/EEC of 24 June 1992;
Construction logistics	Janné, 2018; Sveriges byggindustrier, 2017; Österman, 2017; Koskela and Vrijhoef, 2000; Lange and Schilling, 2015; Ekeskär and Rudberg, 2016; Mossman, 2007; Seppänen and Peltokorpi, 2016; Skjelbred et al., 2015; Shigute and Nasirian, 2014; van Laarhoven et al., 2000; Lundesjö, 2015; Güner et al., 2017; Jonsson and Mattson, 2012; Sullivan et al., 2010; Apte and Viswanathan, 2010;
Lean production	Liker, 2004; OICA, 2017; Bellgran and Säfsten, 2010; Olhager, 2013; Gao and Low Pheng, 2014; Polesie, 2011; Josephson and Saukkoriipi, 2007; Keyton and Locher, 2016; Josephson and Björkman, 2011; Lange and Schilling, 2015; Silva and Cardoso, 1999; Hines and Rich, 1997; Koskela, 1992; Johansson and Mathisson-Öjmertz, 1996;
Value Stream Mapping	Keyte and Locher, 2016; Bellgran and Säfsten, 2010; Rother and Shook, 2001; Finnsgård et al., 2011; Langbeck et al., 2012;

Figure 3 shows how the four main areas, covered in the theoretical framework, have contributed to answer all three research questions. How the four main subjects have been used to answer the research questions are presented in Chapter 3, *Methodology*.

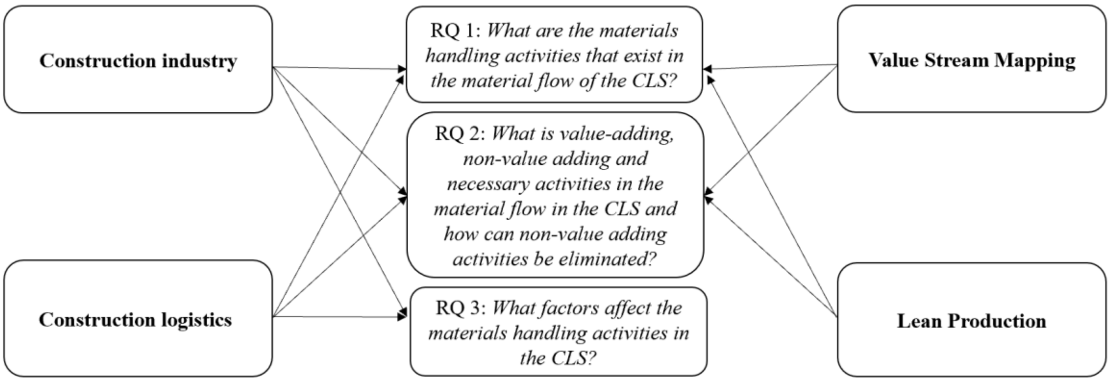

Figure 3: Conceptual framework of the four main subjects of the theoretical framework and which research question each subject has contributed to answer.

2.1 Construction industry

This section provides the theoretical framework regarding construction industry and problems construction companies are facing. Regulations and directives related to construction industry and construction logistics are presented as well. Theory introduced in this section will be used to answers all three research questions.

The construction industry is quite different from other manufacturing industries. The difference of a construction site compared to a regular manufacturing site is that the production is temporary, and that the factory is arranged around one single product (Koskela and Vrijhoef, 2000). A construction site has a fixed position layout, as can be seen in Figure 4. Instead of moving the product between different stations, material and personnel have to be moved to the product (Bellgran and Säfsten, 2010). In contrast to other manufacturing industries, the production at a construction site is dependent on the prevailing climate. Josephson and Björkman (2011) explains that weather can cause unpredicted production stops and construction material need to be stored properly to avoid getting damaged from rain and snow. Weather can have negative impact on the production progress and cause extra costs, some flexibility in production plans is therefore needed.

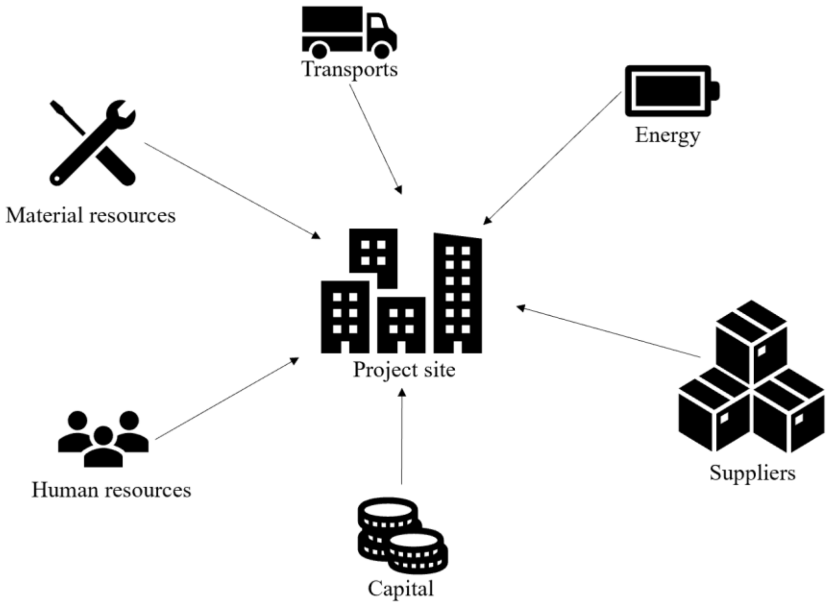

Figure 4: Fixed position layout of a construction production site.

The construction supply chain and network structure of a construction project are complex, as can be seen in Figure 5. Byggkommissionen (2002) explains that a construction project usually consists of one or several main contractors, construction entrepreneurs, consultants, architects, the state, municipalities and the end-users. All different actors must cooperate and combine their different material flows and processes. The main contractor is responsible for the coordination. The complex network structure of a construction project leads to higher costs and lower productivity compared to other manufacturing industries (Ekeskär and Rudberg, 2016).

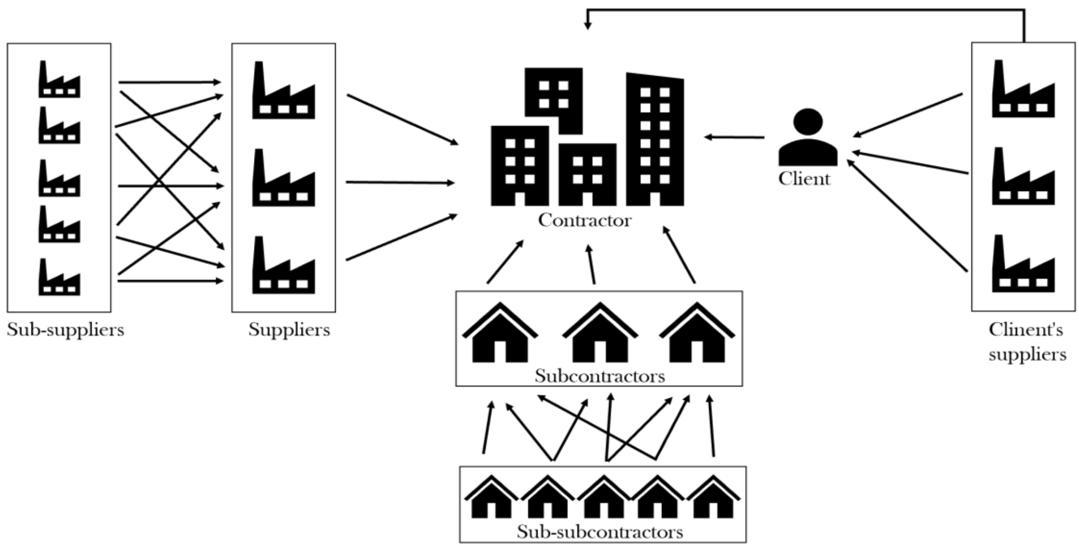

Figure 5: Supply chain in construction industry (Adapted from Xue et al., 2007).

A construction project is a temporary organization and each time a new project is started, new business structures are being formed (Janné, 2018). The network structure can be seen as two-fold since the different actors work independent from each other, but are at the same time dependent on each other's work since the construction activities are done in sequence and if one activity is late, all the following activities will be delayed as well (Dubois and Gadde, 2000). It is the main contractor's responsibility to control and coordinate the production to ensure that problems will be avoided both during and after the construction process (Byggkommissionen, 2002). The problem is that the contractor and the overall project managers usually have little control over daily processes and operations since these services are performed by subcontractors and sub-subcontractors (Dubois and Gadde, 2000).

Josephson and Saukkoriipi (2005) made an investigation on productivity in construction projects and found that 33,4 percent of the total working time is put on unnecessary activities that can be eliminated without having any effect on the final product. 10 percent of the total project cost is costs due to inefficient resource use, such as waiting times, inactive machinery and wasted materials. Another 10 percent of the total project cost is related to work injuries.

Lack of planning and scheduling are common problems in the construction industry and do often contribute to delays (Thunberg, 2016; González et al., 2014; Chua and Kog, 1999; Faniran et al., 1998; AlSehaimi and Koskela, 2008). Thunberg (2016) state that negative attitudes, trust issues and lack of sharing of information are common communication problems in construction projects. Proper planning should involve a production time schedule, forecast of material requirements and delivery times. All actors should be involved in the production time schedule, including the material suppliers, to give them the possibility to perform proper planning as well. The material delivery schedule needs to be updated continuously during the project to ensure that there are enough resources to meet the production demand. Faniran et al. (1998) state that to increase the effectiveness of a construction project, companies should invest more time in proper planning before the project starts and thereby reduce time spent on monitoring and control during the project.

González et al. (2014) state that major causes for delays in construction projects are bad oversights of the planning process, low productivity and unattained deadlines among the subcontractors. Chua and Kog (1999) explains that success of a construction project can be dependent on quality, schedule and budget performance. This in turn is dependent on project characteristics, the contractual arrangements, the participants and the interactions between the participants. Some mentioned project characteristics are: the surrounding environment, space limitations, project size, economy, politics and location. The authors further conclude that success in a project is not only dependent on the project manager, it is impacted by monitoring and control, the project characteristics and the contractual arrangements. AlSehaimi and Koskela (2008) highlights poor control as one common cause for delays in projects. The authors conclude that problems in the construction industry are often related to the construction site environment or the management, which usually involves lack of planning and coordination as well as inadequate communication and foresight. Frödell et al. (2008) describes that success factors in a project include participation of the client, commitment of the construction management and the workmanship, teamwork, and high-quality standard. To create relevant goals and spread them among all participants is mentioned as an important aspect for a successful construction project.

2.1.1 Regulations and directives in construction industry

There are a lot of responsibilities and directives that needs to be considered during the planning phase and the production phase of construction work. Arbetsmiljöverket (2017), The Swedish Work Environment Authority, describes that manual handling of heavy gods and lack of transportation possibilities are two examples of working conditions that often results in bad ergonomics at a construction site. Suggested actions, to prevent bad ergonomics are better planning; to perform the work tasks in the right order; ensure transportation and lifting possibilities for the material; and to keep the construction site clean and tidy. According to Council Directive 92/57/EEC of 24 June 1992, material and tools need to be placed and stored so that they do not constitutes any danger. Construction workers shall have enough space to perform construction work and material handling. If there is any risk of material falling the area needs to be secured. Bad planning along with deficiencies in coordination between actors are major contributors to work related accidents. Therefore, the directive has certain regulations for planning, projection and coordination for construction sites where more than one actor is involved.

According to Arbetsmiljöverket's directive about construction and civil engineering work (AFS: 1999:3), material that is transported on a construction site need to be planned and stored in a way that prevents accidents and work-related illness (55 §). The impact of the wind needs to be considered when material is being placed on a location aloft (56 §). Arbetsmiljöverket's directive about ergonomics (AFS 2012:2) states that the employer needs to examine if work postures, movements or manual handling task are harmful for the entrepreneurs and investigate if the workload is harmful on its own or in certain combinations with other activities (4 §). Work tasks shall be designed, to the greatest possible extent, in a way that is gentle for the body (5 §). The worksite shall be designed in a way that prevent injuries from heavy lifting and right tools and equipment shall be existing and available (6 §). The employees shall be provided with information about the weight of the goods that are handled manually, and if possible, get information about the center of gravity or on what side most of the weight is distributed (9 §). Arbetsmiljöverket (n.d.) describes that the use of proper equipment when handling goods that weigh more than 15-20 kilos can reduce the risk of illness remarkably and can be advantageous to use for lighter goods as well.

2.2 Construction logistics

This section will provide the theoretical framework regarding logistics that is relevant in this study. concepts related to logistics and how these can be adapted to the construction industry will be presented. Theory from this section is used to recognize construction logistics activities, support proposed improvements of the studied case and identify factors affecting construction logistics. Theory introduced in this section supports answers to all three research questions.

The process of coordinating all the different material flows to a construction site is called construction logistics. In construction projects, the product is produced at the place of consumption and material must be delivered to that place, the project is therefore dependent on that material arrive to the construction site when it is needed (Janné, 2018). Material cost is the largest cost item in construction projects (Sveriges byggindustrier, 2017). Österman (2017) describes that construction companies mainly focus on decreasing material costs, but delivery times and quantities are usually not considered. This can contribute to an expensive storage costs, or that the delivered material needs to be rearrange which can lead to quality issues and more time spent on materials handling. Koskela and Vrijhoef (2000) explains that non-value-adding activities are normally found in the construction supply chain, and materials handling costs can sometimes be as high as 250 percent of the material price in construction projects. Construction logistics involves planning, execution and documentation as well as to coordinate material flows, resources and information flows (Lange and Schilling, 2015). The material flow of a construction site can be seen in Figure 6.

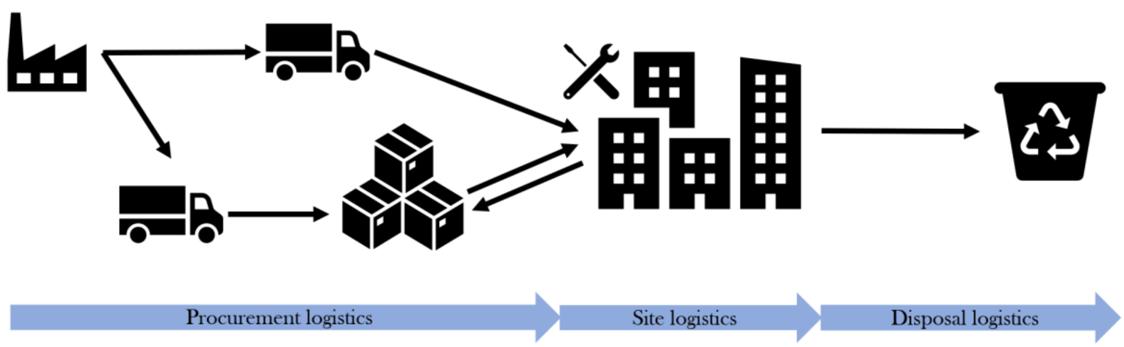

Figure 6: Material flow in a construction project.

Ekeskär and Rudberg (2016) acknowledge the importance of having some sort of logistic strategy in construction projects and state that in large projects it is a necessity to be able to make the material supply work. Mossman (2007) declare that good construction logistics involves how people, information, equipment and material reach the worksite in a safe and convenient way. Optimized construction logistics can contribute to (Lange and Schilling, 2015):

- Reduced inventories, which frees space on site
- Reduced time spent on material search

- Material being delivered at the right time and to the right place
- Levelling out the workload for equipment and resources
- Better workflow
- A cleaner and safer workplace
- More focus on construction activities for the construction workers
- Better transparency between actors in the construction progress

Seppänen and Peltokorpi (2016) highlights how different factors of the material handling are affected by different logistic strategies, see Figure 7.

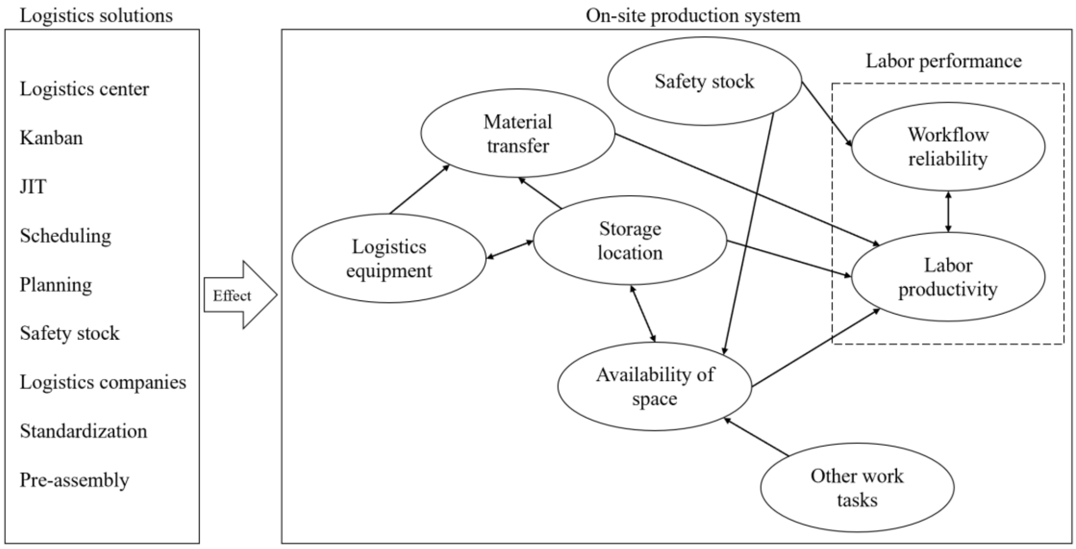

Figure 7: How different logistic decisions affect the on-site production (Adapted from Seppänen and Peltokorpi, 2016).

Skjelbred et al. (2015) describe that the decision of how the logistics setup should look like should be based on conditions of the construction project, e.g.:

- Distance to the suppliers
- Lead time
- Available space
- The level of detail of the plans

2.2.1 Third-party logistics

The handling of material at construction sites has traditionally been kept in-house and handled by the entrepreneurs (Ekeskär and Rudberg, 2016). This leads to that the entrepreneurs spend a lot of time on waiting, moving and looking for material instead of value-adding work (Shigute and Nasirian, 2014). To decrease the time that entrepreneurs spend on materials handling work, some contractors have started to turn to third-party logistics (3PL) providers (Ekeskär and Rudberg, 2016). 3PL can be defined as the use of external parties to perform entire logistics processes or selected logistics activities that have traditionally been performed within an organization (van Laarhoven et al., 2000).

Lundesjö (2015) presents in a report a simplified view of construction projects, divided into three main phases:

- Demolition and groundwork
- Foundation and structures
- Construction, fit-out and refurbishment

According to Lundesjö (2015) it is possible to use 3PL in all three phases and generally the 3PL provider can take a larger responsibility of the entire supply chain and not only be responsible for selected processes. During the demolition and groundwork, the 3PL provider can be responsible for managing bulk movements, central planning of operations and use of shared technology. During the foundation and structure work, the 3PL provider can optimize material deliveries and use of resources, such as vehicles and trucks. During the construction phase, the 3PL provider can be responsible for all operative materials handling tasks, consolidation and the reverse logistic flow. It has been shown that long-term 3PL arrangements, with high level of commitment and integration, improve the performance of the 3PL provider (Ekeskär and Rudberg, 2016).

Skjelbred et al. (2015) discuss that a small construction project on the countryside would not benefit from 3PL, since the cost would be too high, while it might be necessary for a large and complex construction project in an urban environment. The authors further state that the logistics and the site organization shall be planned in an early stage for all projects. A software tool where deliveries can be booked, real time updates are available and unloading resources can be tracked are advantageous to use to manage logistics and site organization planning. Ekeskär and Rudberg (2016) discuss that regulations regarding bookings must be strict to be able to plan the logistics and make it as efficient as possible, but can on the other hand meet resistance from entrepreneurs. In some construction projects, the 3PL only delivers and carry in material at night, to reduce traffic around the construction area during the day. This can lead to an increased utilization of the construction site and resources, since the materials handling and the construction work does not interfere with each other and it reduces the waiting time (Ekeskär and Rudberg, 2016).

In the studied case, the 3PL perform the milk run routes to the construction site. A milk run is a tour where material is collected and delivered in a pre-decided sequence to utilize the space of the transport means (Güner et al., 2017). In the studied case, the 3PL picks up material at the CCC and then at local material and equipment suppliers, to utilize the trucks. On-time deliveries and cost efficiency are two benefits from optimized milk runs (Güner et al., 2017), but to gain benefits from milk runs, proper planning and coordination of the material flow are crucial (Jonsson and Mattson, 2012).

2.2.2 Construction Consolidation Center

Construction material has traditionally been transported directly to the construction site, without any coordination. To reduce the amount of material that is stored at the construction site and to get the possibility to consolidate goods from different suppliers, some construction contractors have started to use different logistics solutions with a construction consolidation center (CCC) (Janné, 2018; Ekeskär and Rudberg, 2016). These logistic solutions ideally include a warehouse that has IT-coordination with the construction process and delivers material at the right time to the construction area or to a checkpoint (Shigute and Nasirian, 2014). By using a CCC or a checkpoint, it is possible to reduce the number of transports to and from the construction site and to control incoming deliveries (Janné, 2018; Apte and Viswanathan, 2010; Sullivan et al., 2010). By having one delivery place, such as a checkpoint, the suppliers will learn to go to the same location, which can minimize the risk that deliveries arrive at the wrong location (Ekeskär and Rudberg, 2016). Material with long and uncertain lead times can be stored at the CCC until it is needed, which decreases the risk of late deliveries. By using a CCC, the risk of material getting lost, stolen or damaged will decrease.

Figure 8 shows the principle of consolidation at a CCC, which should only handle small materials. Large items like roof, walls, concrete, steelwork and full vehicle loads that are needed right away should go directly to site without bypassing the CCC, since there is no point in reloading a full delivery at the CCC (Lundesjö, 2015; Shigute and Nasirian, 2014).

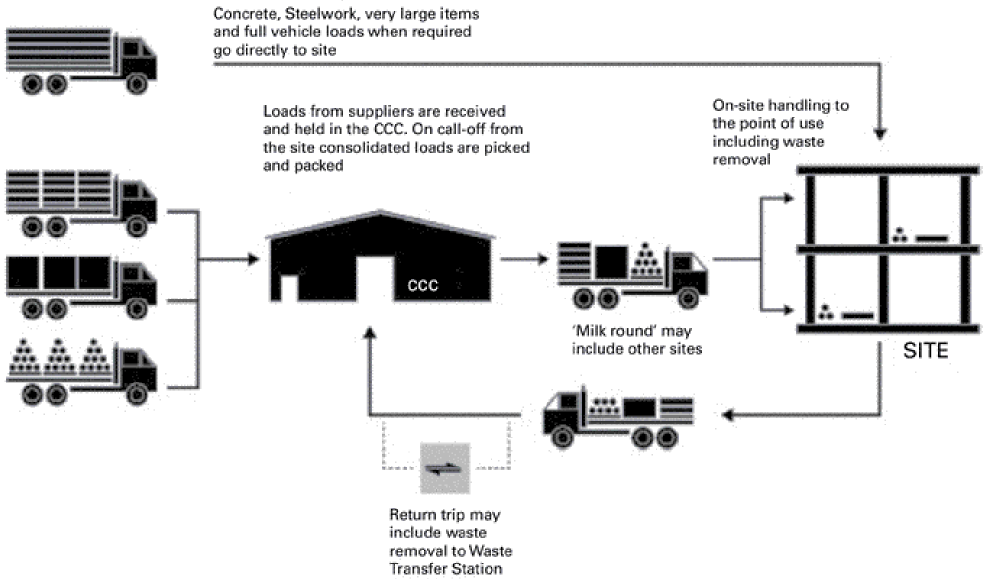

Figure 8: The principle of consolidation with a CCC (Lundesjö, 2015).

Sullivan et al. (2010) made a study that compare the CO_2 emissions for consolidation center deliveries compared to traditional delivery methods. The result, which can be seen in Figure 9, shows that by increasing the level of consolidation, emissions and air pollution can be reduced in urban areas.

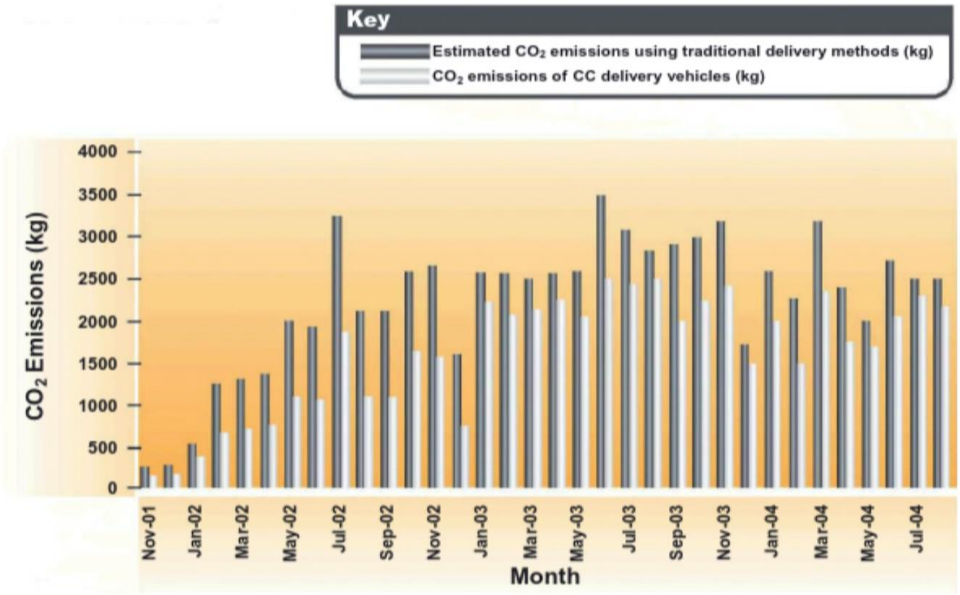

Figure 9: Comparison of CO2 emissions between traditional deliveries and consolidation center (CC) deliveries (Sullivan et al., 2010).

The surrounding environment of the construction site needs to be considered when deciding what storage to use, external or an on-site storage (Shigute and Nasirian, 2014). Sullivan et al. (2010) argues that a CCC is advantageous to use in urban areas; in construction environments where the production cannot disturb the ongoing business, e.g. hospitals or schools; and in environments where security is a priority such as military facilities. For projects without space limitations and with material with a high turnover rate, consolidation centers are not necessary and might not be advantageous to use (Shigute and Nasirian, 2014). Sullivan et al. (2010) explains that there are both internal and external constraints that will affect the logistics, such as legislative; financial; physical, e.g. limited space and accessibility; and environmental and social, e.g. noise, dust and other disturbances for adjacent areas.

One common way to handle material in a CCC is to only consolidate full pallets, which means that full pallets are received from different suppliers and then a mix of different supplier's pallets are loaded together and transported to site (Lundesjö, 2015). To take the consolidation process further, and add more value to the entrepreneurs, it would be possible to break the incoming pallets into smaller parts or packages and consolidate these into mixed pallet deliveries or kits. Each kit would then contain all different parts and material that is needed by an entrepreneur at a specific place and time at the construction site (Lundesjö, 2015). The personnel at the CCC can perform assembly processes of material that is going to the construction site, and thereby reduce the time that entrepreneurs spend on this type of work (Lundesjö, 2015). However, to be able to develop different types of kitting and assembly processes would require advanced planning and site management to be able to work.

Another way for the CCC to add more value to the production process is to unpack some of the material before it is delivered to site. In large and urban construction projects, removal and sorting of packaging material creates a lot of materials handling problems on site (Lundesjö, 2015). For some items, it is possible to remove the outer packaging already at the CCC, which can decrease the amount of packaging material that is delivered to site (Lundesjö, 2015). The CCC can be used to store tools and aids used by the entrepreneurs such as ladders and toolkits, that can be delivered together with the material, when the entrepreneurs need them (Lundesjö, 2015).

A CCC can increase cost due to tied up capital (Ekeskär and Rudberg, 2016). Janné (2018) argues that if a CCC is located too close to the construction site, there is a risk that material deliveries pass through the city, which can lead to that sought-after effect of reducing disturbances on the urban transport system is lost.

2.2.3 Storage policy

Different strategies can be used for how to position material in a storage. The first thing to consider is whether to use fixed or random stock location, which determines if material have a designated place in the warehouse or not (Jonsson and Mattsson, 2012). The advantage of using fixed stock location is that the utilization of the warehouse can be increased. The drawback is that a larger amount of space is required compared to a random stock location.

The layout of the warehouse should contribute to achieving the most rational material flows (Jonsson and Mattsson, 2012). The layout can be based on linear flows, as can be seen in Figure 10, or on U-shaped flows, as can be seen in Figure 11. A linear flow layout can be suitable to use for large volumes of few articles, while a U-shaped layout increases the possibilities to have more efficient handling processes since the inbound and outbound deliveries are placed on the same side (Jonsson and Mattsson, 2012).

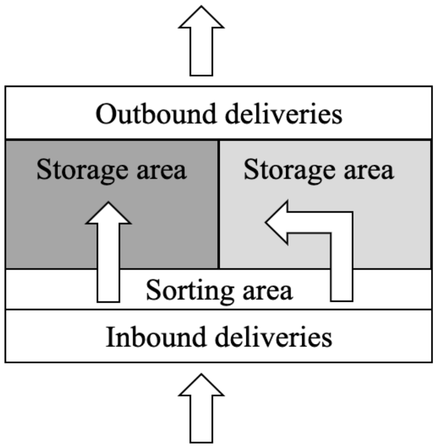

Figure 10: Linear flow layout of a warehouse (Jonsson and Mattsson, 2012).

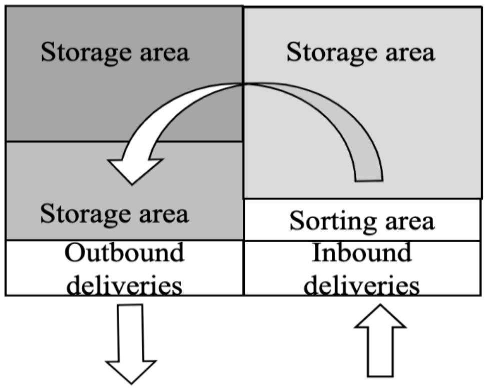

Figure 11: U-layout of a warehouse (Jonsson and Mattsson, 2012).

Zoning is a storage policy where the storage is divided into several smaller storages or zones. By placing products that are similar in terms of how they are handled in the same zone, it is possible to optimize the materials handling (Jonsson and Mattsson, 2012; Lundesjö, 2015). Products can then be stored based on contractors, product families, order frequency or physical attributes of the products. Zoning is most beneficial when using a U-layout (Jonsson and Mattsson, 2012). Zones based on contractors does not utilize space efficiently and is only suitable when there are relatively few contractors (Lundesjö, 2015).

2.3 Lean production

Lean production principles are used to identify areas of improvement for the studied construction logistics flow. This section will give a background to lean production, relevant parts of lean that will be used in this project and how it can be adapted to construction logistics. Theory introduced in this section supports answers to research question one and two.

The Toyota Production System (TPS) is the base for lean production that has dominated the manufacturing industry during the last decades (Liker, 2004). Toyota is often referred to as the most successful automotive company in history and has topped the world ranking of the largest automotive manufacturer for years (OICA, 2017). Lean production has represented a paradigm shift during the second half of the 20th century and it is often considered as synonymous with world-class production (Bellgran and Säfsten, 2010).

Lean production means that all resources such as machines, staff, material and space are used in the smartest and most efficient way possible, so the customer does not have to pay for unnecessary processes (Olhager, 2013). The TPS house, as can be seen in Figure 12, illustrates the most important parts of lean. The goals of lean are high quality, low cost, short lead time, excellent safety and high morale. The two ground pillars are Just-in-Time and Jidoka (to never let a defect pass through to the next step in the production sequence). The base consists of levelled production, standardized processes and visual management, which means to make the problems visible so that they can be fixed right away (Liker, 2004). Teamwork and people are placed in the center since they should be trained to identify waste to be able to contribute to the continuous improvement of an activity (Gao and Low Pheng, 2014).

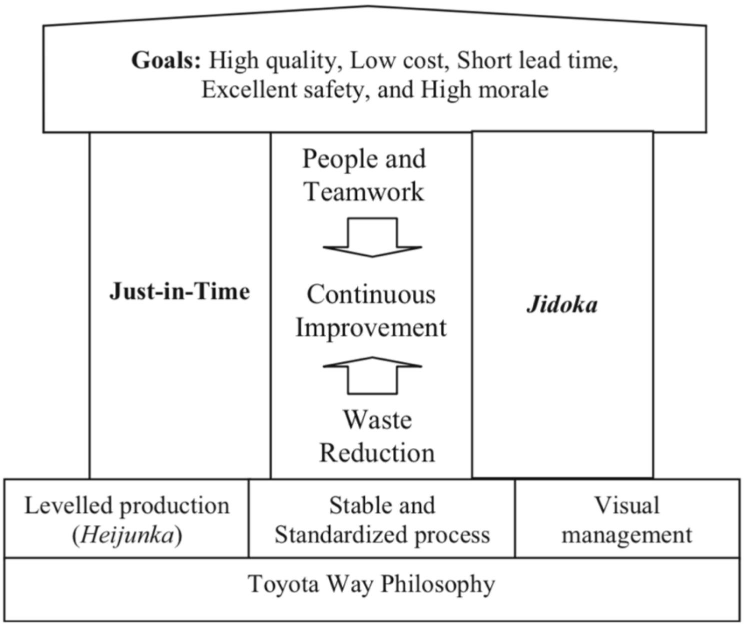

Figure 12: The Toyota Production System House (Liker, 2004).

2.3.1 Just-in-Time

To be able to reduce the amount of material that is stored at a construction site, construction contractors have started to use different logistic solutions to be able to deliver the material Just-in-Time (JIT). JIT means delivering the right product, at the right time, in the right amount and at the right place (Liker, 2004). By using JIT in a construction project, it is possible to reduce the risk of material getting damaged and reduce the amount of time that entrepreneurs spend on searching for material.

2.3.2 Standardized work

Standardized work is an important part of lean production to ensure high quality and to be able to keep the production at a high pace. Standardized work means using well proven techniques that are suitable for the personnel and the processes (Olhager, 2013). To create standardized work, it is important to identify the repeatable elements of a process and find the best way to perform these elements (Gao and Low Pheng, 2014). According to Polesie (2011), standardization is a way to increase productivity in construction industry and by introducing standards, the root causes to production problems can be identified and routines can be established that lead to more consistent operations. Gao and Low Pheng (2014) claim that standardization enables the workers to be part of the process of designing and improving current standards. This means that the construction firms should let every member of the project team be creative and improve standards.

2.3.3 Waste reduction

One key concept of lean production is waste reduction, which means to eliminate everything that does not add value to the value chain (Bellgran and Säfsten, 2010). Waste are activities that are unnecessary and that can be eliminated without having any effect on the final product (Josephson and Saukkoriipi, 2007; Olhager, 2013). Toyota divide waste into three categories (Liker, 2004):

- *Muda*: non-value-adding activities that lengthen lead times and causes extra movements and waiting.
- *Muri*: overburdening people and equipment beyond its limits, which will lead to quality and safety problems.
- *Mura*: unevenness in production systems lead to that there is sometimes too much work for the people to handle and at other times there is a lack of work, which result in waiting.

Muda can be divided into seven major types of non-value-adding wastes, which are (Liker, 2004; Keyton and Locher, 2016):

1. *Over-production*: producing more information or service than what is needed.
2. *Waiting:* customers, information or material waiting.
3. *Unnecessary transport*: movement of material or information.
4. *Over-processing or incorrect processing*: steps that take longer than they should or entire activities that does not add value for the customer.
5. *Excess inventory*: storing more material than needed for longer time than needed.
6. *Unnecessary movement*: movement of personnel.
7. *Defects or corrections*: any activity that is performed to correct an error that has been made.

2.3.4 What is customer value?

To be able to detect and eliminate non-value-adding activities, it is important to first know what value-adding activities are. The first step in a lean transformation is to determine what the customer want from a process. It is both the internal customer, at the next step in the production process, and the external customer that defines what customer value is (Liker, 2004). Value-adding activities is the core of production since it takes raw materials, machinery, time and other resources, and transform them into outputs in the form of products and services of higher value than the inputs (Gao and Low Pheng, 2014). Through a customer's eyes, it is possible to observe any type of process and separate the value-adding steps from the non-value-adding step (Liker, 2004).

A construction project has many customers since there are entrepreneurs, sub-entrepreneurs and one or several clients that are responsible for the outcome of the whole project. According to Josephson and Björkman (2011), the construction sector lacks customer focus, at least regarding how companies use the customer's money.

In logistics, products are usually just stored and transported, and not transformed into something else (Lange and Schilling, 2015). Customer value increases when the product is delivered with the right quality, within the right budget, at the right time, and at the right place with the correct specification (Silva and Cardoso, 1999; Lange and Schilling, 2015). Keyte and Locher (2016) describe customer value when delivering a service, and divide materials handling activities into three categories:

1. *Value-adding activities*: create value that the customer can see
2. *Necessary non-value-adding activities*: create no value that the customer can notice but is necessary to do in order to support the business
3. *Non-value-adding activities*: create no value for the customer or the business

Hines and Rich (1997) describes these different categories of activities. Non-value-adding activities are pure waste and should be eliminated completely, examples would be waiting and double handling. Necessary non-value-adding activities are waste as well, but are necessary under the current operating procedures, examples would be unpacking deliveries and walking long distances to pick up parts. These are the most common activities in a service business. These activities are not important for the customer but are crucial for the company and can therefore not be eliminated. Value-adding activities create value for the customer and involves processing of raw material or semi-finished products using manual labor.

Koskela (1992) describes value-adding as an activity that converts material and information towards what is required by the customer and non-value-adding as activities that take time, resources and space but does not add any value. Transportation and inventory are activities that are normally categorized as non-value-adding, but these can be seen as value-adding in one sense since they are required to deliver the product to the customer at the right time and to the right place (Olhager, 2013). Value-adding and non-value-adding activities in a material flow process can be categorized as activities that change the condition of the material (Johansson and Mathisson-Öjmertz, 1996). By performing activities that rearrange the material, from the first condition to the second condition (that is defined as how the customer want the material to be arranged), see Figure 13, the materials handling activities can create value for the customer.

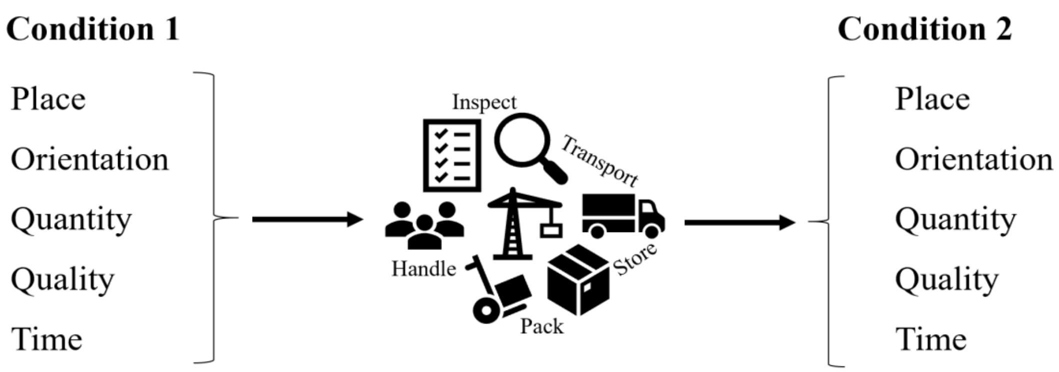

Figure 13: Material flow processes, conditions and variables. Adapted from The Transformation Model (Johansson and Mathisson-Öjmertz, 1996).

2.3.4.1 Customer value in construction logistics

In order to decide what activities that are value-adding, non-value-adding and necessary in a materials handling process, the definitions must be presented. Construction logistics does not involve any transformation of products and the definition of value-adding, non-value-adding, and necessary work needs to be defined and adapted. In construction logistics, value-adding activities can be defined as:

- Activities that create value that the customer can see (Keyte and Locher, 2016)
- Activities that transforms material and information towards the customer expectations (Koskela, 1992)
- Activities that changes or rearranges the conditions of the material towards the customer requirements (Johansson and Mathisson-Öjmertz, 1996)
- Activities that contributes to that the product is being delivered JIT (Silva and Cardoso, 1999; Lange and Schilling, 2015; Olhager, 2013).

Activities can be divided into handling, administration, transportation and storage (HATS) and these can add value for the customer in different ways. The definitions of value-adding activities for construction logistics, used in this project, are:

- *Handling*: Activities that rearranges the material towards the customer requirements and contribute to delivering the material JIT.
- *Administration:* Activities that contribute to delivering the material JIT with the right information.
- *Transportation:* Activities that move the material closer to the delivery point.
- *Storage:* Activities that contribute to delivering the material at the right time.

As presented in the previous section, necessary work can be defined as:

- Activities that creates no value that the customer can see but is necessary for the company in order to be able to deliver value for the customer (Keyte and Locher, 2016; Silva and Cardoso, 1999; Lange and Schilling, 2015).
- Activities that does not create value for the customer but is necessary for the process and cannot be eliminated (Hines and Rich, 1997).

The definition of a necessary non-value-adding activity used in this project is: “Activities that are necessary to do in order to be able to deliver JIT, with the right information“ or “Activities that are necessary to perform because of the specific construction environment or because the client requires it and it cannot be eliminated”

Non-value-adding work can be defined as:

- Activities that does not create value for the customer nor the company (Keyte and Locher, 2016).
- Activities that are pure waste and can be eliminated (Hines and Rich, 1997).
- Activities that takes time, resources and space without contributing to any value (Koskela, 1992).

A non-value-adding activity in construction logistics, is in this project defined as: “Activities that does not contribute to any value for the customer nor the client and can be eliminated.”

2.4 Value Stream Mapping

This section presents a background to the value stream mapping tool, how it is performed and the different steps of the process. The theory in this section is used to answer research question one and two.

The Value Stream Mapping (VSM) process is a lean planning tool that enables the ability to see the flow on a physical map and focus on what is important to reach the company’s vision (Rother and Shook, 2001). VSM can be used for different types of manufacturing processes and businesses. VSM helps to visualize processes in a system perspective and to find areas of improvement by identifying problems that affects the system performance (Keyte and Locher, 2016).

In the VSM, the customers, the processes, factual boxes, storages, the material flow and the information flow should be involved and considered (Bellgran and Säfsten, 2010). The material and information flow are equally important, and it is therefore important to map both (Rother and Shook, 2001). Facts are gathered for each process in the production system and are written out on the map (Bellgran and Säfsten, 2010). The mapping is used to describe current and future state of a production process, and follows the steps shown in Figure 14.

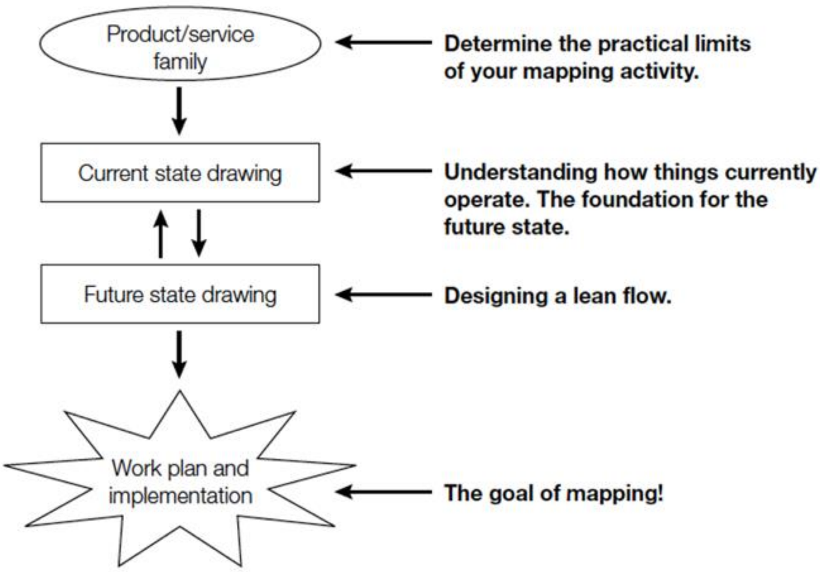

Figure 14: Steps in VSM analysis (Keyte and Locher, 2004).

The first step in the VSM process is to choose the scope of the value flow and to choose which product family to follow. A product family is a group of products that have similar handling steps through the different processes (Bellgran and Säfsten, 2010). The level of detail must be decided at the beginning of the process. The mapping process usually start at the single factory level, as can be seen in Figure 15, and then the level of detail can be changed later in the process, if necessary (Bellgran and Säfsten, 2010). For this project, the level of detail is a single factory level since it considers the work processes from when the material arrives at the CCC or at the construction site to when it reaches the delivery point at the construction site.

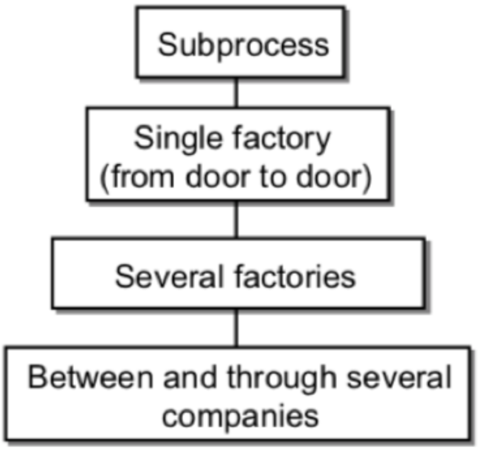

Figure 15: Alternative levels of detail for a product family's value steam (Rother and Shook, 2001).

The second step in the VSM process is to create a current state drawing, see Figure 14. A current state map helps to visualize the process and information shall be gathered to be able to point out problem areas (Keyte and Locher, 2016). The product family should be followed through the process and data should be collected along the way to be able to assess the material flow (Rother and Shook, 2001). Which data that should be measured depend on the process.

Finnsgård et al. (2011) have created a framework for VSM of logistic processes that includes a HATS analysis, which enables the categorization of different activities in a material flow. HATS include four categories of activities that affect the component along the flow: handling, administration, transport and storage levels. This categorization of activities can be useful to show how many of the activities in the flow that are of a certain kind and how much time that is spent on these types of activities. The HATS analysis was used in this project to see how activities in the four categories were affected by the three different delivery planning approaches. Langbeck et al. (2012) did a case study with the aim to develop a methodology for VSM in supply chains. The study showed that some components that can be considered when analyzing material flows are:

- Number of activities
- Time for each activity

- Number of times in buffers and storage
- Time in storage
- Throughput time
- Distances

In this project, the focus was to localize differences in activities depending on the three different delivery planning approaches and the main data that was collected was therefore number of HATS activities. Distances were of interest to observed be able to see if and how much the transportation distances varied dependent on the different planning approaches.

From the current state, and the highlighted problems, a future improved state should be developed with suggestions on how to tackle current problems. To create a future state drawing is the third step in VSM analysis presented in Figure 14. The future state should be drawn in the same way as the current state, with the processes in systematic order and with help of symbols. Even though waste cannot be fully eliminated, it can often be reduced. Questions that can be helpful to go through when developing a future state are (Keyte and Locher, 2016):

1. What is the customer demand?
2. Which steps and activities are value-adding, and which are waste?
    a. Why is this step or activity performed in the current state?
    b. What can be done differently and still meet the customer demand?
    c. Is the typical order of the steps what generates waste?
    d. Which assumptions are the current work process based on?
    e. Are current guidelines for control and administration suitable?
    f. What knowledge is crucial to perform this step?
3. How would fewer interruptions affect the workflow?
4. How will the interruptions be controlled?
5. How can the activities be levelled?
6. How will the new process be managed?
7. What changes and improvements need to be done in the process to achieve the future state?

2.5 Factors affecting construction logistics

This section summarizes identified factors that can affect construction logistics. The summary is based on information presented in previous sections in the theoretical framework and is used to answer research question three.

Table 2 presents a summary of factors that have been identified in the theoretical framework. Each factor has an explanation of how it can affect the construction logistics that which is based on the literature. These factors presented are used to localize factors that drive efficiency in the CLS.

Table 2: Summary of factors that can affect the construction logistics.

Factors	Explanation	References
Directives and regulations	• Directive for work conditions • Directives for ergonomics • Directives on how to store material	Thunberg, 2016; Chua and Kog, 1999; Arbetsmiljöverket; EU; Sullivan et al., 2010;
Size of project	• Affects time spent on planning • Affect how advantageous a 3PL is	Chua and Kog, 1999; Faniran et al., 1998; Skjelbred et al., 2015;
Cost and budget	• Affects time spent on planning • Clients mainly focus on reducing material cost • Storage cost • Budget for logistics • CCC can increase tied up capital • CCC can reduce the amount of thrown away material	Chau and Kog, 1999; Faniran, 1998; Skjelbred et al., 2015; Sullivan et al., 2010; Österman, 2017; Fang and Ng, 2011; Ekeskär and Rudberg, 2016;
Time duration	• Long-term 3PL arrangements affect the performance of the 3PL	Ekeskär and Rudberg, 2016
Available space	• Available space for material storage on construction site • Available space for incoming deliveries • CCC advantageous for construction sites with limited space • CCC unnecessary for projects without space limitations	Chau and Kog, 1999; Skjelbred et al., 2015; Seppänen and Peltokorpi, 2016; Shigute and Nasirian, 2014; Sullivan et al., 2010; EU;
Surrounding environment and location	• Sensitive for dust or noise • Surrounding traffic should be considered when choosing logistics setup • Urban area or rural area • CCC useful in urban areas	Chau and Kog, 1999; Skjelbred et al., 2015; Sullivan et al., 2010; Shigute and Nasirian, 2014;
Construction site environment	• CCC advantageous for construction work at or close to an ongoing business (hospital, school etc.) • CCC advantageous for construction work at security areas (military facilities)	AlSehaimi and Koskela, 2008; Sullivan et al., 2010;

	• Other logistics flows to consider	
Type of material	• CCC advantageous for small material • Large material should go directly to site • Turnover rate/demand • Weather sensitive • Sensitive material can be stored in the CCC and reduced the amount of damaged material	Apte and Viswanathan, 2010; Lundesjö, 2015; Shigute and Nasirian, 2014; Arbetsmiljöverket; Sullivan et al., 2010; EU; Seppänen and Peltokorpi, 2016;
Storage location	• Affects distances, space, need for equipment/resources • Affects the possibility to control the delivery process • A CCC to close to the construction site will not help to reduce the disturbances in an urban area	Seppänen and Peltokorpi, 2016; Janné, 2018; Sullivan et al., 2010;
Distance	• Distance to suppliers should be considered when choosing logistics setup	Skjelbred et al., 2015;
Lead time and safety stock	• Affects the need to store material	Skjelbred et al., 2015; Seppänen and Peltokorpi, 2016;
Possibility to transport	• Needs to consider if transports can get through to the construction site • How much traffic that is allowed in the area can affect the choice of logistics setup • CCC can reduce the number of vehicles to and from construction site • CCC make it possible to restrict deliveries to the construction site	Ekeskär and Rudberg, 2016; Sullivan et al., 2010; Janné, 2018;
Emissions	• Connected to number of transportations • Emissions can be reduced with CCC	Sullivan et al., 2010
Number of actors involved	• Many different actors that must combine their flow, leads to high cost and low productivity • Actors work independent but are dependent on each	Ekeskär and Rudberg, 2016; Dubois and Gadde, 2000; Janné, 2018;

	other in the production sequence • Construction projects are temporary organizations involving new actors each time	
Phase of construction project	• 3PL can be useful in all construction phases	Lundesjö, 2015;
Resources for materials handling and transportation on site	• IT-service good to have control over resources • 3PL someone to keep track of the resources • Resource planning is important • Lack of resources can affect the complexity of the projects • Need to ensure that resources are available when needed • Type of resources/equipment affect the storage location and the possibility to transfer material • There must be right resources/equipment available to reduce accidents/injuries	Seppänen and Peltokorpi, 2016; Arbetsmiljöverket; Ekeskär and Rudberg, 2016; Lundesjö, 2015; Thunberg, 2016;
Planning and coordination	• Planning and coordination can reduce the risk of accidents • Planning and coordination increase the ability to finish projects on time • Need of planning and coordination is affected by the complexity and number of actors involved in the project • 3PL can help to plan/coordinate	Thunberg, 2016; Faniran et al., 1998; Skjelbred et al., 2015; Frödell et al., 2008; Seppänen and Peltokorpi, 2016; Faniran et al., 1998; AlSehaimi and Koskela, 2008; Arbetsmiljöverket, 2017; Lundsjö, 2015; González et al., 2014;
Control and overview	• The success of a project it impacted by monitoring and control of the process • Delays often caused by bad oversight and control of the planning • Control of production to avoid problems • Difficult to have control of everyone involved in the construction project	Chua and Kog, 1999; AlSehaimi and Koskela, 2008; Byggkommissionen, 2002; Dubois and Gadde, 2000; Janné, 2018; Sullivan et al., 2010;

	• CCC or checkpoint to control incoming deliveries	
Communication and transparency	• Affects how well the logistics on site works • Affects the possibility to plan and utilize resources • Is essential for a positive progression of the production	Skjelbred et al., 2015; Janné, 2018; Frödell et al., 2008; AlSehaimi and Koskela, 2008; Lange and Schilling, 2015;
Management's and main client's attitude	• The managements attitude affects all contractors attitude • Main contractor/management responsible for coordination on site	Chua and Kog, 1999; AlSehaimi and Koskela, 2008; Frödell et al., 2008;
Climate and weather	• Weather can cause delays and production stops • Material needs to be stored properly	Josephson and Björkman, 2011;
Number of unloading zones	• One or a few unloading zones lead to less deliveries to wrong location	Ekeskär and Rudberg, 2016;
Consolidation and utilization of trucks	• Full trucks shall not be unloaded at a CCC, unnecessary work • Size of the vehicles used affects the possibility to fill trucks and how many transports that is needed • Throughput time/turnover of material • Communication and ability to plan affects the consolidation rate • Full trucks with high turnover is unnecessary to unload at a CCC	Sullivan et al., 2010; Shigute and Nasirian, 2014;

3. Methodology

This chapter presents the research strategy and work procedure of this thesis. The data collection process is explained as well as how the analysis of the data was conducted to be able to present improvement suggestions and identify factors that drive efficiency in the CLS. The chapter is divided into four main parts: Research strategy and work procedure, Data collection, Data analysis and Research quality.

3.1 Research strategy and work procedure

This section presents the research strategy and the work procedure for this study.

To answer the research questions, a literature review, an interview series and a case study were performed. VSM was used to create an overview of the CLS, map activities, analyze if the activities are value-adding or not and to identify factors that affect the CLS. How the different parts of the data collection process have contributed to answering the research questions can be seen in Figure 16.

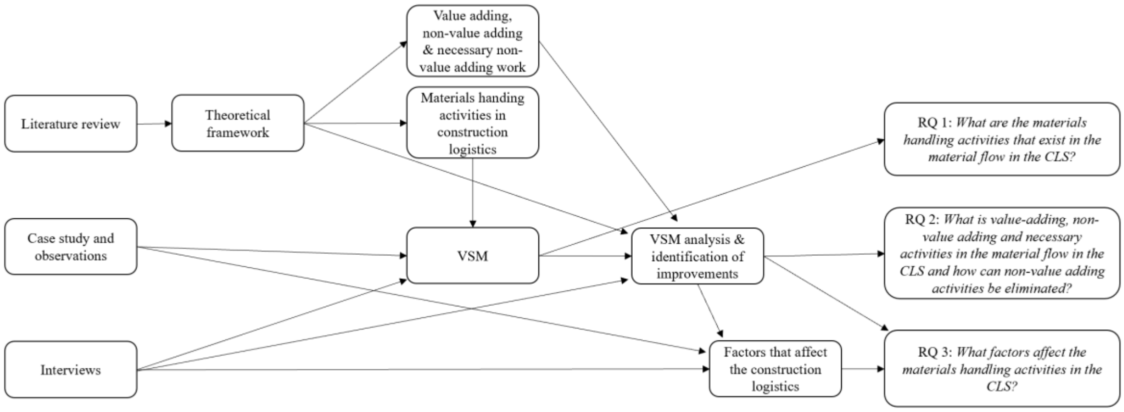

Figure 16: An overview of how the literature review, the case study and observations and the interviews have contributed to answering the research questions.

A case study with real-life observations was performed in order to understand the setup and the details of the CLS properly. Since the CLS only was used in one construction project at the time when this master thesis was carried out, a single case study was accomplished. The studied case used all parts of the CLS: the IT-system, the 3PL and the CCC, and was therefore evaluated as a suitable reference case. To study how the CLS works in real life was crucial to understand the material flow and the informational exchange in detail. To establish an overview of the CLS, process maps of the current state were drawn. This enabled the possibility to identify the materials handling activities in the CLS, categorize the activities into value-adding, non-value-adding and necessary, and identify factors impacting these activities. To get enough information about the CLS and to get insight about why activities are performed, the authors both observed and asked questions during the case study. How the mapping processes and the case study was carried out is presented further in Section 3.2.3 *Case study*.

Interviews were conducted to understand how to do adapt the VSM to a logistics process instead of a production process and what data that could be of interest to gather. The interviews helped to understand why some activities are performed and to identify factors that affect construction logistics. The persons interviewed and how these interviews were conducted is presented in Section 3.2.2 *Interviews.*

A literature study was performed to create the theoretical framework, which includes information about common problems in the construction industry and in construction logistics; factors that affect the logistics; different logistics setups that can be applied; lean production and value stream mapping. The theoretical framework was used to answer all three research questions. How the theoretical framework was created and used is presented in Section 3.2.1 *Literature review.*

Before the research work started, a structured plan for the work procedure was created in form of a network diagram, see Figure 17. The network diagram visualizes the work sequences of this study and how the different parts are connected.

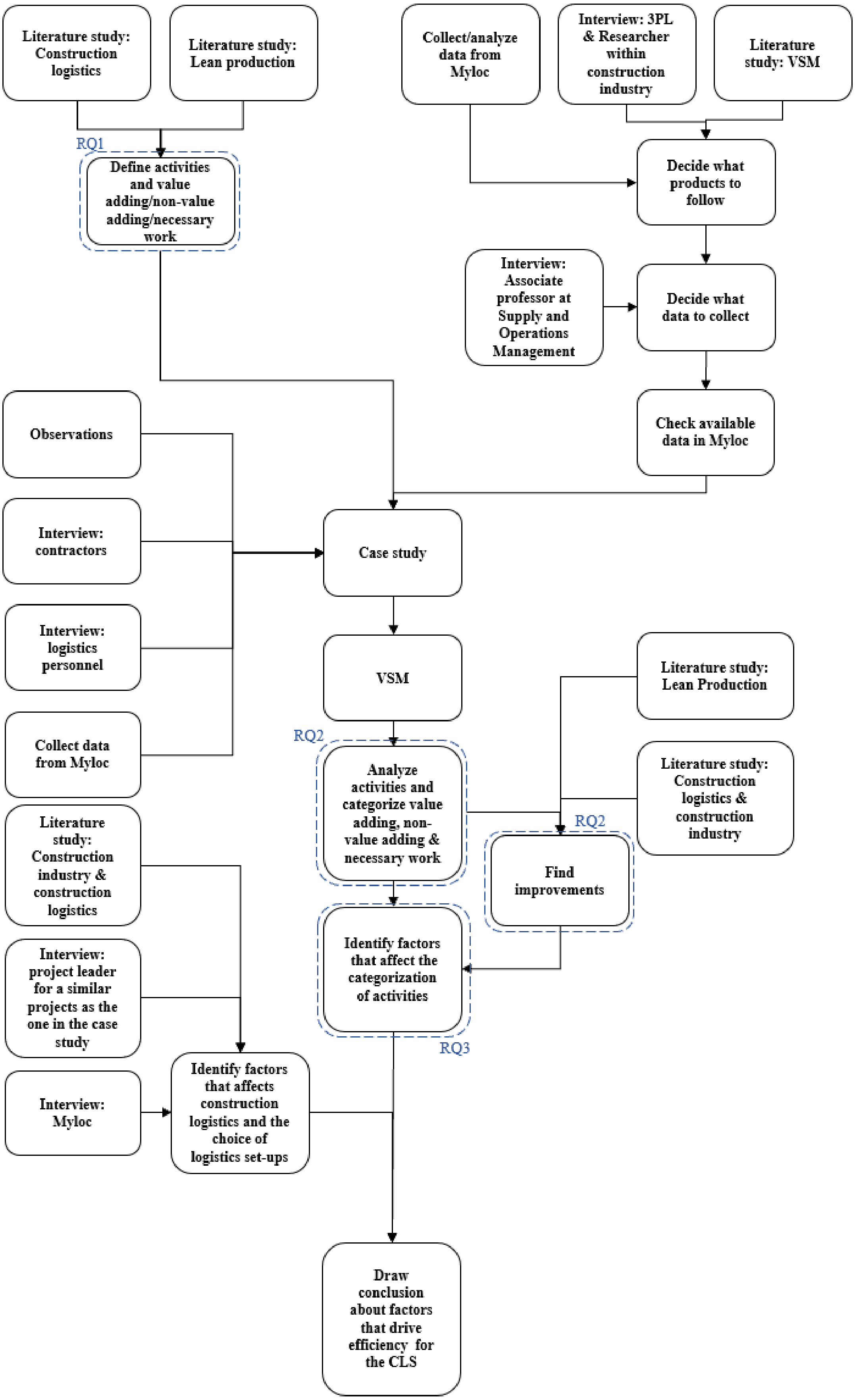

Figure 17: An overview of the work procedure.

3.2 Data collection

This section presents the data collection process in this study. The section is divided into three main parts: Literature review, Interviews and Case study.

Triangulation has been used for the data collection and consists of a literature study, interviews and a case study with observations. Collecting data in three ways enabled the possibility to check and compare answers and information, to determine if the information was trustworthy or not. The triangulation was mostly addressed to identify factors, for the VSM analysis and to find areas of improvements, which is presented further in Section 3.3 *Data analysis*. The information gathered during the data collection created the foundation for the results and made it possible to answer the research questions.

3.2.1 Literature study

A literature study was performed to create the theoretical framework of this study. The focus was to increase knowledge about the construction industry, construction logistics, factors that affect construction logistics, lean production principles and VSM methodology. Main databases that was used for the search was: Chalmers online library, Google Scholar, Scopus, IGCL database and DiVA. Information about regulations was mainly received from Arbetsmiljöverket's webpage and at the European Union webpage. The physical library at Chalmers was used for printed literature. Papers that were considered relevant had a connection to: construction logistics, lean construction, the reference case involving a 3PL and a CCC, VSM for logistic processes or factors affecting the construction work or construction logistics.

Keywords used during the search were: *construction logistics*, *lean construction*, *construction logistics center*, *consolidation center*, *3PL*, *3PL in construction industry*, *lean production*, *value stream mapping*, *value stream mapping in construction industry*, *construction logistics* and *construction logistics solution*. When searching with keywords, a screening was conducted to be able to determine if these articles could be useful. After that first screening, the articles that were relevant for this project were selected and read more carefully. Abstracts were reviewed in order to decide if an article was applicable or not. Reference lists were investigated in order to find additional literature within the area for further research.

The collected information was divided into four main areas: Construction industry, Construction logistics, Lean production and Value Stream Mapping. To gain insight about the culture in the construction industry was crucial to identify factors that affect construction logistics and to increase knowledge about how to gain acceptance among contractors. All factors identified in literature were compared to the factors intercepted during the case study, which facilitated the possibility to draw conclusions about which factors that drive efficiency for the CLS.

Theory about construction logistics and different construction logistic setups was used to find areas of improvement for the CLS and to compare the factors identified in the studied case with the factors identified in literature. The theory about lean production and VSM were used for preparations and execution of the mapping process.

3.2.2 Interviews

In this study, interviews were conducted to gain knowledge about how to perform a VSM for a materials handling process, the CLS and the current situation at the reference case, areas of improvement, and factors that has an impact on HATS activities. Table 3 shows the areas of expertise of the interviewees and to what part of the project the interviewee has contributed. No material supplier was interviewed. Two suppliers were asked to participate, but both declined the request. All interviewees that participated in this master thesis have been kept anonymous, to increase the possibility that areas of concerns would be raised.

Interviews can provide insight about the situation, but it is time-consuming, both the preparations and the analysis, and the interviewer can affect the answers undesirably (Denscombe, 2010). In this study, some interviews were conducted face-to-face while some were performed via Skype, due to long distances.

All interviews in this study were semi-structured. Semi-structured interviews are flexible and give the interviewee the possibility to speak freely and develop ideas along the way, but still follow a list of questions and problems that the interviewer want to cover (Denscombe, 2014). To prepare questions in advance made it possible to define the goal of the interview and to create questions appropriate for the interviewee’s field of interest, which is highlighted as important by Fowler (1995). The interview guide for the 3PL personnel can be seen in Appendix A. The prepared questions for the 3PL personnel were the same regardless on if it was personnel working at the construction site or at the CCC. This saved some preparation time before the interview and ensured that the same information was gathered from the different actors. The interview guide for entrepreneurs working at the construction site can be seen in Appendix B. The interview guide used for Myloc and the interview guide used for the interview with a project leader for the similar construction project can be seen in Appendix C and D.

After each interview, a summary was sent to the interviewees that wanted this, to ensure that the answers had been noted correctly by the interviewers. Yes and no questions were avoided to best possible extent, to not disturb the flow of interview (Berlin and Adams, 2017; Fowler, 1995).

Table 3: Summary of the interview series.

Person interviewed	Interview date	Interview type	Area of contribution
3PL personnel working with materials handling at the construction site (case study)	2019-02-19	Skype	• Preparation for case study • VSM
Researcher/professor within construction industry	2019-03-01	Skype	• Preparation for case study • VSM
Associate professor at Supply and Operations Management	2019-03-12	Physical	• VSM • Improvements of current state
3PL personnel working with the materials handling at the CCC (case study)	2019-03-27	Physical	• VSM • Improvements of current state
3PL personnel working with the materials handling at the construction site (case study)	2019-03-28	Physical	• VSM • Improvements of current state • Factors affecting the CLS
Contractor (case study): project leader	2019-03-28	Physical	• Improvements of current state • Factors affecting the CLS
Contractor (case study): production manager and team leader	2019-03-28	Physical	• Improvements • Factors affecting the CLS
Project leader for a construction project on a similar project as the case study	2019-04-03	Physical	• Factors affecting construction logistics
3PL personnel working with materials handling at the construction site and at CCC (case study)	2019-04-05	E-mail	• VSM
Product owner of Myloc applications	2019-04-08	Skype	• Factors affecting construction logistics

Factors that can affect the interviewees answers undesirably are the interviewer's age, gender or accent. To reduce the risk of this, the interviewer needs to think of what clothes to wear and to stay neutral to statements being made during the interview (Denscombe, 2014). For those interviews that were conducted face-to-face, clothing and facial expressions during the interview were considered. The interviewers were wearing jeans, t-shirt and winter jackets to not stand out. The way questions are asked can largely influence the answers given in an interview, generally it is important to talk less and listen more as well as talking about the customer's problems instead of possible solutions or ideas (Fitzpatrick, 2013). It was important to mediate that the aim of the interviews was to gain knowledge about construction logistics and to collect areas of concern from the interviewees. The focus during the interviews was to listen a lot and absorb as much information and standpoints as possible. In the beginning of each interview, the researchers presented themselves, the aim of the interview and how the information would be used. The question was raised if it was okay to take notes. The interviews were not recorded, due to personal integrity for the interviewee, and taking notes was considered being sufficiently to collect all information needed.

It was important to get the point of view of the people working with the CLS and was therefore of great importance to make the interviewee feel comfortable enough to tell their truth. It is of great significance that the people being observed or interviewed, would not be mistreated and that they understand that they have the possibility to decline to participate or to answer (Berlin and Adams, 2017). Personal integrity had to be respected and answers could not be pushed by the researchers.

3.2.3 Case study

The case that was studied in this project was the reconstruction of Norrland's University hospital (NUS) in Umeå, where ÅF has the overall responsibility for the construction logistics. This project was as a good reference case since it is was the only ongoing project where the CLS was used at the time of this master thesis project. It contained all parts of the CLS: IT application for bookings, communication and tracking of parcels; a CCC for intermediate storage; a 3PL provider that is responsible for all operative work, the resources for unloading at the unloading zone and the carry-in services. Some suppliers were connected to the CLS and all three delivery planning approaches were evaluated in this project, which made it possible to see how these affected the HATS activities and the information flow.

Denscombe (2014) explains that the aim of a case study is to investigate and discover not only what goes on in the current situation but to understand why things occur, to understand the complexity of the situation and the interplay between relationships and processes. A case study can help to explore problems and opportunities with the current situation as well as explain different outcomes and happenings. The analysis can be used to make assumptions of what is happening and why. In this project, the case study and the observations aimed to provide an understanding of the current situation of the CLS and how different factors affect the logistics setup and decisions made in the material handlers daily work. The case study helped to understand the connections between the material and information flow, which enabled the possibility to draw the current state maps. It further helped to identify improvements and factors that affect the construction logistics and drive efficiency. An analyze and discussion about for what other types of projects the CLS could work was performed based on the case study and the theoretical framework.

3.2.3.1 Value Stream Mapping of current state

VSM was used to create the current and future state maps. VSM visualizes both the material flow and the information flow (Rother and Shook, 2001). The current state maps were used to find areas of improvement. By analyzing the process maps and identify problem areas it is possible to examine how these affect the performances (Keyte and Locher, 2016). The first step in the VSM process is to choose the scope of the value flow and to choose which product family to follow (Keyte and Locher, 2004). Before the product family could be chosen, the customer had to be determined, both the internal customer and the external customer, which is an important aspect in the lean methodology (Liker, 2004). Since there are many different actors involved in the construction industry (Ekeskär and Rudberg, 2016) there are a lot of potential customers. To determine who the customers is, a discussion was carried out together with ÅF and a professor in supply and operations management. It was decided that the internal customers in the reference case are the 3PL personnel and the external customers are the entrepreneurs that have ordered the material and the client. The client’s requirements were used for the categorization of the activities, which will be presented in Section 3.3 *Data analysis.*

When determining what flow to follow, it is common to choose the most expensive products in the flow or products that have a large portion of the total volume. For this case, the chosen scope can be seen in Figure 18. The scope included the three types of delivery planning approaches that are available in the current CLS, which are presented further in Chapter 4. *Current state,* as well as the two possible ways the material be transported, direct delivery to the construction site or via the CCC. This scope made it possible to compare the different planning approaches and delivery paths, to see differences in HATS activities, and how the categorization of value-adding, non-value-adding and necessary work differs.

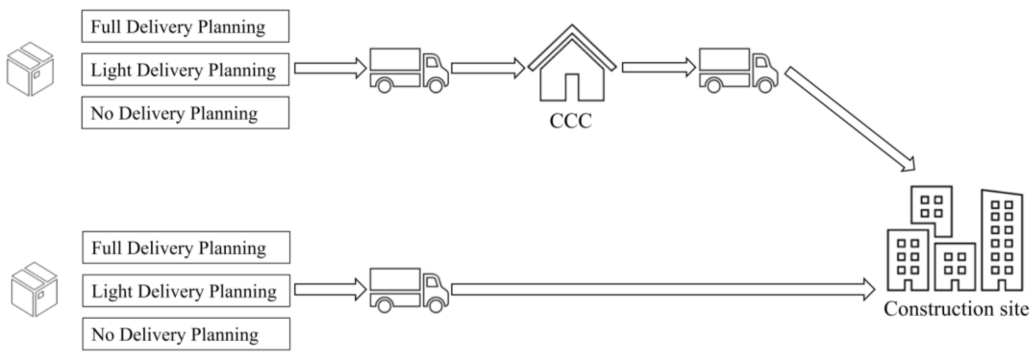

Figure 18: Scope of the value flow for the studied case. Three types of delivery planning approaches have been considered, as well as the flow through the CCC and direct transportation to the construction site.

It was not possible to map all products that pass through in the material flow, and therefore a product family had to be chosen. A product family is a group of products that passes through the processes in the scope on its way to the customer and should be chosen based on the customer's perspective (Rooth and Shook, 2004). In this case, two different products were followed: plywood and ventilation parts. Plywood is delivered on pallets while ventilation parts are often delivered in packages. The choice was based on answers and discussions from interviewees and collected data from Myloc. The two product families follow the chosen scope, comprise a large part of the total volume of material in the material flow, are handled in two different ways due to differences in the wrapping and covers the three different planning approaches. Both plywood and ventilation are commonly used material in all types of construction projects and were therefore seen as favorable to follow to be able to find improvements and factors that are useful for other construction projects as well and not only for the reference case that was studied.

3.2.3.2 Observations

As described by Denscombe (2010), humans tend to interpret things differently and forget what has been observed. It is therefore of great importance to ensure that the observers know what to look for and to systematically record the data in detail. Before the case study, data collection forms were created to ensure that all observers knew what to look for and what data and information to record. What information to collect during the case study were decided based on factors presented by Langbeck et al. (2012), see Section 2.4 *Value Stream Mapping.* The information that was documented during the case study was:

- Description of different types of activities e.g. handling, transportation, administration or storage
- Distances
- Equipment used
- Number of personnel required for the activity
- Type of material: plywood (pallet) or ventilation (package)
- Type of delivery planning: no delivery planning, light delivery planning or full delivery planning

All activities were noted in the execution sequence to be able to draw the VSM afterwards. During the visit, the observation team consisted of six people and each person had a specific task and specific information to look for. This did not turn out as expected, two people managed to collect all information while the others took pictures and observed other things such as how things where stored and what wrapping material that was used.

When the case study was carried out, there were no physical flow to follow at the CCC. Instead, the 3PL personnel had to explain each activity of materials handling and administration in detail, for both inbound and outbound deliveries, for all three delivery planning approaches. Even though times were not measured during the case study and are not involved in the process maps, the results from the VSM indicates differences in number of activities, types of activities and amount of value-adding, non-value-adding and necessary work. Distances from outdoor environment were measured with help of www.hitta.se. Distances inside the hospital were not measured since these distances can vary a lot depending on the location of the delivery.

The observations were only carried out during two days for a few hours, one day at the CCC and one day at the construction site at NUS. This affected the data collection and the precision of the information. This was the reason for why a physical flow could not be followed during the observations in the CCC and why time durations could not be clocked. Information that the authors were not sure about after the visit was complemented with questions via emails.

3.2.3.3 Creation of Value Stream Maps

The first VSM drawings were created the day after the case study on a whiteboard with post-it notes. The actual maps were then created with Microsoft PowerPoint. The activities in the process map were drawn in a systematic order, from left to right, as it should be drawn according to Rother and Shook (2001). Figure 19 presents the different symbols that were used in the mapping process.

Figure 19: Symbols used in the VSM mapping.

The material flow at the construction site and the material flow at the CCC were two different flows and were therefore separated and presented in different maps. In total, nine value stream maps of the current state were created, three for the materials handling at the CCC and six for the materials handling at the construction site. This was done in order to show differences between the three delivery planning approaches and differences in the materials handling between pallets and packages.

During the case study, it became clear that the delivery planning approaches have a major impact on the amount of walking for the logistics personnel. Walking was therefor included, except the walking required for the carry-in services, to show how the amount of walking changes dependent on the delivery planning approach. The symbol of a walking person in the maps indicate all times that personnel must walk and fetch equipment or something else in order to progress the logistics work. There are some walking activities that have no associated distance, that is because the distance was not measured during the case study.

3.3 Data analysis

This section describes how the analysis of the data have been carried out.

To answer the first research question, the activities presented in the current state maps were compiled. The summaries give an overview of differences and similarities between the different delivery planning approaches. From this, a HATS analysis was performed which involved a categorization of the activities into handling, administration, transport and storage (Finnsgård et al., 2011). This categorization of the activities was useful to show how many of the activities that are of a certain kind and how these varies dependent on the delivery planning approach. To focus on how many times the activities are performed instead of the time duration were The HATS analysis analyze how many times certain activities are performed instead of focusing on time duration, due to the fact these were difficult to measure. The current state maps and the HATS analysis gave an indication of what activities that could be eliminated.

To answer research question two, the activities established from the current state maps had to be categorize into value-adding, non-value-adding and necessary work. In order to do this, the definitions presented in Section 2.3.4.1 *Customer value in construction logistics* were used together with discussions between the authors.

The definitions put the contractor, who has ordered the material, and the logistics personnel, who is next in line to handle the material, in focus. The definition for necessary and non-value-adding work involves the clients wishes as well. The reason for why the activities were divided into these different categorizations was to see which activities that are pure waste and can be eliminated without affecting the value-adding work, to see where there was a lot of improvement potential. To analyze if an activity was necessary or not helped to contribute to identifying factors that influences the logistics at the NUS project. In the studied case, necessary activities are typically activities that are performed because of the client's requirements or activities that will contribute to that the right information will be available in the IT-system, which is essential for the CLS.

When analyzing the current solution and trying to come up with improvement potentials, the categorization of activities created the base for which activities that were most crucial to improve. Some improvement ideas have been generated based on experience from earlier projects. All areas of improvement could not be found by only studying the current state maps, such as ergonomics, communication, planning and standards etc. These were noticed during observations and analyzed further in the improvement process. The first step in the process of developing a future state and find possible improvements was to work with the questions by Keyte and Locher (2016):

1. What is the customer demand?
2. Which steps and activities are value-adding, and which are waste?
    a. Why is this step or activity performed in the current state?
    b. What can be done differently and still meet the customer demand?
    c. Is the typical order of the steps what generates waste?
    d. Which assumptions are the current work process based on?
    e. Are current guidelines for control and administration suitable?
    f. What knowledge is crucial to perform this step?
3. How would fewer interruptions affect the workflow?
4. How will the interruptions be controlled?
5. How can the activities be levelled?
6. How will the new process be managed?
7. What changes and improvements need to be done in the process to achieve the future state?

Then, improvements were developed based on trying to eliminate the seven types of Muda, non-value-adding waste (Liker, 2004; Keyton and Locher, 2016):

1. *Over-production*: producing more information or service that is needed
2. *Waiting:* customers, information or material waiting to be serviced or worked on
3. *Unnecessary transport*: movement of material or information
4. *Over-processing or incorrect processing*: steps that take longer than they should or entire activities that does not add value for the customer
5. *Excess inventory*: storing more material than needed for longer time than needed
6. *Unnecessary movement*: movement of personnel
7. *Defects or corrections*: any activity that is performed to correct an error that has been made

Only two future state maps were created, one for the CCC and one for the construction site, to visualize possible improvements of the current state. Implementation of suggested improvements is not in the scope of this project and the future state maps will therefore only show the most optimal material flow with the full delivery planning approach.

To answer research question three, information and data from the theoretical framework, the interviews and the observation were compiled. In literature, different factors that both affect the construction progress and the construction logistics were found together with pros and cons of different logistics setups for certain construction characteristics. The factors where noted in a table together with the literature reference and a short explanation of what the factor mean. This table is presented in Section 2.5 *Factors affecting construction logistics*. The knowledge about these factors helped to identify factors for the studied case, analyze the HATS activities and see connections between certain activities and factors. The analyze of the activities helped to provide deeper knowledge about the impact and effect of certain factors.

The factors identified for the studied case, together with a short explanation of how these affect the CLS is presented in Chapter 7. Factors identified in the theoretical framework and in the studied case were compared to gain knowledge about what factors that can affect the CLS in other construction projects.

3.4 Research quality

This section presents a summary of how validity, reliability, generalizability and confirmability of this thesis have been considered during project along with a discussion about it. The summary is based on information presented in the previous sections.

The study is a qualitative study and the methodology is mainly based on interviews and observations instead of calculations and quantifiable results that are used in quantitative studies. The validity of qualitative data is not easy to judge since it cannot be demonstrated that it is correct in the same way that numbers can (Denscombe, 2014). Triangulation was used in this master thesis with three different ways to collect data. This made it possible to check and compare answers and information collected from interviews, literature and observations, to be able to determine the validity of the information. Why some identified factors could not be confirmed with the triangular approach is reviewed in Chapter 7 and 8.

The reliability of a study is related to if the same results and conclusions would have been achieved if someone else collected the data (Denscombe, 2014). As a check on reliability, it is necessary to compare the results with other researchers' findings. Other studies within the area have been considered and observations from the case study have been compared to findings of similar research projects. Improvements and factors that have been found are based on occurrences that happened during the day of the visit, which has affected the result to some extent. If more observations would have been performed, other improvements and factors could probably have been found.

Qualitative research is normally based on a relatively small number of cases and it is therefore important to raise the question about transferability of the study and if the results of the study can be found in similar cases (Denscombe, 2014). An analyze for what other types of projects the CLS would be suitable for was performed based on results from the studied case. Each part of the CLS have been analyzed separately, to raise knowledge about for what other types of projects the CLS could be used for. Literature about logistics in general and results from other studies have been used to increase the transferability of the study.

The objectivity of a research concerns to which extend the results are free from influences of the researches (Denscombe, 2014). The objectivity of the master thesis has been considered since interviews have been conducted with people from different instances and with different roles throughout the whole supply chain in the NUS project and other projects. Data has been confirmed by different people and different point of views have been considered. Material suppliers have not been interviewed, which is a weakness in this thesis. The lack of insight of the material suppliers' point of view and opinions about the CLS made it difficult to suggest improvements that would be beneficial for the material suppliers. A summary of the answers from interviews was sent to the interviewees to ensure that their answers has not been influenced.

4. Current state

This chapter presents the current state of the CLS in the construction project at NUS. The case is described in detail and the data that has been collected during the VSM process is presented. The information presented in this chapter is used to answer all three research questions.

4.1 Construction logistics solution at Norrland's university hospital

This section presents how the different parts of the CLS works and how these are used at the reconstruction project at NUS. This section gives the background information for the current state maps presented in Section 4.2 and the suggested improvements presented in Chapter 6.

NUS is one of the largest hospitals in Sweden and is ongoing a renovation that is planned to be finished in 2020. Several buildings of the hospital will be renovated, and the construction is integrated in the hospital business, as can be seen in Figure 20.

Figure 20: An overview of NUS. Buildings marked in green will be renovated or rebuilt.

The county of Västerbotten is the client of the construction project and to be able to accomplish the renovation without interfering with the ongoing activities at the hospital, ÅF has been hired to take responsibility for the logistics of the project. ÅF has implemented the CLS at the reconstruction of NUS and the aim is to coordinate all different material flows, deliver material JIT to the construction site and minimize disturbance of the ongoing hospital business. Figure 21 shows an overview of the main parts that are included in the CLS at the construction project at NUS.

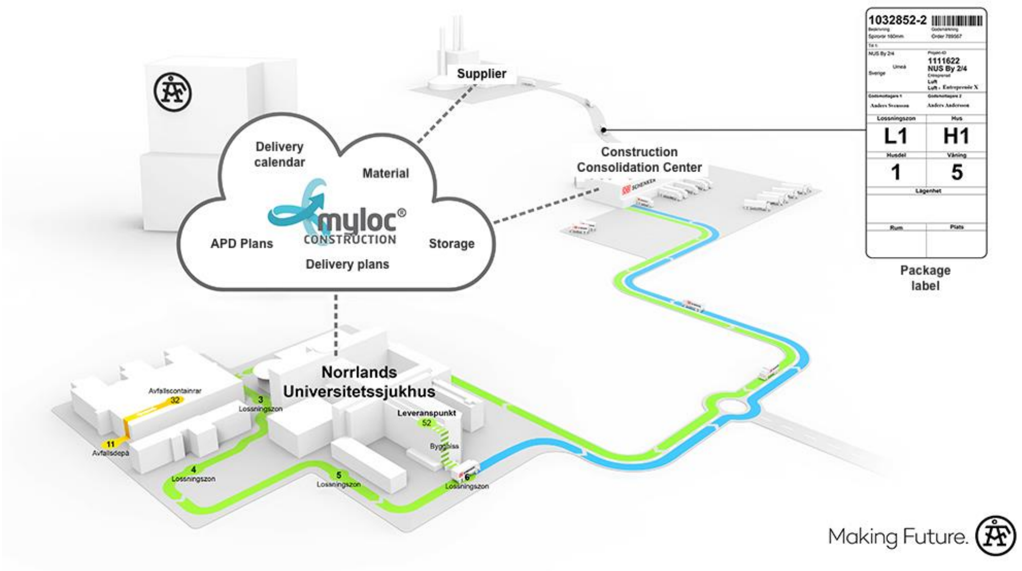

Figure 21: The parts of the CLS used at the construction project NUS.

The parts of the CLS at NUS that are within the scope of this thesis are:

- ÅF, that is the project manager of the CLS.
- An IT-system provided by Myloc.
- A CCC located 15 minutes from NUS.
- A 3PL, DB Schenker, which is responsible for all operational logistics activities at the CCC and at the construction site.

The CLS can lead to increased sustainability in the construction project within three areas: economic, social and environmental sustainability. From an economical point of view, the CLS can decrease time spent on handling materials by increasing efficiency of the logistic processes. Better planning and coordination lead to that less time is wasted on non-value-adding activities such as waiting. The use of a CCC can increase the environmental sustainability if material is being consolidated, since the number of transports arriving to the construction site will be reduced. From a social point of view, the CLS contribute to increasing sustainability by making sure that the construction project does not disturb the hospital staff nor the patients.

4.1.1 The IT-system in the construction logistics solution

Myloc is the technical information system that is being used for communication between different actors in the CLS. It is the platform where all planning and booking of material deliveries take place. The parts of Myloc that are being used are:

- Online calendar that is visible for all actors that are involved in the project.
- Delivery planning tool for entrepreneurs and suppliers. The entrepreneurs plan and book material deliveries in Myloc. The DB Schenker personnel can accept bookings or reschedule if the material cannot be delivered at the desired time. Suppliers can use Myloc to add the right information about the material to the system.

- Booking of resources for unloading, at the unloading zone, and carry-in material to a specific delivery point at the hospital, specified by the entrepreneurs.
- Entrepreneurs can call off material from the CCC when it is needed.
- Scanning of labels, provides the possibility to track parcels and to know where material should be delivered.

The online calendar is used as the main tool to book and plan material deliveries in the current logistic solution. It is visible for all actors that are involved in the project, but the entrepreneurs can only see their own bookings and their own projects. The aim of the logistic solution is that entrepreneurs and suppliers will use Myloc by registering all orders and all information needed in the system, e.g. type of material, volume and weight. When the entrepreneurs know approximately how much material they need, and at what time, they create a forecast plan in Myloc to increase the level of planning. This makes it easier for DB Schenker personnel and suppliers to plan their work and create forecasts of material demand. When the entrepreneurs know exactly what they need and at what time, they call-off material from the supplier or from the CCC. ÅF has decided that this must be done at least 24 hours before the material is needed. The entrepreneurs can decide if material should be delivered to the CCC or directly to the construction site at NUS and if the material should be delivered to the right delivery point at the construction site or if they want to go and collect it at the unloading zone. The unloading zones is the stars (L-marks) in Figure 22. DB Schenker personnel can control and level the material flow by rescheduling bookings and suggest new delivery times.

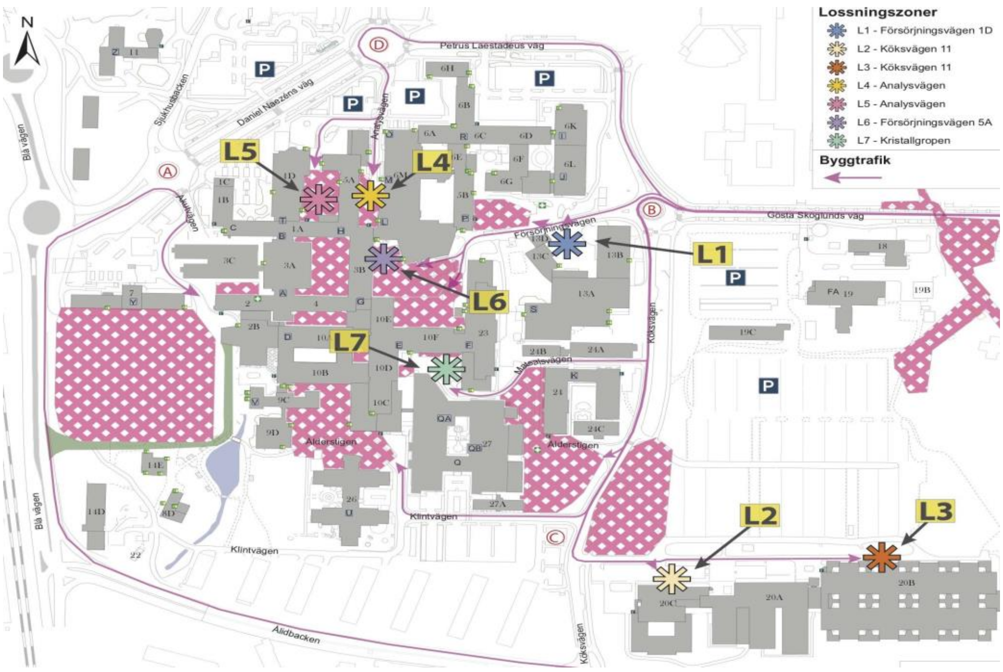

Figure 22: The stars represent the unloading zones for material deliveries at NUS. The pink areas represent construction areas at NUS.

4.1.2 Delivery planning approaches

In most construction projects, material is being delivered to the construction site unannounced. To avoid this from happening, ÅF has started to include material suppliers into the CLS and has developed two delivery planning approaches: full delivery planning and light delivery planning.

Three of the largest material suppliers at the construction projects at NUS are connected to Myloc and are using full delivery planning. Full delivery planning means that when the entrepreneurs have placed an order from the supplier, the suppliers register the order in Myloc, pack the order and print a package label from Myloc that corresponds to the information in the system. Full delivery planning facilitates the work for DB Schenker operators since the package label only needs to be scanned to attain all necessary information about the delivery, e.g. who has ordered it and where it should be delivered.

If a supplier is not connected to Myloc, another approach can be used that is called light delivery planning. Light delivery planning implies that when the entrepreneurs place an order at a material supplier, they simultaneously register a booking in Myloc and get a booking number that is sent to the supplier. This booking number is then attached to the parcel. By registering the booking in Myloc and adding the booking number to the parcel, DB Schenker operators can search for the code in Myloc and find all necessary information. When entrepreneurs and suppliers do not use any of these two delivery planning approaches, material is usually delivered unannounced to the construction site. This is referred to as no delivery planning. No delivery planning requires a lot of time spent on administrative work, such as tracking the parcel, calling entrepreneurs and trying to find out who has ordered the material, when it is needed and to what location it should be delivered.

The material studied in this project was plywood and ventilation. Plywood is being delivered by light delivery planning or no delivery planning, while ventilation can be delivered by full delivery planning, light delivery planning or no delivery planning.

4.1.3 Material handling at the Construction Consolidation Center

Entrepreneurs can order material to the CCC, where it can be stored until it is needed in the construction project. The CCC can be used as a buffer, to store construction material there instead of at the construction site where space is limited. The CCC is located about 15 minutes from NUS, in connection to DB Schenker's main logistic terminal in Umeå. Construction material can be stored in two available areas:

- Indoor storage (CCC warehouse)
- Outdoor storage (CCC tent)

Two times a day, material that has been called-off is packed at the CCC and then delivered with a milk run truck to NUS with tools and additional packages that are picked up at local suppliers on the way to the construction site.

4.1.4 Material handling at the unloading zone at the construction site

Material can be delivered directly from the suppliers or from the CCC to the construction site. Most material arrive at unloading zone L1, see Figure 22. The layout of unloading zone L1 can be seen in Figure 23. When material arrive at L1, DB Schenker personnel unload the material with a forklift truck, see Figure 24, and place it in a tent at the unloading zone, where sorting of packages takes place. Material is first being sorted based on the entrepreneur that has ordered it, and then based on delivery point at the hospital.

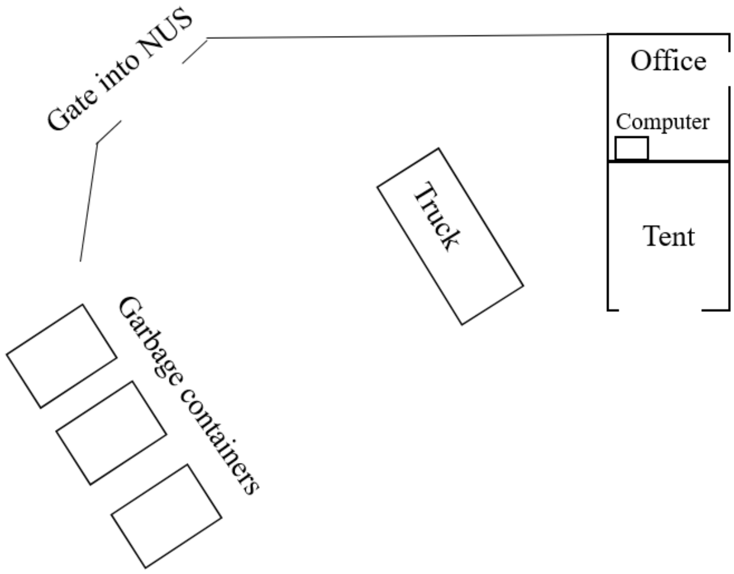

Figure 23: Layout of unloading zone L1 at NUS.

Figure 24: Material is being unloaded at the unloading zone L1.

4.1.5 Material deliveries to the delivery points at the construction site

When material has been sorted, it is transported to the gate into NUS by forklift, see Figure 23. At the gate, material is loaded onto a hand-pallet truck and then it is transported through the culverts of NUS, as can be seen in Figure 25, to the delivery point decided by the entrepreneurs. One of the delivery points at NUS can be seen in Figure 26. NUS is a large hospital and the distances between unloading zone L1 and some of the delivery points are long. Because of the ongoing hospital business, some walkways and elevators can only be used at certain times. DB Schenker personnel is currently estimating one carry-in delivery to take up to 45 minutes and it usually requires two people to handle bulky and heavy material.

Figure 25: Personnel from DB Schenker transports material to the delivery point, through the culverts of NUS.

Figure 26: One of the delivery points at NUS.

4.2 Current state Value Stream Map

This section presents the current state maps of the material flow at the construction site at NUS and at the CCC. This section helps to answer all three research questions.

The data that has been collected during observations have been used to create current state maps. The activities presented in the maps will be summarized and analyzed further in Chapter 5 and 6. Nine maps have been drawn, three of which are presented in Figure 27, Figure 28 and Figure 29. The maps give an indication of the complexity of the material and informational flow and visualizes how these are connected. The maps show the activities in the execution sequence, the distances, operators needed for each task, and differences in activities between packages and pallets. All nine current state maps can be seen in Appendix E, F and G.

Plywood is delivered in bundles or pallets, while ventilation parts are delivered in packages. This affects the HATS activities at the construction site at NUS, see Figure 27 and Figure 28. The red cross in Figure 28 visualize that one sorting activity is not being performed when handling pallets instead of packages at the construction site.

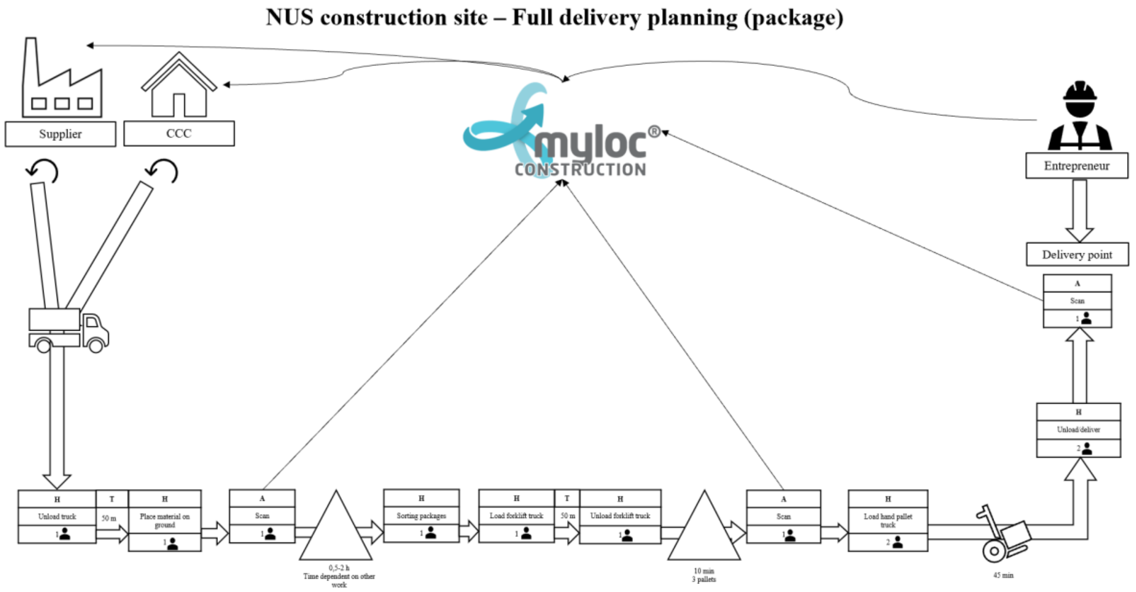

Figure 27: VSM of material flow at the construction site at NUS with full delivery planning (packages).

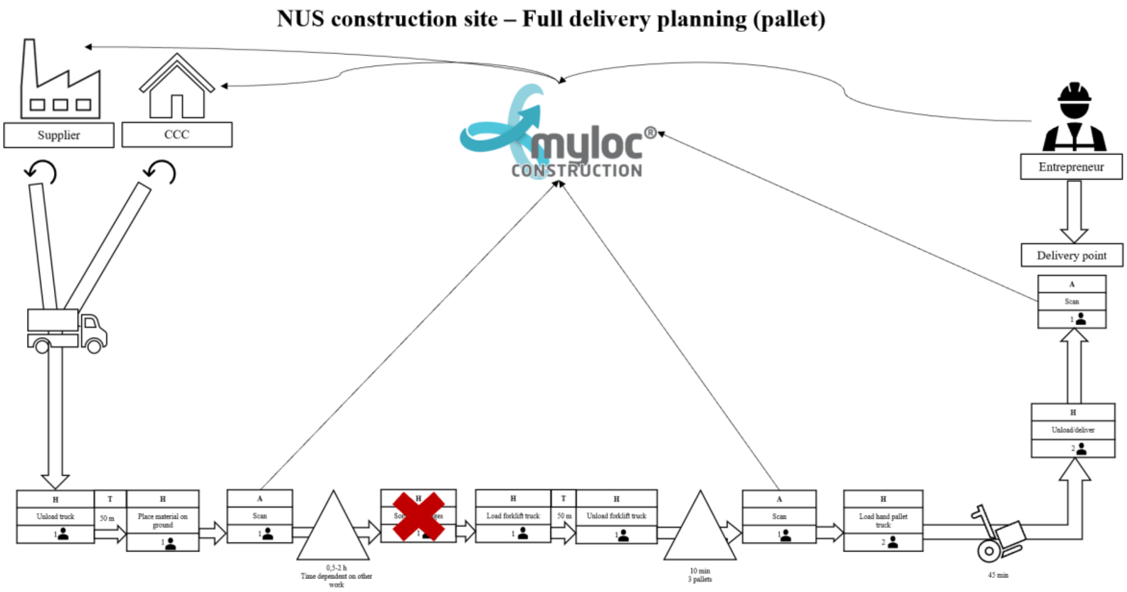

Figure 28: VSM of material flow at the construction site at NUS with full delivery planning (pallets). The red cross visualizes the sorting activity that is not performed when handling a pallet instead of a package.

At the CCC, the material can be stored outdoors in the CCC tent or indoors in the CCC warehouse. At the CCC warehouse the material can take two different routes until it is stored. The route to and at the CCC tent is the route at the bottom in Figure 29.

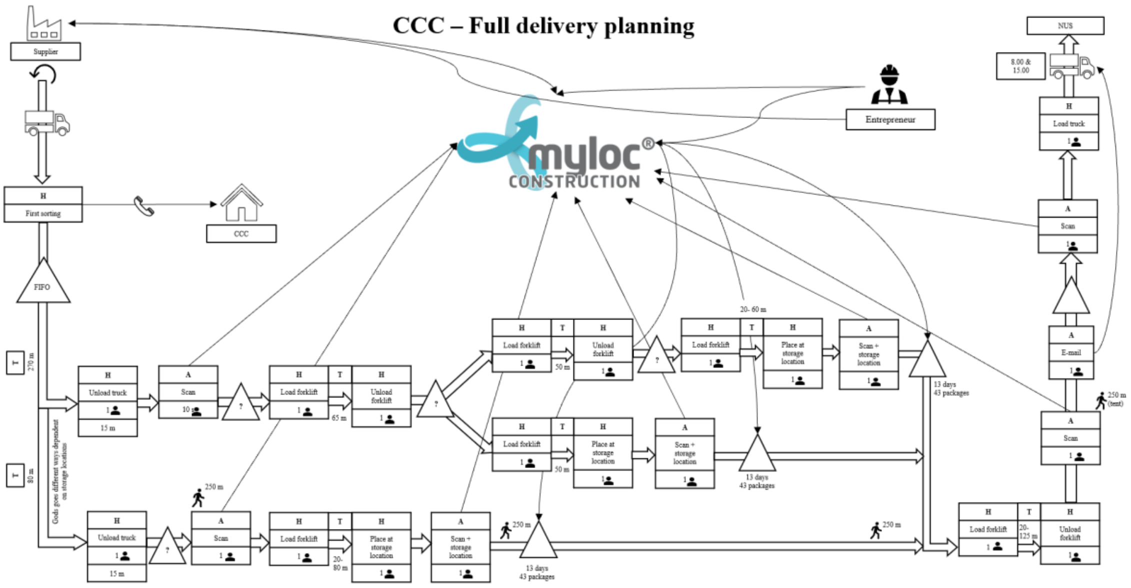

Figure 29: VSM of CCC with full delivery planning.

5. Materials handling activities

This chapter aim to answer research question one by presenting the activities identified during the VSM process. The presentation of the activities is followed by a HATS analysis.

RQ 1: What are the materials handling activities that exist in the material flow of the CLS?

Table 4, Table 5 and Table 6 summarizes the activities in the material flow at the construction site at NUS and at the CCC. The tables show the frequency of each activity for the three delivery planning approaches. The activities are not stated according to the execution sequence. The summaries are based on the current state maps, presented in Chapter 4 and in Appendix E, F and G.

Table 4: Summary of activities at NUS for all three delivery planning approaches. The summary is based on the activities performed to handle one package. For deliveries of pallets, the sorting activities are not performed.

NUS - Construction site								
Full delivery planning			Light delivery planning			No delivery planning		
Type of activity	Activity	No. of times performed	Type of activity	Activity	No. of times performed	Type of activity	Activity	No. of times performed
S	Storage	2	S	Storage	2	S	Storage	2
T	Transportation of material	3	T	Transportation of material	3	T	Transportation of material	3
H	Load	2	H	Load	2	H	Load	2
H	Unload	4	H	Unload	4	H	Unload	4
H	Sorting	1	H	Sorting	2	H	Sorting	2
A	Scanning	3	A	Scanning	3	A	Scanning	3
			A	Search for delivery part	1	A	Search for delivery part	1
			T	Walk to office	1	T	Walk to office	1
			T	Walk from office	1	T	Walk from office	1
			A	Print label	1	A	Print label	1
			A	Label package	1	A	Label package	1
			A	Check delivery note	1	A	Check delivery note	1
			A	Add infomartion	1	A	Track package	1
						A	Create parcel in Myloc	1
Total		15			23			24

There are significant differences between the delivery planning approaches regarding number of activities performed. Full delivery planning requires the least number of activities and no delivery planning requires the largest number of activities.

Table 5: Summary of activities at CCC warehouse for all three delivery planning approaches. The summary represents the activities needed to handle one package that takes to longest route in the CCC warehouse.

CCC - Warehouse								
Full delivery planning			Light delivery planning			No delivery planning		
Type of activity	Activity	No. of times performed	Type of activity	Activity	No. of times performed	Type of activity	Activity	No. of times performed
H	First sorting	1	H	First sorting	1	H	First sorting	1
S	Storage	6	S	Storage	6	S	Storage	6
T	Transportation of material	5	T	Transportation of material	5	T	Transportation of material	5
H	Load	5	H	Load	5	H	Load	5
H	Unload	5	H	Unload	5	H	Unload	5
A	Scan	4	A	Scan	4	A	Scan	4
A	E-mail	1	A	E-mail	1	A	E-mail	1
A	Phone call to CLC	1	A	Phone call to CLC	1	A	Phone call to CLC	1
			A	Check delivery note	1	A	Check delivery note	1
			A	Search for delivery part	1	A	Search for delivery part	1
			T	Walk to computer	1	T	Walk to computer/officee	2
			A	Print label	1	A	Print label	1
			T	Walk to packages	1	T	Walk to packages	2
			A	Label package	1	A	Label packages	1
			A	Add infomartion i Myloc	1	A	Register in Myloc	1
						A	Track package	1
						A	Note package information	1
Total		28			35			39

Table 6: Summary of activities at CCC tent for all three delivery planning approaches. The summary represents the activities needed to handle one package that takes to longest route in the CCC tent.

CCC - Tent								
Full delivery planning			Light delivery planning			No delivery planning		
Type of activity	Activity	No. of times performed	Type of activity	Activity	No. of times performed	Type of activity	Activity	No. of times performed
H	First sorting	1	H	First sorting	1	H	First sorting	1
S	Storage	3	S	Storage	4	S	Storage	4
T	Transportation of material	3	T	Transportation of material	3	T	Transportation of material	3
H	Load	3	H	Load	3	H	Load	3
H	Unload	4	H	Unload	3	H	Unload	3
A	Scan	4	A	Scan	4	A	Scan	4
A	E-mail	1	A	E-mail	1	A	E-mail	1
A	Phone call to CLC	1	A	Phone call to CLC	1	A	Phone call to CLC	1
T	Walk to tent	2	A	Check delivery note	1	A	Check delivery note	1
T	Walk from tent	2	A	Search for delivery part	1	A	Search for delivery part	1
			T	Walk to tent	3	T	Walk to tent	4
			A	Print label	1	A	Print label	1
			T	Walk from tent	3	T	Walk from tent	4
			A	Label package	1	A	Label packages	1
			A	Add infomartion i Mylo c	1	A	Register in Myloc	1
						A	Track package	1
						A	Note package information	1
Total		24			31			35

The results from the HATS-analysis can be seen in Table 7, Table 8 and Table 9. Most of the performed activities are handling and administrative activities. The number of administrative activities varies the most between the delivery planning approaches, both at the construction site at NUS and at the CCC. Even though it only differs one activity between light and no delivery planning at the construction site, this extra activity can mean up to 30 min extra work. Material that arrive at the CCC and at the construction site with no delivery planning can take up to 30 minutes extra to handle compared to full and light delivery planning since DB Schenker personnel might have to call entrepreneurs and track parcels.

Table 7: HATS-analysis and summary of activities at NUS.

NUS - Construction site	Full delivery planning	Light delivery planning	No delivery planning
Handling	7	8	8
Administration	3	8	9
Storage	2	2	2
Transport	3	5	5
Total	**15**	**23**	**24**

Table 8: HATS-analysis and summary of activities at CCC warehouse.

CCC - Warehouse	Full delivery planning	Light delivery planning	No delivery planning
Handling	11	11	11
Administration	6	11	13
Storage	6	6	6
Transportation	5	7	9
Total	**28**	**35**	**39**

Table 9: HATS-analysis and summary of activities at CCC tent.

CCC - Tent	Full delivery planning	Light delivery planning	No delivery planning
Handling	7	7	7
Administration	6	11	13
Storage	4	4	4
Transportation	7	9	11
Total	**24**	**31**	**35**

Packages and pallets are transported the same routes and placed in the same intermediate storages independent of the delivery planning approach, see Appendix E, F and G. The variation of transportation and administrative activities between the delivery planning approaches are due to extra walking for the personnel and that information needs to be tracked or added in the IT-system when material is delivered with no or light delivery planning.

6. Value-adding, non-value-adding and necessary activities

This chapter aims to answer research question two by presenting the categorization of identified HATS activities, and the identified areas of improvement for the current state. The chapter is divided into four parts: Categorization of materials handling activities, Elimination of non-value-adding activities, Improvements based on lean production principles and Long-term improvements for the construction logistics solution.

RQ 2: What is value-adding, non-value-adding and necessary activities in the material flow in the CLS and how can non-value-adding activities be eliminated?

6.1 Categorization of materials handling activities

This section presents the categorization of the activities identified in the current state maps. The categorizations are based on definitions stated in Section 2.3.4.1 Customer value in construction logistics.

Table 10, Table 11 and Table 12 presents the categorization of the activities at the construction site at NUS, at the CCC warehouse and at the CCC tent. The activities have been divided into value-adding (VA), non-value-adding (NVA) and necessary non-value-adding (NNVA). Complete tables can be seen in Appendix H and I.

Table 10: Categorization of HATS activities handling a package at the construction site at NUS for all three planning approaches.

NUS - Construction site									
	Full Delivery Planning	**HATS**	**Value**	**Delivery Planning Light**	**HATS**	**Value**	**No Delivery Planning**	**HATS**	**Value**
1	Unload Truck	H	NNVA	Unload Truck	H	NNVA	Unload truck	H	NNVA
2	Drive to tent	T	NVA	Drive to tent	T	NVA	Drive to tent	T	NVA
3	Place material on ground	H	NVA	Place material on ground	H	NVA	Place material on ground	H	NVA
4	Scanning	A	NNVA	Sorting of packages	H	NVA	Sorting of packages	H	NVA
5	Sorting packages	H	NVA	Check delivery note	A	NNVA	Check delivery note	A	NNVA
6	Storage	S	NNVA	Storage	S	NNVA	Storage	S	NNVA
7	Load forklift truck	H	NNVA	Walking to office	T	NVA	Walk to office	T	NVA
8	Drive to gate	T	VA	Search for delivery part	A	NNVA	Search for delivery part	A	NNVA
9	Unload forklift truck	H	NVA	Add information in Myloc	A	NNVA	Track package	A	NVA
10	Storaga	S	NVA	Print label	A	NNVA	Register i Myloc	A	NNVA
11	Scanning	A	VA	Walking from office	T	NVA	Print label	A	NNVA
12	Load hand pallet truck	H	NVA	Label package	A	NNVA	Walk from office	T	NVA
13	Transport delivery point	T	VA	Scanning	A	NVA	Label package	A	NNVA
14	Unload	H	VA	Sort packages before delivery	H	VA	Scanning	A	NVA
15	Scanning	A	VA	Load forklift truck	H	NNVA	Sort packages before delivery	H	VA
16				Drive to gate	T	VA	Load forklift truck	H	NNVA
17				Unload forklift truck	H	NVA	Transportation	T	VA
18				Storage	S	NVA	Unload forklift truck	H	NVA
19				Scanning	A	VA	Storage	S	NVA
20				Load hand pallet truck	H	NVA	Scanning	A	VA
21				Transport delivery point	T	VA	Load hand pallet truck	H	NVA
22				Unload delivery	H	VA	Transport delivery point	T	VA
23				Scanning	A	VA	Unload deliver	H	VA
24							Scanning	A	VA

A large share of the non-value adding activities are unnecessary walking, intermediate storage and change of transportation equipment that leads to extra loading and unloading activities for the logistics personnel. At the CCC warehouse, material is moved several times before it is placed in its storage location. Due to a lot of transportation of material and intermediate storages, there is a large number of non-value-adding activities in the CCC warehouse, see Table 11. This table presents the worst-case scenario at the CCC warehouse with the largest number of activities. These non-value adding activities are not connected to the delivery planning approaches.

To be able to store material at the CCC, the material must be unloaded from the truck, and this activity has therefore been classified as necessary. At the construction site at NUS, some of the loading and unloading activities are classified as necessary since the material must be unloaded at a specific unloading zone. That is a requirement from the client in order to not disturb the ongoing business and its internal logistics flows.

Table 11: Categorization of HATS activities at the CCC warehouse for all three planning approaches.

CCC - Warehouse									
	Full Delivery Planning	**HATS**	**Value**	**Light Delivery Planning**	**HATS**	**Value**	**No Delivery Planning**	**HATS**	**Value**
1	First sorting	H	NVA	First sorting	H	NVA	First sorting	H	NVA
2	Call BLC	A	NVA	Call BLC	A	NVA	Call BLC	A	NVA
3	Storage	S	NVA	Storage	S	NVA	Storage	S	NVA
4	Transport	T	NVA	Transport	T	NVA	Transport	T	NVA
5	Unload truck	H	NNVA	Unload truck	H	NNVA	Unload truck	H	NNVA
6	Scanning	A	VA	Check delivery note	A	VA	Check delivery note	A	NNVA
7	Storage	S	NVA	Walk to computer	T	NVA	Walk to computer	T	NVA
8	Load Forklift	H	NVA	Search for delivery part	A	NNVA	Search for delivery part	A	NNVA
9	Transport	T	NVA	Add information	A	NNVA	Track package	A	NVA
10	Unload forklift	H	NVA	Print label	A	NNVA	Walk back	T	NVA
11	Storage	S	NVA	Walk back	T	NVA	Note package information	A	NNVA
12	Load forklift	H	NVA	Label parcel	A	NNVA	Walk to computer	T	NVA
13	Transport	T	NVA	Scanning	A	NVA	Create parcel in Myloc	A	NNVA
14	Unload forklift	H	NVA	Storage	S	NVA	Print label	A	NNVA
15	Storage	S	NVA	Load forklift	H	NVA	Walk back	T	NVA
16	Load forklift	H	NVA	Transport	T	NVA	Label parcel	A	NNVA
17	Transport	T	NNVA	Unload forklift	H	NVA	Scanning	A	NNVA
18	Place at storage location	H	VA	Storage	S	NVA	Storage	S	NVA
19	Scanning + storage location	A	VA	Load forklift	H	NVA	Load Forklift	H	NVA
20	Storage	S	VA	Transport	T	NVA	Transport	T	NVA
21	Load forklift	H	NNVA	Unload forklift	H	NVA	Unload forklift	H	NVA
22	Transport	T	NNVA	Storage	S	NVA	Storage	S	NVA
23	Unload forklift	H	NNVA	Load forklift	H	NVA	Load Forklift	H	NVA
24	Scanning	A	NNVA	Transport	T	NNVA	Transport	T	NVA
25	Email	A	NNVA	Place at storage location	H	VA	Unload forklift	H	NVA
26	Storage	S	NVA	Scanning + storage location	A	VA	Storage	S	NVA
27	Scanning	A	NNVA	Storage	S	VA	Load forklift	H	NVA
28	Load Truck	H	NNVA	Load forklift	H	NNVA	Transport	T	NNVA
29				Transport	T	NNVA	Place at storage location	H	VA
30				Unload forklift	H	NNVA	Scanning + storage location	A	VA
31				Scanning	A	NNVA	Storage	S	VA
32				E-mail		NNVA	Load forklift	H	NNVA
33				Storage	S	NVA	Transport	T	NNVA
34				Scanning	A	NNVA	Unload forklift	H	NNVA
35				Load truck	H	NNVA	Scanning	A	NNVA
25							E-mail	A	NNVA
25							Storage	S	NVA
25							Scanning	A	NNVA
25							Load truck	H	NNVA

Most of the administrative activities have been classified as necessary. The traceability of material is important in the CLS, which ensures built in quality (Liker, 2004), and it has been decided that information about all material shall be available in Myloc. The traceability requires that some administrative activities are being perform even if it does not add value for the customer. Because most of the necessary activities are administrative tasks, the variation in amount of necessary activities is connected to the delivery planning approaches.

Table 12: Categorization of HATS activities at the CCC tent for all three delivery planning approaches.

CCC - Tent									
	Full Delivery Planning	**HATS**	**Value**	**Light Delivery Planning**	**HATS**	**Value**	**No Delivery Planning**	**HATS**	**Value**
1	First sorting	H	NVA	First sorting	H	NVA	First sorting	H	NVA
2	Call BLC	A	NVA	Call BLC	A	NVA	Call BLC	A	NVA
3	Storage	S	NVA	Storage	S	NVA	Storage	S	NVA
4	Transport	T	NVA	Transport	T	NVA	Transport	T	NVA
5	Unload truck	H	NNVA	Unload truck	H	NNVA	Unload truck	H	NNVA
6	Storage	S	NVA	Storage	S	NVA	Walk to tent	T	NNVA
7	Walk to tent	T	NNVA	Walk to tent	T	NNVA	Check delivery note	A	NNVA
8	Scanning	A	VA	Check delivery note	A	NNVA	Walk back	T	NVA
9	Load Forklift	H	NVA	Walk back	T	NVA	Search for delivery part	A	NNVA
10	Transport	T	NNVA	Search for delivery part	A	NNVA	Track package	A	NVA
11	Place at storage location	H	VA	Add information	A	NNVA	Walk to tent	T	NVA
12	Scanning + storage location	A	VA	Print label	A	NNVA	Note package information	A	NNVA
13	Walk from tent	T	NNVA	Walk to tent	T	NVA	Walk back to CLC	T	NVA
14	Storage	S	VA	Label parcel	A	NNVA	Create parcel in Myloc	A	NNVA
15	Walk to tent	T	NNVA	Scanning	A	NVA	Print label	A	NNVA
16	Load forklift	H	NNVA	Load forklift	H	NVA	Walk to tent	T	NVA
17	Transport	T	NNVA	Transport	T	NNVA	Label parcel	A	NNVA
18	Unload forklift	H	NNVA	Place at storage location	H	VA	Scanning	A	NNVA
19	Scanning	A	NNVA	Scanning + storage location	A	VA	Load forklift	H	NVA
20	Walk from tent	T	NNVA	Walk back	T	NNVA	Transport	T	NNVA
21	E-mail	A	NNVA	Storage	S	VA	Place at storage location	H	VA
22	Storage	S	NVA	Walk to tent	T	NNVA	Scanning + storage location	A	VA
23	Scanning	A	NNVA	Load forklift	H	NNVA	Walk back	T	NNVA
24	Load truck	H	NNVA	Transport	T	NNVA	Storage	S	VA
25				Unload forklift	H	NNVA	Walk to tent	T	NNVA
26				Scanning	A	NNVA	Load forklift	H	NNVA
27				Walk back to CLC	T	NNVA	Transport	T	NNVA
28				E-mail	A	NNVA	Unload forklift	H	NNVA
29				Storage	S	NVA	Scanning	A	NNVA
30				Scanning	A	NNVA	Walk back to CLC	T	NNVA
31				Load truck	H	NNVA	E-mail	A	NNVA
32							Storage	S	NVA
33							Scanning	A	NNVA
34							Load truck	H	NNVA

When materials are being stored in the CCC tent, the personnel need to walk there to collect material and then walk back to the CCC warehouse. One "walk to tent" activity and one "walk back" has been classified as necessary work since it must be done at some point, but all other walking back and forth has been classified as non-value-adding.

The ongoing hospital activities at NUS cannot be disturbed. This contributes to that some HATS activities at the construction site at NUS are necessary to perform. Storage time in the CCC is sometimes dependent on delays or production stops caused by happenings in the ongoing business. The time spent in intermediate storage at the construction site is sometimes dependent on restrictions in transportation ways and elevators that can be used.

When materials are delivered to the unloading zone at NUS, it is unloaded and placed in a tent. When all material has been unloaded and marked with the right labels, it is moved closer to the culverts where it is stored for maximum ten minutes before it is transported to the delivery point. The reason why the material is unloaded and stored in a tent instead of closer to the culverts is due to space limitations and that it cannot disturb internal logistics processes. Certain unloading zones have been set up for construction material at the hospital area to not interfere with ambulance traffic. This affects handling processes and distances that material needs to be transported at the construction site.

The number of administrative activities is affected by the delivery planning approach. For the logistics personnel, full delivery planning eases the work and reduces the time spent on administrative activities, which in turn affect the time material is stored in intermediate storage before it can be placed in the long-time storage at the CCC or be delivered to the delivery point at NUS. The time spent on administrative work for no delivery planning has a correlation to the type of material, the wrapping around the material and the clarity of information on the associated delivery note. What type of material, standard or customized product, along with the clarity of the delivery note from the material supplier affects the time it takes to establish a correct description of the parcel in Myloc. The wrapping affects the possibility to see what items the parcel contains and thereby the time spent on tracking information about the parcel. The time is related to if there is more than one parcel paired together, like three packages or a pallet and a package that belongs together and constitutes the whole parcel. The HATS activities are affected by type of material and the type of parcel, a small package can be carried by hand while a pallet requires equipment for transportation. Type of material affect if material should be stored inside or outside, at the CCC.

6.2 Elimination of non-value-adding activities

This section presents improvements for the current state and the HATS activities at the construction site at NUS and the CCC, by eliminating localized non-value-adding activities.

The elimination of non-value-adding activities is based on the mapping of the current state activities and categorization of value-adding, non-value-adding, and necessary activities presented in the previous section. The future state map and improvement suggestions are created with focus to eliminate as many non-value-adding activities as possible. Generally, when material is delivered with full delivery planning, the number of activities that are non-value-adding can almost be fully eliminated, compared to light delivery planning and no delivery planning.

The future state maps present the future state of the construction site at NUS and at the CCC, see Figure 30 and Figure 31, with suggested improvements that are presented in the following sections. The future state maps are based on a full delivery planning approach.

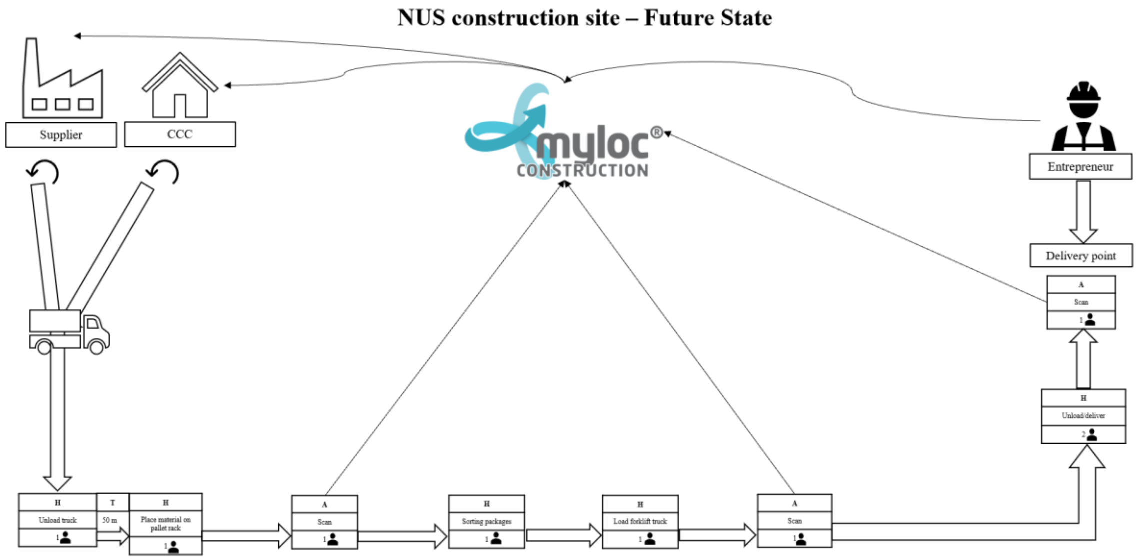

Figure 30: Future state map of the construction logistics at the construction site at NUS.

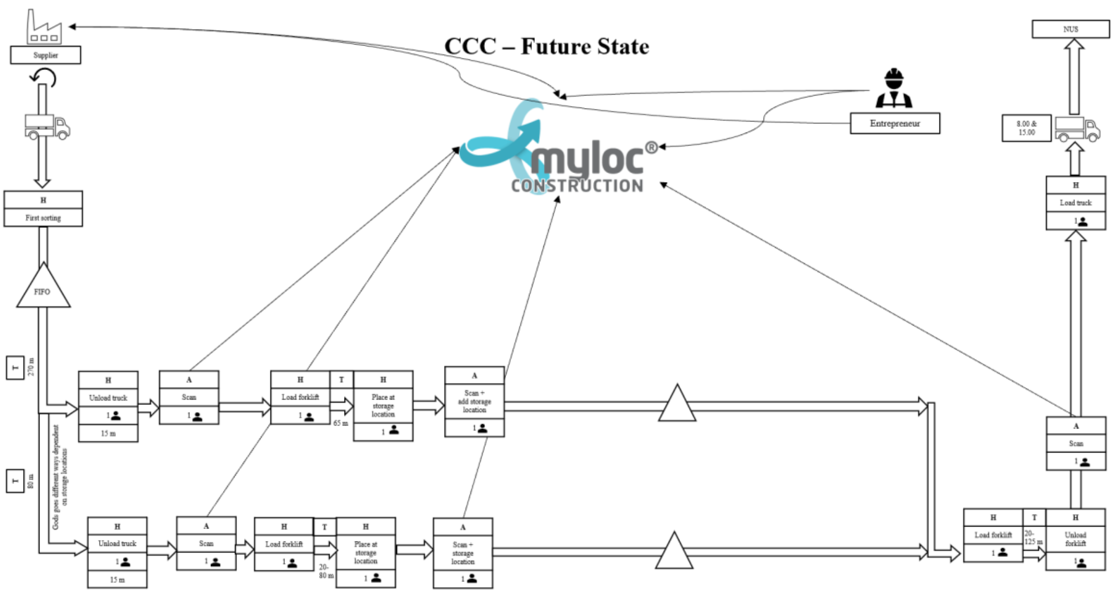

Figure 31: Future state map of the construction logistics at the CCC.

Lack of planning causes delays, which affects project schedule and cost (González et al., 2014). If the entrepreneurs and the suppliers would plan deliveries further ahead, it would be possible for DB Schenker personnel to plan better as well. This would lead to that non-value-adding activities could be eliminated and the conditions for DB Schenker personnel to be able to deliver the material JIT would improve. When material is delivered unannounced to the CCC or to NUS, the logistics personnel must call entrepreneurs, create a description and add information about the parcel to Myloc, print labels, and figure out where it should be delivered. When entrepreneurs plan further ahead, it is possible for the DB Schenker personnel to plan and book equipment that facilitate the unloading and transportation of material. For some materials there is a need to book a wheel truck one day ahead to be able to unload the delivery. By planning further ahead, it is possible to plan deliveries for the upcoming days, which can save a lot of time during the next day. If the wheel truck is not booked at the right occasion, DB Schenker personnel must either wait until it is available or use their other truck that cannot handle too heavy material, which is a safety issue.

6.2.1 Elimination of non-value-adding activities at the unloading zone

When material is delivered unannounced to the unloading zone, the DB Schenker personnel must walk to the computer in the office at the unloading zone. Unnecessary movement of people is one of the seven major wastes in lean production (Liker, 2004). One issue with the layout at the unloading zone is that there is no entrance from the tent to the office, as can be seen in Figure 32, which leads to that personnel must walk around the tent to get to the office and then walk through the office to get to the computer. If the layout of the office and the tent could be changed, unnecessary movement could be reduced.

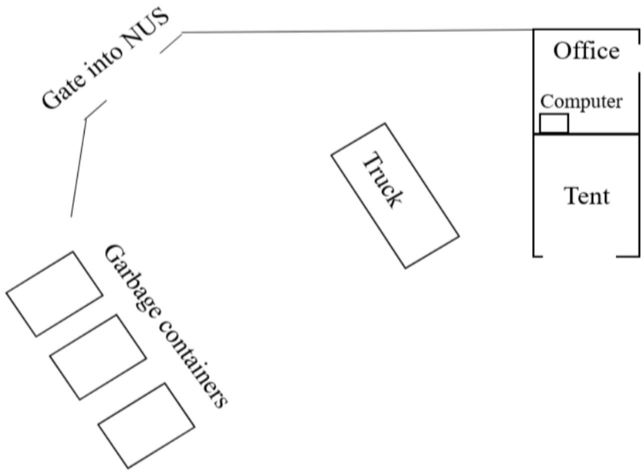

Figure 32: Layout of unloading zone 1 at NUS.

In the current state, DB Schenker personnel are walking with hand-pallet trucks to almost all delivery points at NUS, which takes time and requires resources. One carry-in delivery is estimated to take 45 minutes and the logistics personnel usually work together two and two. The fifth question to go through when developing a future state is how the activities can be levelled (Keyte and Locher, 2016). Carry-in is the activity that takes the most time out of all activities, according to DB Schenker. Carry-in is estimated to take up to 45 minutes while other activities such as scanning only takes a few seconds and this leads to the activities are not levelled. One way to level out this activity could be to invest in new equipment that can be used to transport material in the culverts. The best equipment would be a forklift that can transport material faster in the culverts and outside on the courtyard as well, which would reduce the number of times the logistics personnel must load and unload the forklifts.

Packages arriving at the construction site at NUS, with no or light delivery planning, are currently sorted by DB Schenker personnel two times. The first time based on the name of the person who has ordered the material and the second time based on the delivery point. The first sorting is not necessary to execute to be able to deliver the material JIT, but is performed to facilitate the work of checking the packages against the attached delivery note. The packages that arrive with full delivery planning only requires the second sorting. If all parcels would be delivered with full delivery planning, the first sorting step could be eliminated.

6.2.2. Elimination of non-value-adding activities at the construction consolidation center

With some improvements, more material could be stored in the CCC tent instead of in the CCC warehouse. A lot of construction material can be stored outside without getting damaged. It is less expensive to store material in the CCC tent compared to at the CCC warehouse and it is located closer to the terminal, which means that less transportation is required within the area. Unnecessary movement and transport are two major types of wastes in lean production (Liker, 2004; Keyton and Locher, 2016). A computer and a printer should be installed in the tent so administrative activities can be performed there. This would reduce the number of times that the personnel must walk back and forth between the CCC warehouse and tent.

Before material arrives at the CCC, it is always unloaded at DB Schenker's main logistics terminal first. The personnel at the terminal usually calls the person that is responsible in the CCC warehouse to ask if material should be delivered to the tent or to the warehouse. Over-processing are activities that take longer than they should and does not add any value for the customer (Liker, 2004; Keyton and Locher, 2016). DB Schenker should set up standards for what type of material that should be stored in the CCC tent and what should be stored at the CCC warehouse. One additional improvement would be if the suppliers could deliver the material directly to the tent or to the warehouse, without passing by the terminal. This would eliminate three non-value-adding steps in the current state.

In the current state, there are three intermediate storage locations inside the CCC warehouse. These intermediate storage places lead to longer lead times and causes extra movements and waiting, which does not add any value for the customer (Liker, 2004; Keyton and Locher, 2016). The most optimal route would be if the material would go directly from the truck to the storage location in the CCC warehouse or tent and later on directly to the milk-run truck.

Two times a day, a milk-run truck delivers material to NUS from the CCC. To prepare these deliveries, an email must manually be sent to the truck driver, including a list of material that should be included in the shipment and information about where to collect material. This activity, sending an e-mail, can be seen as over-processing and has not been classified as value-adding for the customer (Liker, 2004; Keyton and Locher, 2016). One improvement that would eliminate this activity would be if a list of all material ordered by the entrepreneurs would automatically be sent to the truck driver.

Each parcel is currently being scanned four times at the CCC and three times at the construction site. Some scanning activities is seen as over-processing, which means that more information than needed is being produced (Liker, 2004; Keyton and Locher, 2016). Some of the scanning activities could be eliminated or merged together. It should at least be evaluated if all these scanning activities are necessary or if some of them can be removed, especially the two final scanning activities at the CCC.

6.2.3 Increase the number of deliveries to the construction consolidation center

In March 2019, only fourteen percent of the total number of trucks to the construction project delivered material to the CCC. If the number of consolidated transports would increase, direct transportations into the construction site could be reduced, which would reduce emissions and air pollution in the urban areas (Sullivan et al., 2010). From the VSM, it was clear that a lot of non-value-adding activities and necessary non-value-adding activities are performed at NUS where space is limited compared to the CCC. It would be beneficial if more activities could be moved further back in the supply chain and be performed at the CCC instead of at the construction site. More demand should be put on entrepreneurs to plan further ahead and store material at the CCC then suborder it to the construction site JIT. This would reduce the number of heavy transports in the city center of Umeå and increase the fill rate of each truck arriving at the construction site.

ÅF needs to set stricter regulations for what type of material that can be delivered directly to the unloading zones at NUS and what type of material that should be delivered to the CCC. Using a CCC can lead to an increased cost from tied up capital (Ekeskär and Rudberg, 2016). The CCC should be utilized more to ensure that the sought-after benefits of having a CCC are not lost. In the current solution, only fourteen percent of the number of transports with construction material goes to the CCC, therefore the full potential of having a CCC cannot be achieved.

Very large items, concrete, steelwork, roof, walls and full vehicle loads that are needed right away should go directly to the site without bypassing the CCC, since there is no point to reload a full delivery at the CCC (Lundesjö, 2015). This is of course a matter of space and the possibility to store material without risking that it gets damaged. Material with high turnover should not be stored in the CCC, but other construction material, especially small items that are delivered in packages should be stored at the CCC (Shigute and Nasirian, 2014).

6.3 Improvements based on lean production principles

This section describes additional improvement that have been detected during observations and interviews. The suggested improvements are based on seven major types of wastes in the lean production principles (Liker, 2004; Keyton and Locher, 2016).

6.3.1 Improvements of materials handling processes

Handling of construction material at the CCC is dependent on one person responsible for all construction material. Without this person, the daily operational processes would not work. Standards should be set up for how different types of materials should be handled, if material should be stored in the CCC tent or at the CCC warehouse, how it should be stored, and how everything should be reported in Myloc. By introducing standards, the root causes to production problems can be identified and routines can be established that lead to more consistent operations (Polesie, 2011). This would make it easier for other employees and newly hired to perform all activities and handle all types of deliveries. These guidelines can be posted in Myloc so the information is visuable for everyone. It is important to remember that lean production is not about making one improvement and think that everything is perfect, it is about continuous improvements. Standards should continuously be improved (Gao and Low Pheng, 2014), and DB Schenker must let all employees in the project team be part of the process of designing and improving current standards.

The planning for where and how to store material in the tent should be improved. In the current state, products are stored on top of each other at each storage place. The personnel must move materials to reach the correct parcel and double check if it is the right product. Material is currently stored based on material supplier and according to a random stock location. Storing based on supplier is not the most optimal approach when many different contractors are involved, and it does not utilize space in the most efficient way (Lundesjö, 2015). Since the incoming construction material generally has low volume and many variants, the most suitable warehouse strategy would be U-layout and zoning (Jonsson and Mattsson, 2012). Material can be stored based on low frequency in the back and high frequency closer to the outbound area, seen Figure 33, or based on how the material is handled. It would be possible to utilize the height of the tent to a greater extent, currently all material is stored on the ground, but this would require other equipment than what is currently available.

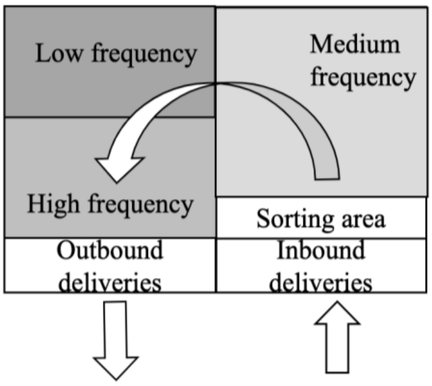

Figure 33: Zoning of the CCC tent based on ordering frequency of the products.

Mossman (2007) declare that good construction logistics involves how people, information, equipment and material reach the worksite in a safe and convenient way. Answers from interviews show that the entrepreneurs occasionally have problems with damages or defects on the goods. Jidoka can be implemented in the project to make sure that a defect will not pass through to the next step in the production sequence (Liker, 2004). If damages have occurred before the material is delivered to DB Schenker, it is important that it is noticed and reported to the suppliers. Visual controls should be developed to ensure that defect products do not continue downstream to the entrepreneurs at the construction site. Damages can occur after material has been delivered to DB Schenker and this should be minimized to the highest extent possible. Currently, DB Schenker is sorting some packages onto pallets, without securing the goods, seen Figure 34 and Figure 35. This problem can easily be solved by using pallet collars to ensure that the packages will not fall off the pallet.

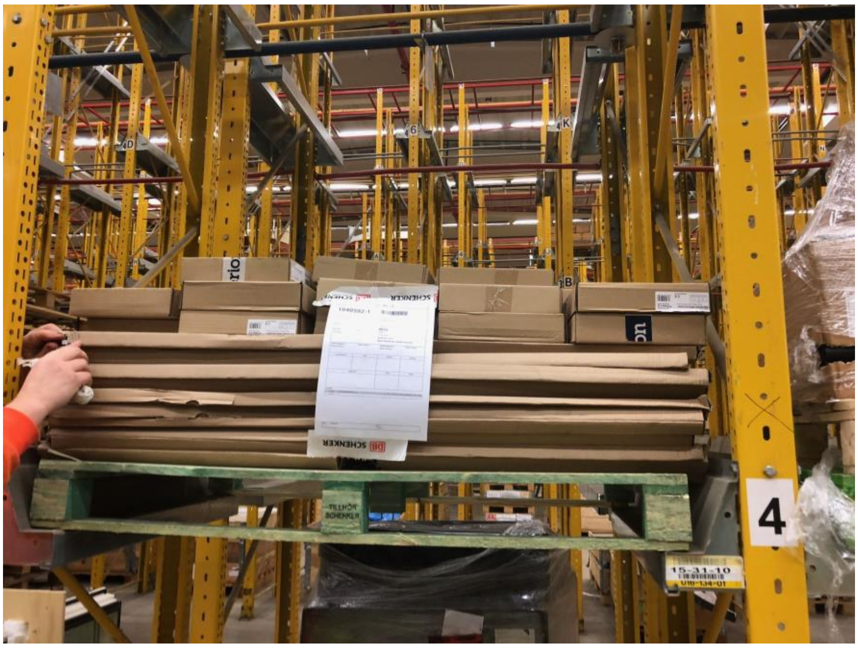

Figure 34: Storage of material without securing the goods, the packages can easily fall off the pallet and cause transportation damages.

Figure 35: Storage of material without securing the goods, the packages can easily fall off the pallet and cause transportation damages.

Some material, such as special orders of ventilation material, see Figure 36, are quite difficult to handle. It usually requires extra work and is currently stored on pallets. To make the handling easier and to not risk transportation damages on the material, DB Schenker should invest in some sort of rack for this type of material.

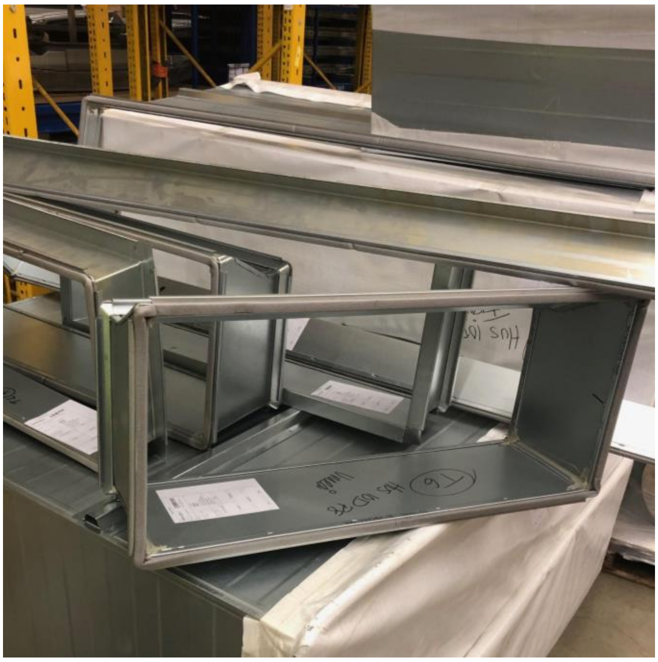

Figure 36: Special order of ventilation material.

Standards should be developed for what that is considered as a parcel. Right now, one parcel can be one package or one pallet, which varies a lot for different types of material such as the customized ordered parts of ventilation material. The reporting of material is not consistent, which makes it difficult to improve working processes.

6.3.2 Communication and transparency between actors

Answers from interviews shows that the entrepreneurs would appreciate to have meetings with all other entrepreneurs, sub-entrepreneurs and the 3PL personnel, in the beginning of a project. At such meeting, the entrepreneurs can explain what is expected from the logistics services, and 3PL personnel can give feedback on what is possible to perform. Answers from interviews show that entrepreneurs sometimes find it challenging that DB Schenker personnel does not have enough knowledge about construction material. Frödell et al. (2008) found that one of the success factors in a construction project is participation of the client. A startup meeting could be necessary to get all actors involved, to discuss issues and inform the 3PL about specific construction materials.

Some material delivered from suppliers are not delivered with the right load carriers, see Figure 37 and Figure 38. Delivered material that needs to be rearrange can lead to quality issues and unnecessary time spent on handling activities. Material delivered like this, is hard to transport and cannot be stored in the CCC tent, due to increased risk of damages.

Figure 37: Windows can be delivered on blocks instead of pallets, which increases the risk for transportation damages from forklifts.

Figure 38: A delivery of a window with only half the window secured on a pallet, which increases the risk for transportation damages.

Stricter requirements must be put on the material suppliers, to ensure that material is delivered with the right load carriers. To increase efficiency, material can be packed according to the order of installation. This would of course require that the entrepreneurs inform DB Schenker about the order of installation, e.g. give each part a number, so it is possible to pack and deliver the parts in the right order.

Answers from interviews indicate that entrepreneurs do not know if the suppliers have labeled and delivered the material in the right way or not. One way to solve this problem could be that DB Schenker personnel report defaults to the entrepreneurs and the material suppliers. This will improve the communication and transparency of the material flow and create documentation of how often these problems occur. It will lead to more administrative work for DB Schenker personnel but could improve the information flow in the long run. Inadequate communication between actors is one common reason for why delays occur in construction projects (AlSehaimi and Koskela, 2008).

6.3.3 Higher requirements on entrepreneurs

The entrepreneurs play an important role in reducing wastes in the material flow. DB Schenker personnel cannot be experts of all construction material. It is not always easy to add descriptions of material in Myloc or to know how to handle all types of material. DB

Schenker personnel and the entrepreneurs must communicate so that the entrepreneurs provide DB Schenker personnel with the right information about each parcel by adding all information in Myloc. Information and communication are crucial to give DB Schenker personnel the ability to create value for the entrepreneurs. The entrepreneurs can put more requirements on the material suppliers to handle and deliver material in the right way, since they are the supplier's customers. Generally, it is important that the entrepreneurs improve their planning and try to plan further ahead. Lack of planning is a common cause for delays in construction projects (AlSehaimi and Koskela, 2008). With more demands on planning, it will be easier for both DB Schenker personnel and the materials supplier to plan further ahead which will create more value for the entrepreneurs in the long run. Thunberg (2016) explains that planning, involving production time schedule, forecast of material requirements and delivery time, is important and the plan needs to be shared with the suppliers to give them the possibility to plan as well.

The large amount of excess material that is ordered by the entrepreneurs need to be reduced. Entrepreneurs often only focus on the purchase cost and buy large quantities to get a reduced price. What is not thought about is the expensive storage cost and that more time is required to take care of extra material, which is a problem that has been highlighted by Österman (2017). Answers from interviews, conducted in this project, show that the entrepreneurs generally order more material than needed, to not risk shortage of material in the project or higher cost by gradually buying some extra material. Material is the largest cost item in construction industries (Sveriges byggindustrier, 2017). Ordering more material than needed leads to more handling, more returns, less space available on the construction site and more wrapping material to handle.

6.3.4 Ergonomics

The ergonomics for the materials handling personnel at NUS should be considered and improved. According to Josephson and Saukkoriipi (2005), work related injuries can amount up to 10 percent of the total project cost in construction projects. The sorting of material that is delivered to NUS is currently being sorted on the ground, see Figure 39 and Figure 40. This could easily be improved by investing in some sort of pallet rack for the tent, so the sorting can be performed in a more ergonomic position. Bad ergonomics is a waste categorized as muri in the lean philosophy and should be eliminated to increase the safety for the personnel (Liker, 2004). By using a pallet rack, unloading of the trucks would become more efficient, since it would create a designated place to put material at after unloading the truck. In the current state, all pallets are placed randomly on the ground in the tent. This leads to that pallets might have to be moved to be able to reach pallets that have been placed behind.

Figure 39: Sorting of material at unloading zone L1.

Figure 40: Sorting of packages at unloading zone L1.

Another improvement regarding the ergonomics is to invest in more equipment for the logistics personnel. The employer is responsible for the design of the worksite and shall help to prevent injuries from heavy lifting by ensuring availability of tools and aids needed (AFS 2012:2). The forklift truck used for unloading deliveries at the unloading zone at NUS, is not suitable for all material deliveries, mainly because of the limited weight it can handle. One improvement would be to invest in a new forklift truck that can handle heavier material.

According to DB Schenker personnel, it is quite common that delivers arrive at the same time at the unloading zone at NUS. DB Schenker personnel should become better at rescheduling to avoid deliveries arriving concurrently. This would increase the utilization of the resources but require that DB Schenker personnel will deny some bookings and suggest new delivery times. Another suggestion is to have two forklifts available for incoming deliveries, but this would not increase the utilization of resources, only hide the problems with planning and rescheduling. According to Josephson and Saukkoriipi (2005), about 10 percent of the total project cost is related to inefficient use of resources, such as inactive machinery, and this should be avoided to the best extent possible.

Another ergonomic issue is customized products with ungainly shapes, for example ventilation parts, see Figure 41. Many of the parts for ventilation installation are customized, which leads to a lot of orders that are difficult to handle for DB Schenker personnel. It can be products that are heavy and have odd shapes, which means that it is not obvious where the center of gravity is. This leads to handling problems since it is crucial to carry the heaviest side of the product closer to the center of the forklift, to not risk that the forklift will be unbalanced. One way to solve this problem could be to require suppliers to mark the center of gravity on each parcel. The logistics personnel need information about the weight and center of gravity of the goods that are handled manually (Arbetsmiljöverket, n.d.).

Figure 41: Ventilation parts that has arrived at NUS

Generally, there is a need for DB Schenker to become more prepared for handling all different types of gods incoming to the unloading zone. The personnel should not have to risk their own safety or health to be able to deliver the material JIT. According to Arbetsmiljöverket's directive about ergonomics (AFS 2012:2), the employer needs to examine if work postures and movements of manual handling task are harmful for the body and investigate if the workload is harmful on its own or in certain work combinations.

6.3.5 Improvements of the IT-system

Myloc is the IT system that is used in the CLS and is used as the main platform for communication between all actors. To improve visual controls in the CLS, all written communication that is needed should be easy to access for everyone (Gao and Low Pheng, 2014). Answers from interviews showed that additional functions in Myloc can increase the value for the entrepreneurs. Some of the entrepreneurs think that the CLS has decreased their possibility to track deliveries and to know what material that has arrived to the CCC, to the unloading zone at NUS or to the delivery points. To increase the transparency of the material flow, the entrepreneurs would benefit from knowing where the material is and when it has arrived. All this information is already available in Myloc, so it is probably possible to provide the entrepreneurs with the information.

During interviews, the entrepreneurs expressed that one improvement of the IT-system could be the possibility to choose for which parcels notifications are desired. Some entrepreneurs desire more notification and some desires less. Another suggestion from the entrepreneurs is to be able to prioritize material when placing an order in Myloc, so the logistics personnel can deliver material with high priority first. According to Myloc, entrepreneurs can prioritize bookings by choosing the time of delivery during the day. The entrepreneurs usually book deliveries to 7 a.m., regardless of when the material is needed during the day. DB Schenker personnel presumes that the material is not needed until later that day and material is therefore seldom delivered at 7 a.m. This leads to that entrepreneurs do not know when material will be delivered, and the idea of prioritizing deliveries with time does not work. To solve this problem, DB Schenker personnel need to reschedule and level out the workload throughout the day.

The most valuable information for the entrepreneurs is to know when material has arrived at the delivery point, so they do not have to spend time to go and check for material several times every day. If DB Schenker personnel would scan the parcel and the delivery point when material is delivered, it would increase the certainty that the right parcel has arrived at the right place, even though it would require an extra scan activity.

During interviews, uncollected material at the delivery points was raised as an issue. This causes problems for DB Schenker personnel when delivering new material to the same delivery point that it is already full. The space at the delivery points is limited, see Figure 26, and material is not supposed to be stored there. To increase the level of control and minimize the risk of uncollected material, some sort of control must be developed. It is possible for DB Schenker personnel to create a deviation report in Myloc when material that has not been collected is discovered, but there are many different delivery points at NUS, and material is not delivered to all points every day. To get continuity and solve problems as they occur, it would be better if the entrepreneurs could report in Myloc when parcels are collected. If the entrepreneurs would scan the parcel, or report in some other way, when material is collected, the status of the material could be changed in Myloc. This would provide the possibility to keep track of material that has been collected and which that has not. Bad oversight of the planning process and lack of monitoring and control during the production are mentioned as common problems in the construction industry (González et al., 2014; Chua and Kog, 1999; AlSehaimi and Koskela, 2008). The change would require more education to involve everyone in a new way of working. This will take time and should be considered before changing the routines.

Another feature the entrepreneurs have suggested is to increase the transparency in the planning processes, by letting everyone that is involved in a project see all activities that are planned in the online calendar, and not just their own activities. Mossman (2017) explain that better transparency in the construction progress is one success factor that optimized construction logistics can lead to.

All parcels arriving at the unloading zone at NUS have an attached delivery note, which contains detailed information about the material in the parcel. DB Schenker personnel usually does not keep these notes, but some entrepreneurs need them to keep track of what parts that has been ordered and delivered. The entrepreneurs suggested that it would be beneficial if the delivery note could be scanned and uploaded to the specific booking in Myloc. This would, however, require one additional activity. The main problem here is that there is not enough information about the material that is booked for delivery in Myloc. The best way to solve this issue would be if the entrepreneurs could add more information about the material in Myloc when the order is placed at the material suppliers. Then, information would always be available to everyone involved in the process, instead of requiring DB Schenker personnel to add more information.

Additional information that could be available in Myloc is the standards for how to handle the arriving parcels and how to report it in Myloc. The CLS is currently dependent on a few people at DB Schenker who are responsible for construction material. By developing standards that are available for everyone, it is possible for new employees to perform the work and the CLS would not be dependent on just a few people. It would be possible to have information about elevators and transportation rounds that are currently closed, which would facilitate the delivering routes at NUS.

6.4 Long term improvements for the construction logistics solution

This section presents improvements that cannot be implemented in a short period of time, due to high costs and the fact that it requires increased site management.

One long-term improvement regarding planning is to put more time on planning routes at the construction site and develop a strategy for how the routes should be performed. Delivering one pallet of material to the right delivery point is currently estimated to take 45 minutes. The production is constantly changing and since it is a hospital environment, specific areas and elevators can suddenly be closed, which means that new routes must be planned to reach certain delivery points. If DB Schenker personnel would spend more time on planning the routes, the time for deliveries could probably be reduced. Route planning can be performed in the current state, but the problem is that too much materials arrive to NUS unannounced and this interferes with DB Schenker's working processes, which reduce the possibility to plan. To be able to plan delivery routes, the number of deliveries with full delivery planning must be increased and it is necessary to develop a strategy for how route planning can be performed in the best way. This will take time and is the reason for why route planning is considered a long-term improvement.

In the current CLS, DB Schenker personnel only consolidate full pallets at the CCC. As presented in the theoretical framework, it would be possible to break incoming pallets into smaller parts or packages and consolidate these into mixed pallet deliveries or kits, which would add more value to the entrepreneurs (Lundesjö, 2015). Each kit would then contain all different parts and materials that are needed by an entrepreneur at a specific place and time at the construction site. It would be possible for DB Schenker personnel to perform some assembly processes that currently are performed at the construction site. To include kitting in the CLS will require a lot of planning and sharing of information between DB Schenker, entrepreneurs and suppliers, but could lead to utilizing the CCC more and improve the CLS further. Sullivan et al. (2010) describes that an increased level of consolidation and thereby a reduced number of transportations into the construction site, can reduce the emissions and air pollution in urban areas.

Another long-term improvement that would reduce the amount of wrapping material that is going into and out from the construction site, is to remove unnecessary wrapping already at the CCC. Garbage from all packaging material can be a larger volume than the actual construction material and should not be transported to the construction site at all, if it is not necessary to avoid transportation damages (Josephson and Saukkoriipi, 2007).

7. Factors affecting the construction logistics solution

This section aims to answer research question three and to increase knowledge about factors that drive efficiency of ÅF's CLS. A summary of the identified factors affecting the CLS is presented together with an analysis connecting these with the factors identified and presented in the theoretical framework.

RQ 3: What factors affect the materials handling activities in the CLS?

Table 13 presents the identified factors affecting the HATS activities in the CLS. Each factor is presented along with a short explanation of its meaning and how it affects activities. The summary is based on the analysis of necessary activities, presented in Chapter 6, and information obtained during the case study and interviews.

Table 13: Factors affecting the materials handling activities in the CLS in the studied case.

Factors of the NUS project	**What does it mean in the NUS-case?**	**How does it affect material handling activities?**
Time duration	• The NUS case is a project with long time horizon which affect the possibility to implement the CLS	• Time for training in Myloc to ensure standardized work, which affects the time spent on administrative activities for DB Schenker personnel • Time to adapt, make changes and continuously improve CLS • DB Schenker personnel have had time to learn about specific construction material in the project • DB Schenker personnel have had time to learn delivery routes
Available space	• Limited space at the construction site	• Material cannot be stored at the construction site; material needs to be delivered JIT • Material can only be stored at specific delivery points, inside the markings • Material can only be delivered to specific unloading zones • Enough space for trucks to turn around at the unloading zone

	• Available space in CCC	• A lot of space available, material is stored according to random stock location • Affect the urgency to utilize space • Long storage times for certain materials, no urgency to set regulations for storage times
Surrounding environment and location	• Urban area ○ Limited space around the construction site ○ Heavy traffic around the construction site ○ Limited transportation ways into the construction site ○ Noise sensitive	• Specific unloading zones for deliveries need to be used • Consolidation is needed to reduce number of deliveries to the construction site • Limited possibilities to store material on the construction site
Construction site environment	• Ongoing business ○ Elevators can only be used at restricted times (before 08:00, between 12:00-12:45 and after 16:00) ○ Restricted walkways inside NUS ○ Hospital activities cannot be disturbed ○ Material deliveries cannot block transportation ways for NUS personnel and visitors ○ Daily deliveries for internal logistics need to be considered	• Material needs to be stored at marked delivery points • Material can only be stored inside the markings • Material can only be unloaded in specific areas • Construction area cannot be enclosed with a fence • Delivery routes needs to be planned • Coordination with internal logistics
	• Hospital environment ○ Hospital activities are the main priority ○ Noise sensitive ○ Dust sensitive	• Delays in project • Unpredictable production stops can affect storage time and JIT deliveries • Delivery routes need to be considered
Type of material	• Variation in size, weight, shape etc. affects how material is handled	• Takes more time to establish good descriptions in Myloc for customized material • Customized products are more often delivered to the wrong location, more time spend on correcting mistakes • Many different materials to handle and transport, different resources are needed

Storage location	• The CCC is located 15 min away from the construction site	• Affects which resource to use to transport material to the construction site • Affects the lead time from CCC to NUS • Milk-runs via suppliers to the CCC
Distance	• Distances at the construction site	• Long distances at the construction site at NUS • DB Schenker personnel need to plan routes and be aware of available walkways to not spend time on unnecessary walking • Newly hired can have difficulties to find the right delivery points • Long distances for the entrepreneurs to go and see if material has been delivered
	• Distance to supplier	• Route for the milk-run • Milk-run truck picks up material and equipment from local suppliers
Lead time and safety stock	• The contractors can store critical material with long lead times at the CCC	• Size of safety stock affects available space in storage • Material with long lead time is stored longer in the CCC
Possibility to transport	• Transportation to the construction site	• Requirement from client to reduce the number of deliveries to and from NUS, consolidation is required • Planning of deliveries is necessary
	• Transportation on the construction site	• Restricted walkways inside the hospital • Delivery routes need to be planned • The logistics personnel have to take a longer route to get to the delivery point
Number of actors involved	• Many suppliers, sub-suppliers, entrepreneurs, sub-entrepreneurs and actors involved	• Many actors to coordinate, involve and train in Myloc • Different material descriptions for DB Schenker personnel to interpret when material is delivered unannounced
Phase of construction project	• Different phases of construction project mean a	• Planning and coordination of deliveries and resources

	large variety of materials to handle	• Carry-in service in combination with carry-out service • Different materials require different descriptions in Myloc • Different material deliveries require different resources and handling
Planning and coordination	• Planning and coordination are crucial to plan delivery routes, prioritize deliveries and ensure that the right equipment is available	• Rescheduling deliveries to improve planning, utilization of resources and to level out the workload • When entrepreneurs update Myloc with the right information, it is possible to book the right resources and plan carry-in routes • Full- and light delivery planning provide the possibility to plan
Control and overview	• Lack of control has contributed long storage times and that material has not been collected from the delivery points	• Some material has been stored at the CCC for a long time, which is costly and takes up space • Material has not been collected from the delivery points, which affects the possibility to deliver new material
	• Available information in Myloc	• Information about material, delivery points, time for delivery etc. increase the possibility to plan routes and utilize resources • All information in one place • Correct information provides traceability • To create and update the system with correct information takes time
Communication and transparency	• Communication and transparency between actors are crucial for DB Schenker personnel to be able to utilize resources and space	• No start-up meeting between the contractors and DB Schenker personnel, which makes it difficult to communicate • An overview of the schedule facilitates the coordination and rescheduling of deliveries • Communication is crucial when something is done incorrectly, to ensure that it will not happen again

Management's and main client's attitude	• Decision about the CLS was initiated from the top client, all actors involved must follow direction for the CLS	• Easier to implement CLS and improvements when it is initiated from the top • Affect if the entrepreneurs are obliged to use Myloc • Affects the attitude towards the three different planning approaches
Climate and weather	• Northern Sweden climate with long winters and snow	• Gravel on ground that affects the possibility to use certain equipment outside • Snow affects the available space at the unloading zones • Affects the urgency to get material inside and the possibility store material outside
Number of unloading zones	• All available unloading zones are not being used, most deliveries go to L1	• DB Schenker personnel present at L1 to unload material • Resources located at L1, no need to move resources to other unloading zones • Where the material is unloaded affects the distances the material needs to be transported on site to the delivery point • The truck drivers deliver to the same location every time (no need to call Schenker to ask about driving directions)
Consolidation and utilization of trucks	• Consolidation and fill rate of trucks affects the number of deliveries that need to be unloaded	• Personnel need to be present and have the right resources available for all deliveries, independent of the fill rate
Unloading zone close to ambulance entrance	• Transportation ways are limited • Deliveries into the construction site need to be minimized • Transportation ways for ambulances cannot be blocked	• Specific unloading zones for deliveries need to be used • Deliveries are only allowed at certain times • Incoming deliveries might have to wait due to ambulance traffic • Consolidation is needed to reduce the number of deliveries to the construction site
A lot of scattered sub-projects	• Provide material to a lot of projects	• Requires resource planning • A lot of different types of deliveries to coordinate • Many delivery points to keep track of, route planning is needed

		• New delivery points for new projects
	• Many actors involved	• Communication with a lot of people, mostly via Myloc • A lot of information that needs to be available in Myloc
Land price	• Affects the storage cost and the urgency to utilize space	• Low land price compared to larger cities, no urgency to utilize space at the CCC • No storage policy for how to store material and how to utilize space • No urgency to reduce storage times
Knowledge and experience of construction material	• Affects the efficiency of the work	• Administrative activities take a lot of time due to difficulties to establish proper descriptions of material in Myloc • Material is not handled in an ergonomic way • Available equipment might not be suitable • Difficult to create standards for work processes
Generation of workers	• To work with a mobile device is not a certainty for everyone	• The time it takes to get used to and accept the Myloc application can be dependent on the generation of workers • Affects the training of Myloc application • If Myloc is not used in the right way, information will not be available

A lot of the factors highlighted in literature were same as the factors identified in the studied case. Factors such as *Time duration*, *Planning and coordination*, *Control and overview* and *Communication and transparency*, have an impact on the CLS. This was not surprising because, lack of planning, transparency and communication are often presented as common problems in literature (Thunberg, 2016; González et al., 2014; Chua and Kog, 1999; Faniran et al., 1998; AlSehaimi and Koskela, 2008; Frödell et al., 2008), as well as poor control and coordination of the ongoing production process (Thunberg, 2016; AlSehaimi and Koskela, 2008; Chua and Kog, 1999).

In the construction industry, where everything is done in a sequence and all actors are dependent on each other (Dubois and Gadde, 2000). *Planning and coordination*, *Communication and transparency* and *Control and overview* are crucial for the construction progress and for the CLS to work efficiently. There are differences in the number of activities performed dependent on which delivery planning approach that is being used, and this indicates that planning affects the efficiency of the CLS. Myloc provides the possibility for DB Schenker personnel to communicate, accept bookings or re-book deliveries and the online calendar increases the transparency. If email and phone-calls would be the main tools for communication, administrative work would take much more time and it would be difficult to have overview over the logistics processes.

Time duration is important since long-term projects give time to implement the CLS, adapt and improve and it and the personnel have time to gain experience. Long-time 3PL arrangements along with commitment and integration improve the performance of the 3PL provider itself (Ekeskär and Rudberg, 2016). In the studied case, the CLS is fully implemented. The logistics personnel have gained knowledge and experience about different construction material, projects and delivery routes. The contractors have had time to adapt to the CLS and get trained in how to use the IT-system. An implementation phase will always be required in projects where the CLS will be used and this needs to be considered when starting a new project. Time available for implementation can be affected by *Time duration.* Without proper implementation, people will not have time to adapt to new ways of working, which will affect the efficiency of the CLS.

Other factors that affect the construction logistics at NUS and have been highlighted in literature are: *Available space* (Chau and Kog, 1999; Skjelbred et al., 2015; Sullivan et al., 2010; Shigute and Nasirian, 2014), *Possibility to transport* (Ekeskär and Rudberg, 2016; Sullivan et al., 2010; Janné, 2018), *Storage location* (Seppänen and Peltokorpi, 2016; Janné, 2018) and *The surrounding environment and location* (Chau and Kog, 1999; Skjelbred et al., 2015; Sullivan et al., 2010; Shigute and Nasirian, 2014). *Available space* affects the possibility to store and transport material, and the need to use a CCC. *Surrounding environment*, an urban area in the studied case, affects *Available space*, number of transports allowed (*Possibility to transport)* and dust and noise sensitiveness *(Construction site environment)*.

The construction site environment will impact the construction logistics (AlSehaimi and Koskela, 2008; Sullivan et al., 2010). At the studied case, *Construction site environment* has a major impact on the logistics and the efficiency of the CLS. The ongoing hospital activities require flexibility of the CLS. DB Schenker personnel need to be aware of which walkways that can be used (*Possibility to transport)* and how to get to different delivery points. Dust and noise need to be considered when transporting and delivering material to certain areas at the hospital. The CCC is located away from the construction site *(Storage location)* and has helped to reduce the number of transports occupying space and disturbing the ongoing hospital business, which is a requirement from the supplier.

Unplanned production stops or delays because of the ongoing hospital business *(Construction site environment)*, can lead to sudden changes in delivery times and storage times at the CCC. In the studied case, where unplanned production stops can occur with short notice, the possibility to store material at the CCC and then order it when it is needed, is a large advantage according to the entrepreneurs. During the interview with a project leader for a construction project at another hospital, it became clear that the ongoing hospital activities and the ambulance entrance *(Unloading zone close to ambulance entrance)* has a large impact on the logistics setup. At the other hospital, the construction site is located further away from the ambulance entrance and it is not a reconstruction project, which makes it possible to enclose the construction area with a fence and use a checkpoint. In this other project, the client has no stated requirements on reducing the number of transports *(Possibility to transport)* because the transports do not disturb the ongoing business. Material can be stored on site *(Available space)* because it is not interfering with internal logistics or ongoing business as in the NUS case. Reconstruction close to an ongoing business that needs to be prioritize has a large impact on the CLS.

Type of material is a factor that is highlighted in literature. In the studied case, a lot of standard products are being used, such as plywood and plasterboards, together with a lot of customized products, such as ventilation parts. This cause problems for DB Schenker personnel, especially when material arrive unannounced and the logistics personnel needs to interpret delivery notes from different suppliers (*Number of actors involved)* to establish detailed description in Myloc. DB Schenker personnel cannot be experts on all different types of materials, no matter if it is standard products or customized products. Customized products are often delivered in more than one package. If these packages are not delivered with full delivery planning, it is difficult for the logistics personnel to keep track of which packages that belongs together, and it takes a lot of time to add correct descriptions of these parcels to Myloc. *Type of material* has a major impact on the HATS activities at NUS. The number of specialized products can have a negative impact on the CLS efficiency. One thing for ÅF to consider is if customized material shall be handled or not in future projects. If it should be handled, it is necessary to provide the logistics personnel with more information about the material, demand suppliers to deliver the material with full delivery planning or decide that a full description about the material in Myloc is not necessary. Better information or training about construction material would probably be beneficial in any case. Many sub-projects (*A lot of scattered sub-projects)* and different phases of each project *(Phase of construction project)*, make it difficult for the logistics personnel to have expertise in all types of material, but some knowledge is necessary to be able to add information in Myloc.

Distance is a factor that has been identified in literature and in the studied case. Long walking distances at the construction site is mentioned as one success factor for the CLS by the interviewed entrepreneurs. Reduced time spent on walking just to check if material has been delivered, is a positive aspect highlighted by the interviewed entrepreneurs. Because of the long distances, it is important to be aware of which passageways and elevators that can be used and how to get to each delivery point, to ensure that material is not transported unnecessarily or to the wrong place. For projects with long distances on site, the 3PL need to plan delivery routes to a greater extent. Even if long distances do not increase efficiency, it makes the CLS advantageous to use because the entrepreneurs can spend less time on walking and more time on value-adding construction work.

Lead time and safety stock affect the need for storage (Skjelbred et al., 2015; Seppänen and Peltokorpi, 2016). Material with long lead times, that is crucial for a project at a certain time is often ordered in advance to the CCC. This leads to that the storage time for this material is quite long, which increases the stock level and tied up capital at the CCC. To be able to order material in advance to the CCC and then deliver it JIT to the construction site is seen as an advantage by the entrepreneurs since it decreases the risk of delays and material getting damaged. It is therefore seen as a strong contributor to the success of the CLS.

Phase of construction project is a factor that varies throughout a project and can vary between different sub-projects. At the reconstruction project at NUS, most of the projects are not in the same construction phase. This requires a lot of different services from DB Schenker personnel and a lot of different material to handle. That a 3PL provider is useful for all construction phases was emphasized by Lundesjö (2015), but no information about if a 3PL is advantageous to use in a project where there are a lot of scattered projects in different construction phases was found.

Management are responsible for coordinating different material flows on site and the management's attitude will impact attitude among all actors (Chua and Kog, 1999; AlSehaimi and Koskela, 2008; Frödell et al., 2008). That *Management's and main client's attitude* affects the CLS was confirmed during interviews. In the NUS case, the decision to implement the CLS was made by the client and the general attitude towards the CLS is positive among entrepreneurs. The client has a major impact on the hired contractors. For projects where ÅF is involved from the beginning, directives from the client about the delivery planning shall be stated from the beginning to ensure that it is being followed.

To only have one unloading zone can be beneficial for the truck drivers that deliver material to a construction site (Ekeskär and Rudberg, 2016). That *Number of unloading zones* impacts the construction logistics at the construction site as well was discovered during the case study. L1 is the unloading zone that is mostly used, and this is beneficial for the 3PL since people and resources are always available at the right place. The backside of only using one unloading zone is that material is not being unloaded as close to the delivery point as possible, instead the material is being transported longer distances at the construction site by DB Schenker personnel that walk with hand-pallet trucks. *Number of unloading zones* will impact *Distance.* A construction project where the material does not have to be transported as far as at NUS, might benefit more from only using one unloading zone. For projects where more than one unloading zones is used, there might be a need to evaluate if it is most advantageous for a milk-run truck to unload all material at one unloading zone or at different unloading zones.

Climate and weather affect the production of a construction project and the need to store material properly (Josephson and Björkman, 2011; AFS: 1999:3). The studied case is located in Umeå, a city in northern Sweden, which implies long winters and cold weather. The CLS provides the possibility to store material properly when unpredictable delays occur and to not risk that material gets damaged. The climate in Umeå affects the material handling at the unloading zones and the weather conditions lead to that some equipment cannot be used for transportations outside. The gravel, snow and ice affect the evenness of the surface, the stability and the speed of the transportation.

To consolidate materials can reduce the number of transports to a construction site (Sullivan et al., 2010). *Consolidation and utilization of trucks* is a factor that affect the NUS case. The CLS provides the possibility to perform milk runs and consolidate parcels and transport them together to reduce the number of transports and trucks driving around the construction area occupying space and roads both in the hospital region and the surrounding urban area. Higher fill rate and less trucks driving around occupying space is positive for a construction project with limited space (*Available space). Consolidation and utilization of trucks* are dependent on how much material that goes via the CCC, the entrepreneur's level of planning, number of orders to pick up at local suppliers and what material that has been ordered (Sullivan et al., 2010; Güner et al., 2017; Jonsson and Mattson, 2012). The fill rate can be dependent on the consolidation rate, since consolidation can improve the utilization of each truck. In the NUS case, material is picked up at local suppliers by the milk-run truck, which have increased the fill rate of the trucks and reduced the number of transports to the hospital area. This is possible because of the short distance to some of the suppliers. Right now, the milk-run truck deliveries material to the construction site at NUS two times a day independent on the fill rate. For each delivery, preparations need to be done. The logistics personnel need to be present at the unloading zone and have right resources available. The same preparations are required for outgoing shipments from the CCC as well, along with some administrative preparations. With less deliveries and a higher fill rate, the personnel and the resources can be utilized better, by reducing time spent on preparations. If the entrepreneurs became better at planning and the DB Schenker personnel became better at rescheduling deliveries, to level out the workload, it could increase the utilization of resources and reduce time spent on preparations for each delivery and shipment. This could however lead to more administrative work and planning for the DB Schenker personnel working at the CCC.

An increased fill rate of the trucks would probably be easier to achieve for a project with less space limitations *(Available space)* than at NUS. With the possibility to store material at site, some material can be delivered in advanced, stored at the construction site and then be delivered to the delivery point JIT. The utilization of trucks for the NUS project should be considered and it should be considered for future projects to achieve better efficiency of the CLS.

A lot of scattered sub-projects put pressure on *Planning and coordination, Communication and transparency* and *Control and overview.* These three factors are important to handle a lot of scattered projects. There are many different delivery points and walkways at the hospital to keep track of and there are a lot of delivery points to deliver material to. It is not possible to have physical overview of the whole supply chain; the personnel cannot be present at all locations and Myloc is therefore crucial to keep track of all information. The fact that there are a lot of spread out delivery points, the delivery routes changes every day, which affects the *Distance* at the construction site.

Land price in combination with *Available space* will impact the urgency to utilize storage. In the studied case, there are a lot of available space and the storage cost is quite low, compared to bigger cities in Sweden. This can be a reason for why the material is placed according to random stock location in the CCC. With a better storage policy, the cost could perhaps be reduced due to better utilization of the space, the parcels could be moved directly to the storage spot instead of moved around inside the CCC, which would reduce the number of handling and transportation activities.

The impact from *Type of material, A lot of scattered sub-projects* and *Number of actors involved* might be a reason for why the CLS in the studied case is so reliant on a few people. It is difficult to establish standards for such large variety of material and DB Schenker personnel are working with these material deliveries every day, which have given them time to gain experience and knowledge. An increase of number of actors in a project increase the complexity, which leads to higher requirements on coordination of the material flows. The CLS can handle this complexity and is advantageous to use for projects where a lot of actors are involved. There is however a limit for how many actors the CLS and the 3PL personnel can handle without proper delivery planning and standards for material handling activities. The more entrepreneurs and suppliers that are involved in a project, the more time will be spent on administrative work. To be able to reach the full potential of the CLS, there is a need to increase the number of deliveries that arrive with full delivery planning and to develop standards.

Generation can be connected to the experience of using mobile devices and computers, which can impact the use of an IT-system. The CLS is dependent on Myloc, and it is therefore important that personnel and contractors are comfortable to handle the application. For people that are not used to handle mobile devices and apps, administrative tasks and training can take more time, and this should be considered when starting new projects.

8. Discussion

The discussion is divided into three parts, one for each research question. Each part consists of reflections about the results obtained in the project.

8.1 Materials handling activities

This section discusses the results obtained for research question one presented in Chapter 5.

RQ 1: What are the materials handling activities that exist in the material flow of the CLS?

The level of detail for this project has been on a single factory level (Rother and Shook, 2001) and the level of detail has not been changed during the process. The reason for this is that the single factory level was enough to get an overview of the whole supply chain. The activities that have been mapped are specific for the NUS project. Some activities are being performed because of factors identified in this specific project, but most of the activities are based on the work performed by DB Schenker and are dependent on their working processes. If another 3PL provider would have been used, some of the activities would probably have been different.

The result show that no delivery planning creates a lot of extra work, both at the construction site at NUS and at the CCC. Light delivery planning is better but still requires a lot of extra activities compared to full delivery planning. The HATS-analysis shows that there is a significant difference in the number of administrative activities for the different delivery planning approaches. By connecting more material suppliers to Myloc and train them to perform the full delivery planning approach, a lot of the non-value-adding activities can be eliminated. However, to connect all material suppliers to Myloc might not be worth it since this would require a lot of time spend on training and development of work procedures. Some material suppliers are responsible for a small portion of the total amount of deliveries to the project, and it might not be worth it to connecting them to Myloc. For these suppliers, the light delivery planning approach might be enough.

8.2 Value-adding, non-value-adding and necessary activities

This section discusses the results obtained for research question two presented in Chapter 6.

RQ 2: What is value-adding, non-value-adding and necessary activities in the material flow in the CLS and how can non-value-adding activities be eliminated?

The categorization of value-adding, non-value-adding and necessary work is based on definitions created based on the theoretical framework. Some activities can be categorized in different ways depending on different viewpoints. Some of the activities have been categorized as necessary or value-adding because of factors identified for this specific project, the classification might not be the same for another project.

All suggested improvements are based on the VSM process and lean production principles and it is not certain that these improvements are the most optimal. There is always a risk of shortcomings when suggesting areas of improvements when the daily working processes have not been studied for a long time. One example is the storage policy of the CCC tent. Material is currently being stored based on material supplier or according to random stock location, and some sort of strategy for storing would probably be more beneficial. Which strategy that should be used depend. Zoning based on frequency is one suggestion, another suggestion could be to classify the warehouse based on how the material is being handled or how much volume it requires.

Many of the non-value-adding activities are performed since most of the material is being delivered with no or light delivery planning. If the construction area could be fenced, a checkpoint could have been used to be able to control the deliveries (Janné, 2018) and impose the contractors to plan better. This would force the contractors to inform the logistics personnel about when material will be delivered and would facilitate the implementation process of the CLS. For the CLS at NUS, the contractors have the possibility to choose planning approach, which might be one reason for why many deliveries arrive unannounced. If the contractors can choose between full delivery planning, light delivery planning and no delivery planning, it is easy to choose no delivery planning because then they do not need to change their way of working.

One of the most important requirements on the CLS is to ensure that the materials handling processes will not interfere with the ongoing activities at NUS. The activities at NUS cannot be disturbed by material deliveries, and this can lead to a lot of waiting for DB Schenker personnel due to closed passages and elevators, incoming ambulances and internal logistic processes. In the afternoon and at night, there are less people working on site and less internal logistic deliveries, and it would be possible to perform some or most of the carry-in deliveries at night. This would increase the possibility for DB Schenker personnel to move around NUS without disturbing other functions. Deliveries at night can lead to an increased utilization of the construction site and equipment, since the materials handling and the construction work do not interfere with each other and it reduces the waiting time (Ekeskär and Rudberg, 2016). Deliveries at night will however increase the cost for personnel and this will have to be considered before starting a night shift. It is important to increase efficiency of the daily work that is already being performed before starting a night shift. Material deliveries should be rescheduled more often to level out the workload.

8.3 Factors affecting materials handling activities

This section discusses the results obtained for research question three presented in Chapter 7.

RQ 3: What factors affect the materials handling activities in the CLS?

Table 14 presents a summary and comparison between factors affecting construction logistics identified in literature and the studied case. Most of the factors from literature were identified as factors affecting the construction logistics in the studied case as well. This discussion focuses on the differences between what was discovered in literature and what was identified in the case.

Directives and regulations about work environment is one factor that was not identified as impacting the construction logistics at NUS. This was not studied properly, which might be the reason for why it was not discovered, but one area of improvement for the material handling at NUS is ergonomics, which indicates that directives are something that needs to be considered. Directives about work environment gives guidance about what equipment to use for material handling at a construction site (AFS 2012:2), how to store material in a secure way (Council Directive 92/57/EEC of 24 June 1992; AFS: 1999:3) and what information needs to be available on packages (AFS 2012:2). Injuries are common in the construction industry, up to 10 percent of the cost in construction projects are related to work related injuries (Josephson and Saukkoriipi, 2005). From a social sustainability perspective, it is important that the 3PL logistics personnel is aware of how to handle construction material, in order to reduce injuries and accidents.

For ÅF to be aware of the regulations and directives that exists is important and it provides the possibility to put requirements on the 3PL that can prevent accidents connected to materials handling done in the CLS. The importance of ergonomics is something that ÅF should consider for future projects. The employer is responsible for investigating if the work postures, movements, manual handling task and the workload are harmful for the workers (AFS 2012:2). ÅF should emphasize the importance of using the right equipment so that the 3PL personnel will not get injured. Knowledge and experience of handling construction material is something that can be important to consider when choosing 3PL for future projects. If it is the first time the 3PL provider works with construction material, ÅF need to inform about directives regarding the work environment. When implementing the CLS, transportation and lifting possibilities for heavy material should be considered, to ensure good work conditions for the logistics personnel. An increased focus on ergonomics could affect the efficiency of the CLS, but this needs to be studied further.

Table 14: Comparison between factors identified in literature and factors identified in the studied case.

Factors	**Literature**	**Case study**
Directives and regulations	X	
Size of project	X	
Cost and budget	X	
Time duration	X	X
Available space	X	X
Surrounding environment and location	X	X
Construction site environment	X	X
Type of material	X	X
Storage location	X	X
Distance	X	X
Lead time and safety stock	X	X
Possibility to transport	X	X
Emissions	X	
Number of actors involved	X	X
Phase of construction project	X	X
Resources for materials handling and transportation on site	X	
Planning and coordination	X	X
Control and overview	X	X
Communication and transparency	X	X
Management's and main client's attitude	X	X
Climate and weather	X	X
Number of unloading zones	X	X
Consolidation and utilization of trucks	X	X
Unloading zone close to ambulance entrance		X
A lot of scattered sub-projects		X
Land price		X
Knowledge and experience of construction material		X
Generation		X

Size of the project was highlighted as a factor that can impact the logistics in literature (Chua and Kog, 1999; Faniran et al., 1998; Skjelbred et al., 2015). How the size of a project affects the CLS was not studied in this project. There are no certain definitions of what a large or small construction project is, and it is therefore difficult to say if this affects the CLS. One thing that could be connected to the project size is cost and budget. 3PL is not beneficial to use in small projects due to the cost (Skjelbred et al., 2015). Low cost was not a requirement from the client in the NUS case, the cost is therefore not a factor that affects the logistics in the NUS case, but it still needs to be considered in future projects. If the CCC is not already existing, it will create an extra cost as well. Budget of the project will affect the client's willingness to implement the CLS.

Cost and budget were not identified as a factor that affects the material handling at NUS, because the cost is not the driving force for the client in this case. However, it is a factor that can impact the CLS and the possibility to implement it. Cost and budget can affect the number of logistics personnel and resources that can be hired, which in turn affects the need to utilize the resource and the capacity of the CLS. For projects with a strict budget, storage cost should be kept as low as possible, which will affect the urgency to utilize space. At NUS, there is a lot of available space at the CCC and material is stored according to random stock location, there is no urgency to utilize the space better, even if it would be beneficial to have a structured storage policy.

Land price can impact the need to utilize storage space better. For cities with higher land price than Umeå or for projects with a tight budget, this can be a factor that needs to be considered. A reason for why *Land price* has not been identified as a factor in literature might be because it is included when cost is discussed, rather than being highlighted as factor on its own.

Site environment, *Available space* and S*urrounding environment* have been identified as important factors in literature, observations and interviews. A CCC and a 3PL is advantageous to use in urban areas (Sullivan et al., 2010), but might not be necessary for projects where limited space is not an issue, as in rural areas (Shigute and Nasirian, 2014; Skjelbred et al., 2015). A CCC is advantageous to use in projects where an ongoing business needs to be considered (Sullivan et al., 2010). An urban area *(Surrounding environment),* space limitations (*Space limitations)* and an ongoing business (*Site environment)* were three contributors to using the CLS at NUS. Sullivan et al. (2010) investigated a case with an ongoing hospital business and concluded that a CCC was advantageous to use for that case. In the NUS case, it was observed that the closeness of construction work in relation to the ongoing businesses and the ambulance entrance (*Unloading zone close to ambulance entrance)* is important. In the NUS project, where a CCC is used, the production is located close to the hospital activities and material is delivered close to the ambulance entrance. For the other hospital that was visited, a CCC is not being used, and the production does not disturb the ongoing activities since it is separated from the ongoing hospital activities and ambulance entrance. In that case, the construction logistics does not interfere with internal logistics processes either. This does not mean that the CLS would not be advantageous to use for that case, but it might be other factors that determines if it is the most optimal setup to use. Ongoing business is one factor that needs to be considered for future projects, but the closeness to these activities and other logistics flows to coordinate with need to be considered as well. For some projects, it might be enough to only provide the logistics services on site and the IT-service and not use the CCC.

Type of material is a factor identified both in literature and during observations at NUS. Small material is advantageous to handle via a CCC while larger components should be delivered directly to the construction site (Shigute and Nasirian, 2014). Large material that is needed right away should not go via the CCC either (Lundsjö, 2015). In the CLS at NUS, plywood and gypsum are handled and stored at the CCC, since there is not enough space to store this material at the construction site. If NUS was not a reconstruction project, it would perhaps be more space available at the construction site and it would be possible to deliver more types of material directly to the construction site. What material that should go via the CCC is something that could be considered in future projects. What type of material that can be categorized as small and large needs to be studied further.

One interesting aspect that has been observed at NUS, but not identified in literature, is the impact of customized products *(Type of material).* Literature focus on big and small material and the turnover rate, but studies regarding standard material versus customized material was not found. The reason for this might be that the customized products have a major impact on the administrative activities, which has not been studied in other cases. Customized products affect the HATS activities in the CLS, it causes problems and decrease the efficiency of the CLS, but to conclude whether to handle customized products or not for future projects needs to be studied further.

Distance is a factor that affects the construction logistics at NUS. The factor was identified in literature but only the aspect that the distance to the suppliers needs to be considered when designing the logistics solution (Skjelbred et al., 2015), and not the impact from the distances at a construction site. At NUS, restrictions of where and how material can be transported affect the logistics work. The routes that are being used are not always the routes with the shortest distances since elevators or certain areas at the hospital can be closed. Why this has not been identified in literature might be because it is connected to the ongoing business and hospital environment. Some transportation distances on site at NUS can perhaps be reduced if other unloading zones than L1 would be used. To only have one unloading zone is mentioned as positive to reduce the number of deliveries to the wrong location (Ekeskär and Rudberg, 2016), but the fact that it affects the distances that material has to be transported at the construction site have not been investigated in previous research. Projects with shorter transportation distances on site might benefit more from only using one unloading zone.

Possibility to transport was identified in literature and for the NUS case. The literature focus on the possibility to transport material to the construction site and the impact from the surrounding traffic (Ekeskär and Rudberg, 2016; Sullivan et al., 2010; Janné, 2018). The possibility to transport on site at NUS and which walkways and elevators that could be use had more impact on the HATS activities than the possibility to transport to the construction site. Why this has not been identified in literature can once again be connected to that it is the combination of factors that have the major impact, rather than just a single factor. The possibility to transport on site is connected to and affected by factors as *Construction site environment, Distance, Type of material* and *Available space*.

To reduce emissions was not in focus for the NUS project and *Emissions* was therefore not identified as a factor that has an impact on the CLS and the logistics activities. The CLS provides the possibility to consolidate and utilize trucks and aims to reduce the number of transports to the construction site, so it is possible to reduce emissions with the CLS. A high level of consolidation can reduce emissions, but it is dependent on the vehicle used, planning and foresight among other things (Sullivan et al., 2010). For a construction projects where the client has requirements on emission, the fill rate of the trucks and the consolidation rate needs to be considered (*Consolidation and utilization of trucks).* A project with requirements on emissions would benefit from using full delivery planning. Better utilization of trucks would perhaps require some flexibility in the delivery time and available space at the construction site, to have the possibility to increase the fill rate of all trucks.

Optimization of construction logistics can contribute to levelling out the workload for resources, both personnel and equipment (Lange and Schilling, 2015). For projects were there are limited resources that are seldom available, there is a major importance to utilize the resources more at the construction site, compared to at NUS. This is probably why *Resources for material handling and transportation on site* was not identified as a factor for the NUS case. The CLS at NUS still has unused capacity, more material and more deliveries can be handled. If the demand on the CLS is increasing at NUS, there will be a need to increase planning and reschedule deliveries to utilize the resources better. The CLS at NUS has not yet been pushed to its full potential, and this might be a reason for why the importance of standards have not been noticed yet. The right resources are not always available at NUS, which leads to time spent on waiting. So, if resources are available or not will affect the efficiency of the CLS, but when resources are missing out it is because the logistics personnel have not been informed about the delivery, not due to bad planning.

A lot of scattered sub-projects is a factor that impacts the construction logistics. It requires coordination of the different material flows and transportation, administration and physical handling of different types of materials. Why this has not been highlighted in literature is perhaps because a case with a specific CLS as the one at NUS, has not been studied before. The combination of scattered projects together with different construction phases and ongoing businesses to prioritize make this factor important for the NUS case.

Knowledge and experience of handling construction material has not been identified as a factor in literature. At NUS, this was identified as a factor that affect the possibility to handle the great variety of material in an efficient way. The reason for why this is not highlighted in literature is perhaps the same as for why customized products has not been mentioned, that it mostly affects the administrative tasks, not the material handing or transportation activities.

Generation was highlighted as a factor during interviews but was not detected in literature. The CLS is dependent on the IT-system. Myloc is used for administrative activities and communication between the logistics personnel and the entrepreneurs. This requires that the people that are working with Myloc can handle the application. This is probably not the most important problem since most people are used to smartphones, but it can be good to be aware of that generation of workers can impact how the CLS is addressed. The training of the application might have to be adapted to different generations. Why this is not highlighted in literature can be because the impact of an IT-system and how it is used in a construction project is usually not studied in detail.

9. Conclusion

The purpose of the study was *to identify potential improvements in the CLS and increase knowledge about factors that drive efficiency in this solution*. Triangulation was used with three different ways to collect data: interviews, literature and observation. This made it possible to determine the validity of the information.

The first research question, "W*hat are the materials handling activities that exist in the material flow of the CLS?*", is answered in Chapter 5. A VSM was used to map the current state material- and information flow activities. The number of HATS activities performed in the material flow in the case study are connected to the different delivery planning approaches. The HATS analysis show that it is the administrative activities the varies the most dependent on which delivery planning approach that is being used.

Research question two, "*What is value-adding, non-value-adding and necessary activities in the material flow in the CLS and how can non-value-adding activities be eliminated?*" is answered in Chapter 6 by categorizing the mapped activities into value-adding, non-value-adding and necessary work according to definitions adapted from the theoretical framework. A future state map was created, and lean production principles was used to eliminate non-value-adding activities and find improvement areas of the current state. The suggested improvements concern all four categories of HATS activities. The identified activities and the associated improvements regarding handling, storage and transportation activities are strongly connected to the work process in this specific case study.

The third research question, "*What factors affect the materials handling activities in the CLS?*", is answered in Chapter 7 by identifying factors in the theoretical framework and from observations and interviews in the case study. There are many factors that affect the CLS and the HATS activities. The theoretical framework and the case study were crucial for analyzing and discuss factors that drive efficiency of the CLS. Most of the factors identified in the case study, that has not been highlighted in literature, are mainly impacting the administrative activities.

What factors that drive efficiency of the CLS is dependent on the certain construction site and its limitations. It is important to understand how all factors influence each other to determine the efficiency of construction logistics. It is crucial to adapt the CLS to the conditions of the specific project and to maintain flexibility during the whole production process.

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Appendix

A. Interview guide for 3PL

- What is your role in this project? How do you use Myloc?
- How many orders per day do you have?
- How many orders per day are delivered with the different delivery planning approaches?
- What is working well with the logistics solution?
- What is not working with the logistics solution?
- How can the logistics solution be changed or improved to facilitate your work?
- What are the largest distractions of your daily work?
- What is your largest problem right now?
- Do you have any improvement suggestions?

B. Interview guide for entrepreneurs

- What is your role in this project?
- Describe how you are working with Myloc and the logistics solution
- How does your work differ when using differ when using different delivery planning approaches? Describe the different activities you have to perform.
  - How much time does the different approaches take?
  - How many telephone calls do the different approaches require?
  - How does the material and information flow differ?
- What is working well with the logistics solution?
- What is not working with the logistics solution?
- What can be changed or improved in the logistics solution to facilitate your work?
- How many days in advance do you usually place an order?
- What affect when you place an order and how much you order each time?
- How do you use Myloc to plan your work? Does Myloc change your way of planning?
- What are the attitudes from material suppliers regarding the different delivery planning approaches?

C. Interview guide for Myloc

- What is your role at the company/what is your profession? What are your work tasks?
- What are the most common reasons for why companies want to use the Myloc application?
- How does different companies use/apply Myloc in their projects? What functions are they interested of?
- How can the functions in Myloc be adapted to different projects?
- How many projects are working with full delivery planning?
- How are Myloc working with continuous improvements?
- For the construction projects where Myloc is used, are there any typical/common characteristics that you have noticed?

D. Interview guide for project leader for similar project

- What is your role? What are your daily work tasks?
- How does your logistics solution/logistics setup look like?
    - Why does it look like this/involve these parts?
- Can you explain the process from the point when an order is initiated at the material supplier to the point when the material is delivered?
- Are the material suppliers connected to the IT-system? Why/why not?
- Who can see the planning/calendar?
- How do all different actors communicate?
- What is special (special characteristics) with this construction project and the material flow/logistics?
- What is working well with the logistics solution?
- What is not working with the logistics solution?

E. VSM for NUS: packages

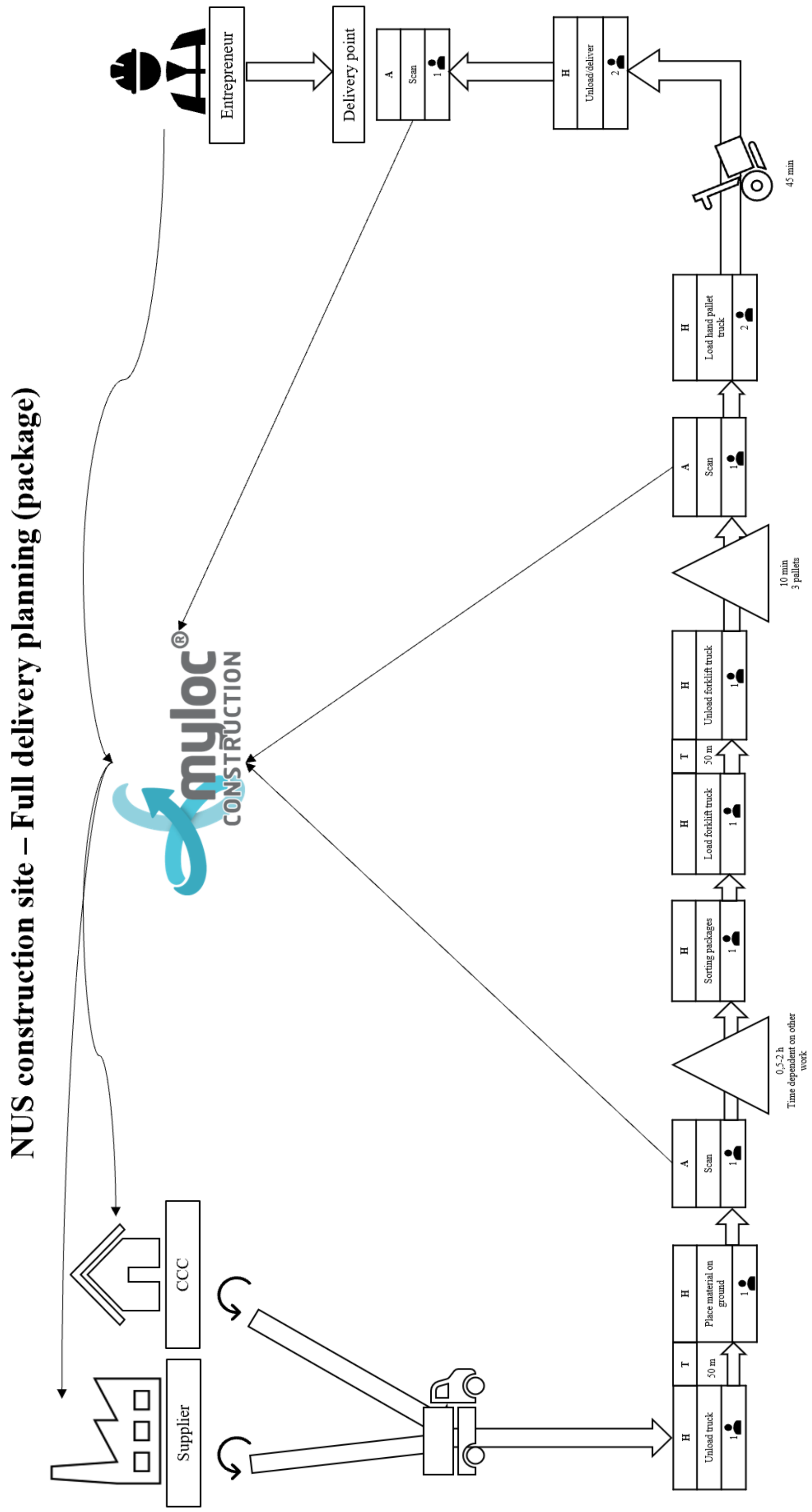

Figure E 1: VSM for full delivery planning at the construction site at NUS, handling a package.

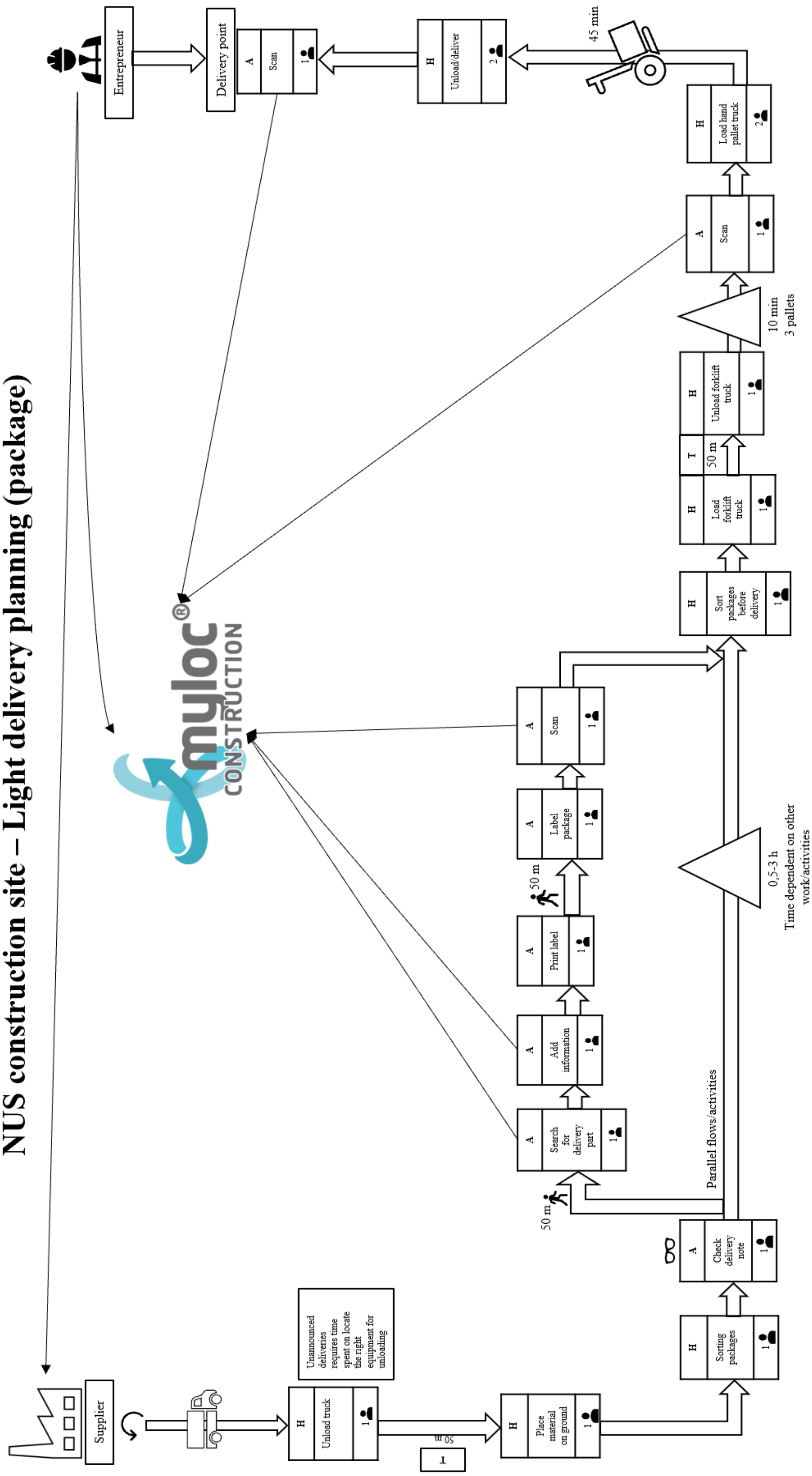

Figure E 2: VSM for light delivery planning at the construction site at NUS, handling a package

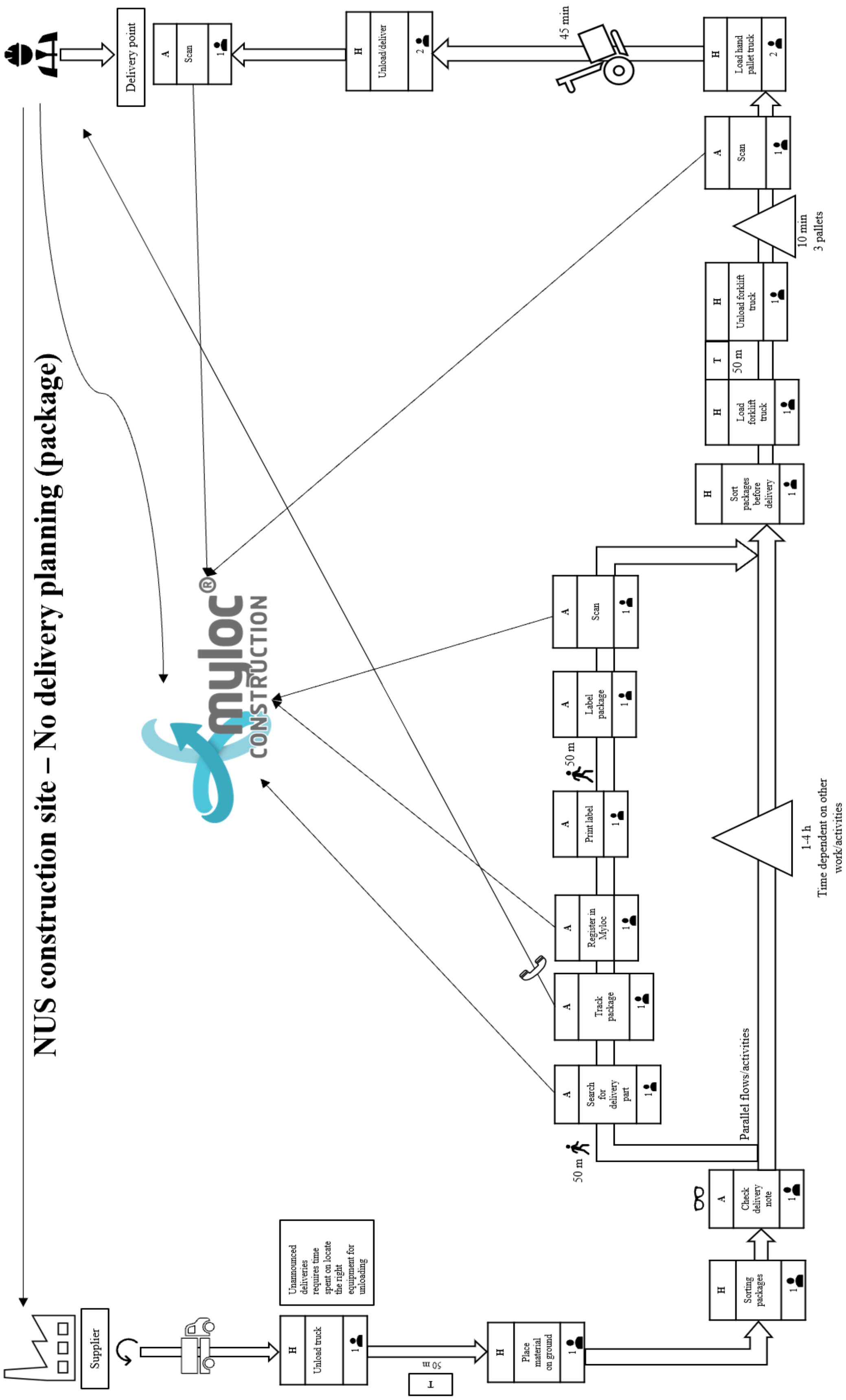

Figure E 3: VSM for no delivery planning at the construction site at NUS, handling a package.

F. VSM for NUS: pallets

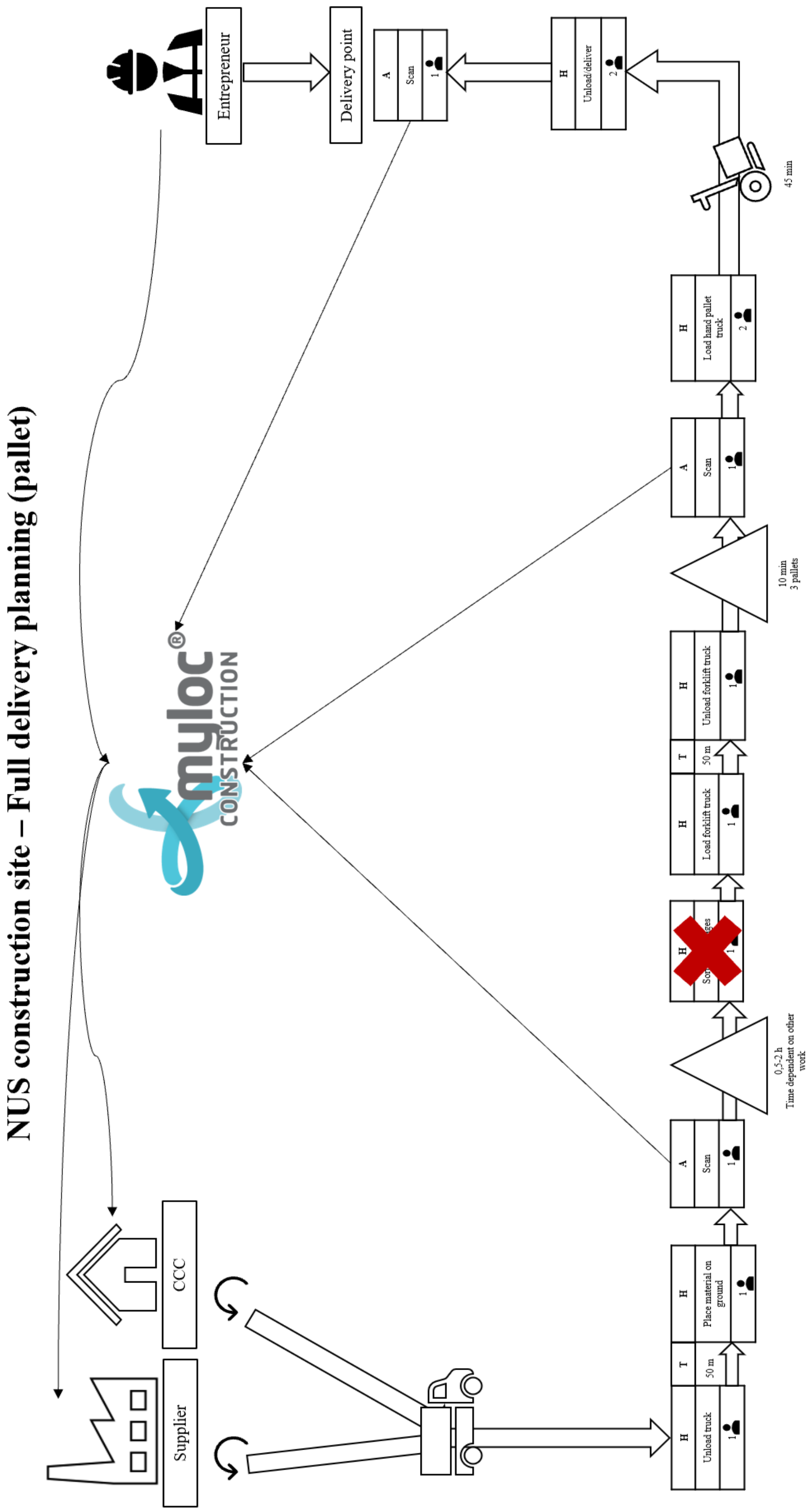

Figure F 1: VSM for full delivery planning at the construction site at NUS, handling a pallet. The red cross visualizes that one sorting activity is not being performed when handling pallets instead of packages.

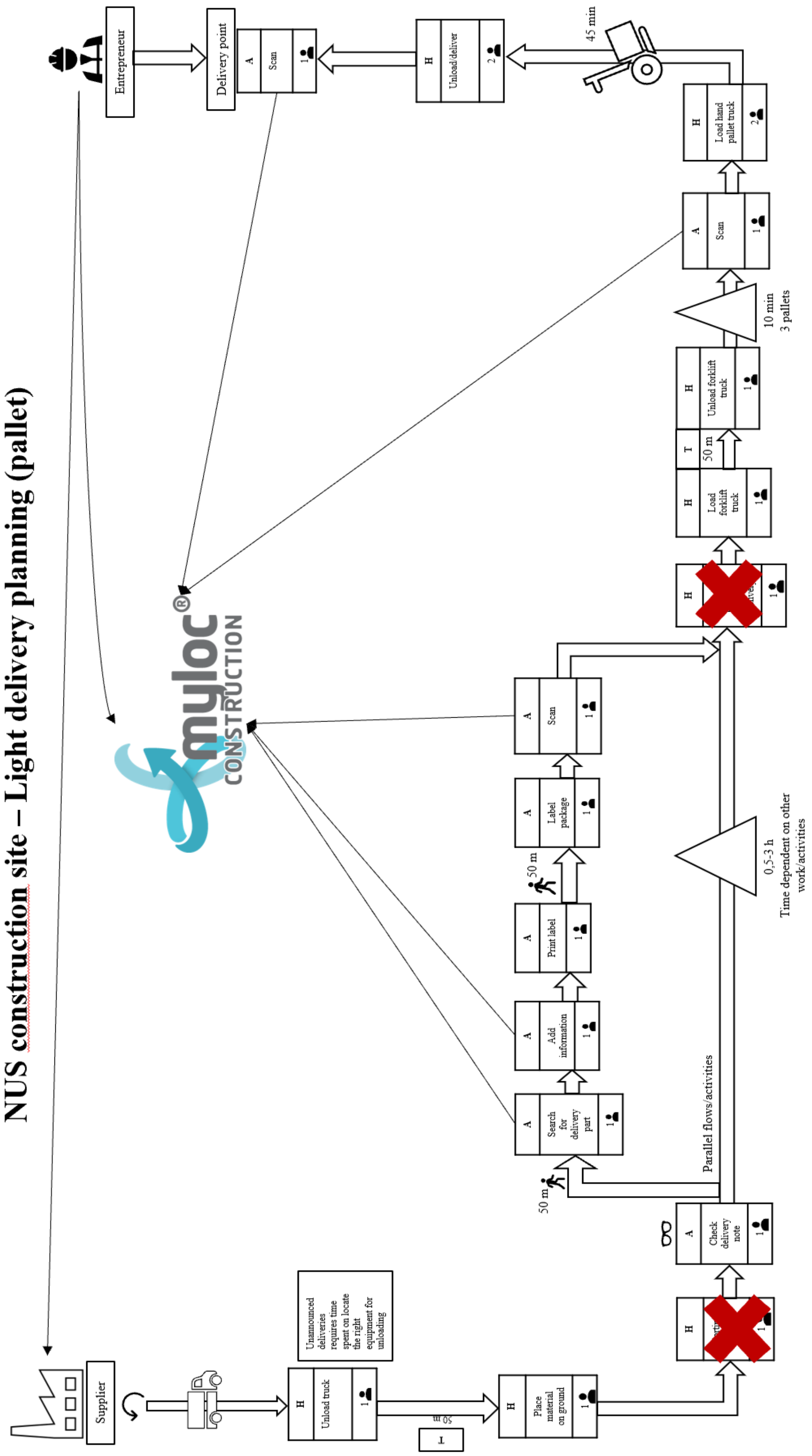

Figure F 2: VSM for light delivery planning at the construction site at NUS, handling a pallet. The red cross visualizes that two sorting activities are not being performed when handling pallets instead of packages.

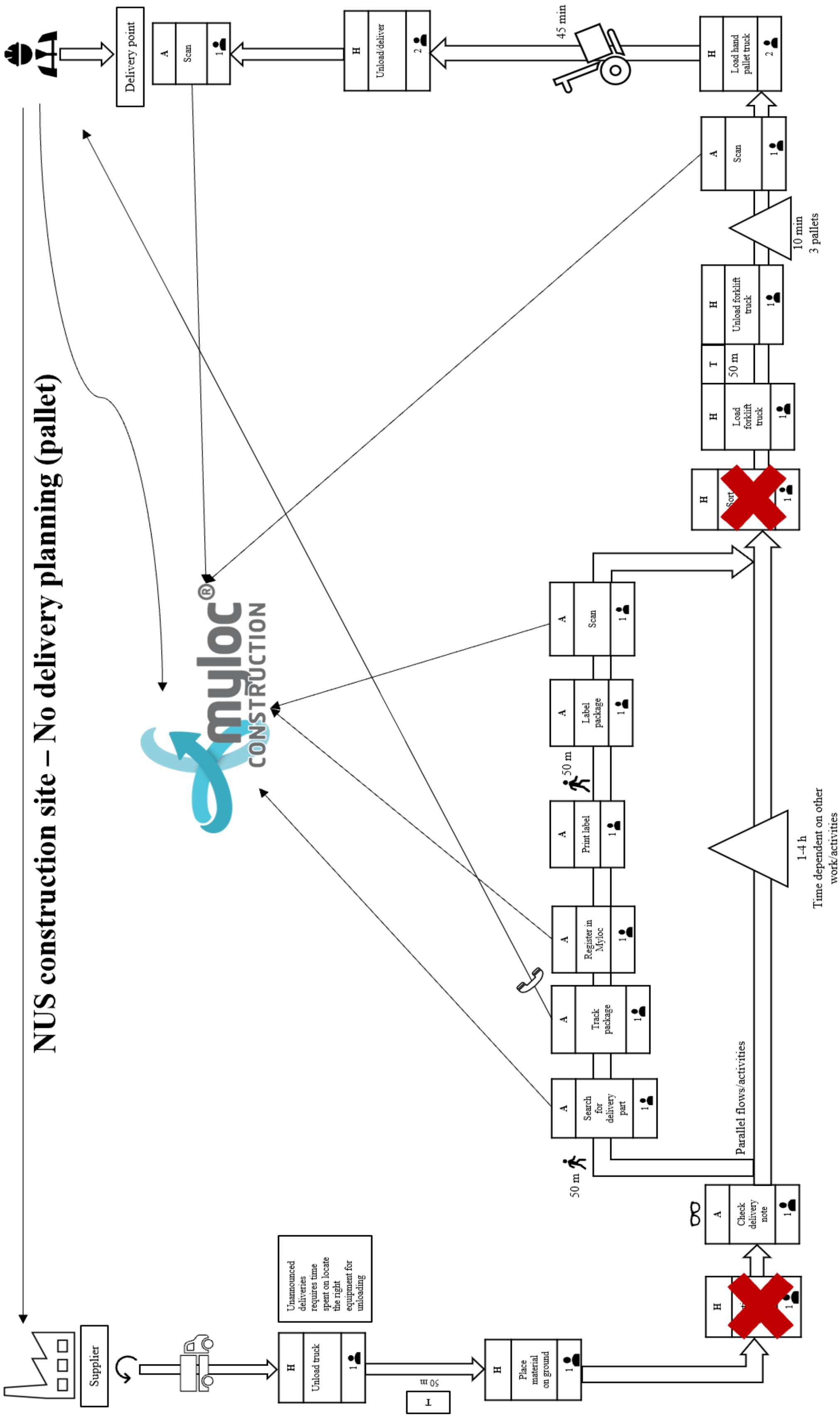

Figure F 3: VSM for no delivery planning at the construction site at NUS, handling a pallet. The red cross visualizes that two sorting activities are not being performed when handling pallets instead of packages.

G. VSM for CCC

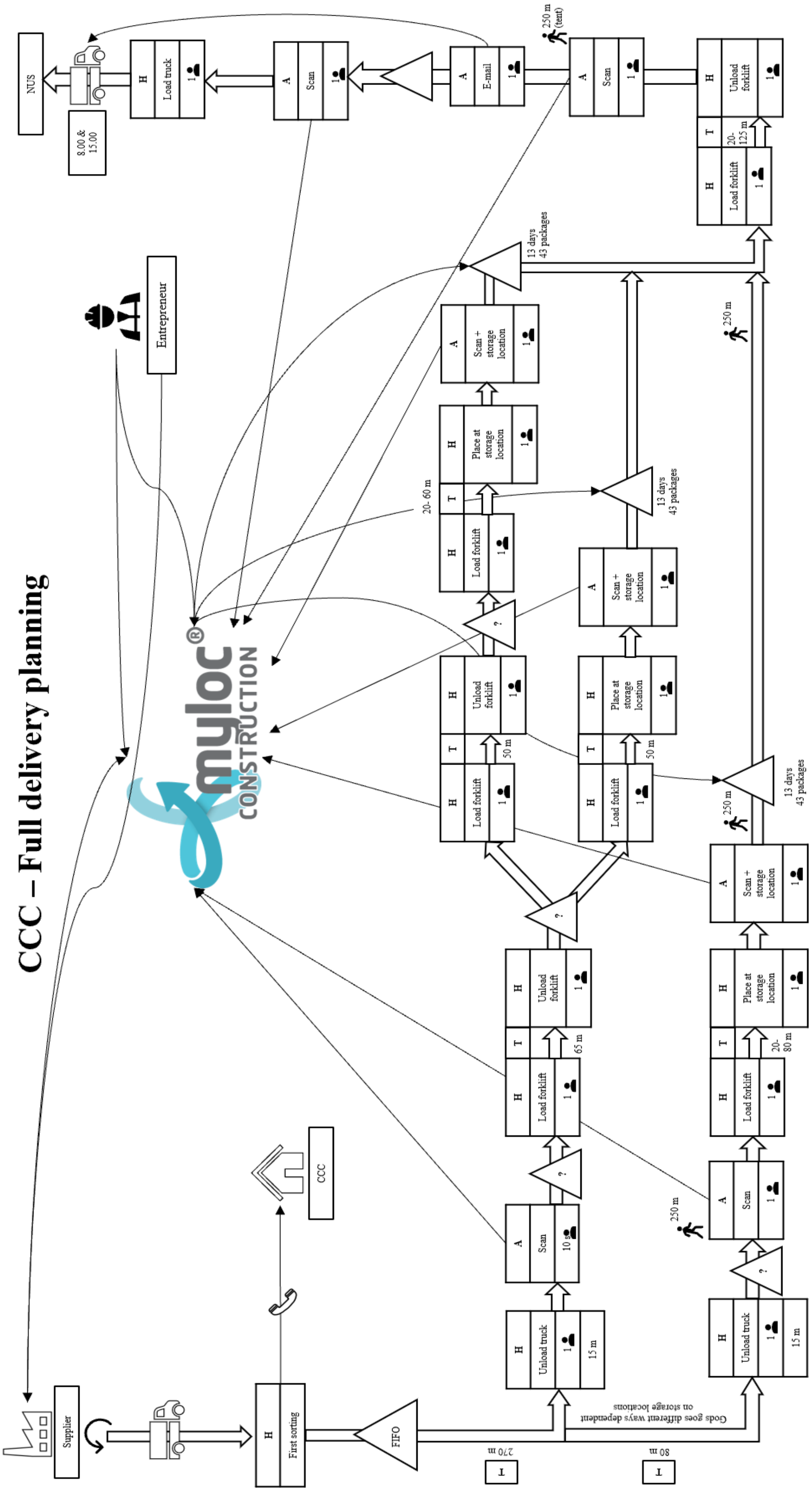

Figure G 1: *VSM for full delivery planning at the CCC tent and CCC warehouse. The flow in the bottom visualizes the flow in the CCC tent.*

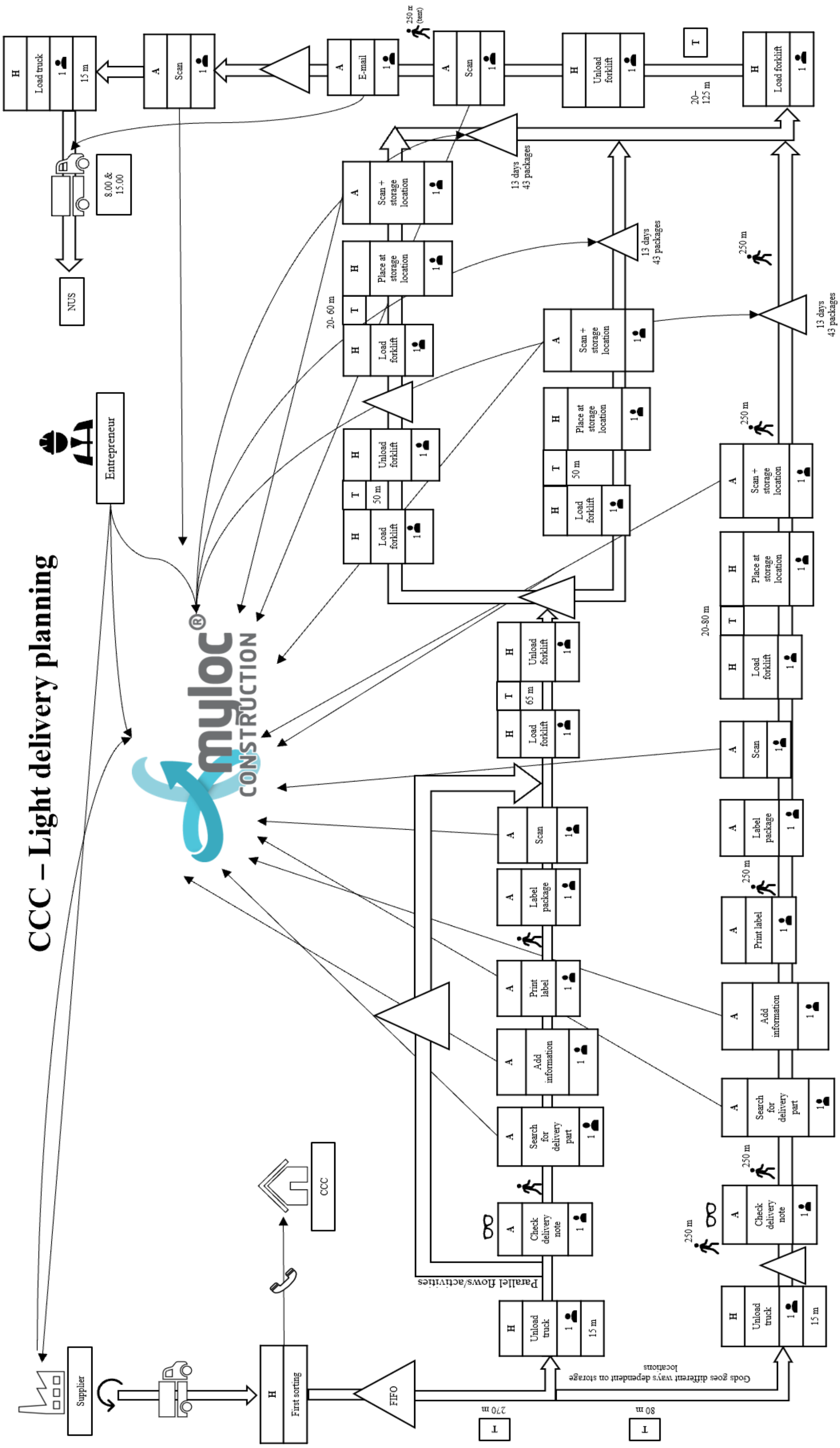

Figure G 2: VSM for light delivery planning at the CCC tent and CCC warehouse. The flow in the bottom visualizes the flow in the CCC tent.

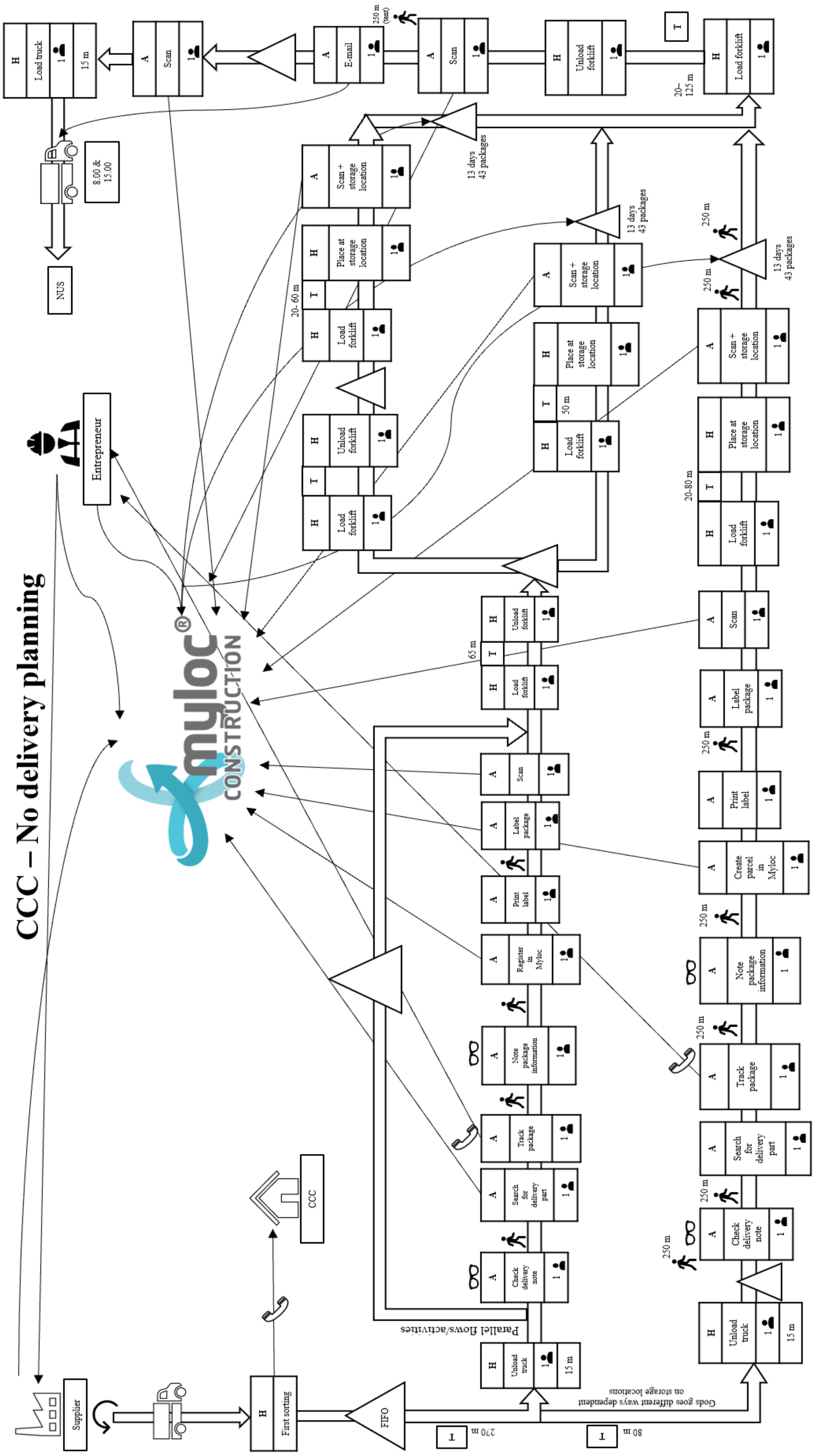

Figure G 3: VSM for no delivery planning at the CCC tent and CCC warehouse. The flow in the bottom visualizes the flow in the CCC tent.

H. Categorization of activities at NUS

Table H 1: Categorization of the material handling activities are NUS for full delivery planning and light delivery planning for packages.

NUS								
Activities	**Full Delivery Planning**	**HATS**	**Value**	**Distance [m]**	**Delivery Planning Light Packages**	**HATS**	**Value**	**Distance [m]**
1	Unload Truck	H	NNVA		Unload Truck	H	NNVA	
2	Drive to tent	T	NVA	50	Drive to tent	T	NVA	50
3	Place material on ground	H	NVA		Place material on ground	H	NVA	
4	Scanning	A	NNVA		Sorting of packages	H	NVA	
5	Sorting packages	H	NVA		Check delivery note	A	NNVA	
6	Storage	S	NNVA		Storage	S	NNVA	
7	Load forklift truck	H	NNVA		Walking to office	T	NVA	50
8	Drive to gate	T	VA	50	Search for delivery part	A	NNVA	
9	Unload forklift truck	H	NVA		Add information in Myloc	A	NNVA	
10	Store	S	NVA		Print label	A	NNVA	
11	Scanning	A	VA		Walking from office	T	NVA	50
12	Load hand pallet truck	H	NVA		Label package	A	NNVA	
13	Walk to delivery point	T	VA		Scanning	A	NVA	
14	Unload	H	VA		Sort packages before delivery	H	VA	
15	Scanning	A	VA		Load forklift truck	H	NNVA	
16					Drive to gate	T	VA	50
17					Unload forklift truck	H	NVA	
18					Storage	S	NVA	
19					Scanning	A	VA	
20					Load hand pallet truck	H	NVA	
21					Walk to delivery point	T	VA	
22					Unload delivery	H	VA	
23					Scanning	A	VA	
24								
25								
26								
27								
28								
	H	7			**H**	8		
	A	3			**A**	8		
	S	2			**S**	2		
	T	3			**T**	5		
	Summary	**15**		**100**	**Summary**	**23**		**200**
	VA		5		VA		6	
	NVA		6		NVA		9	
	NNVA		4		NNVA		8	

Table H 2: Categorization of the material handling activities are NUS for no delivery planning and light delivery planning for pallets (plywood).

	NUS							
Activities	**Delivery Planning Light Pallets**	**HATS**	**Value**	**Distance [m]**	**No Delivery Planning**	**HATS**	**Value**	**Distance [m]**
1	Unload Truck	H	NNVA		Unload truck	H	NNVA	
2	Drive to tent	T	NVA	50	Drive to tent	T	NVA	50
3	Place material on ground	H	NVA		Place material on ground	H	NVA	
4	Check delivery note	A	NNVA		Sorting of packages	H	NVA	
5	Storage	S	NNVA		Check delivery note	A	NNVA	
6	Walking to office	T	NVA	50	Storage	S	NNVA	
7	Search for delivery part	A	NNVA		Walk to office	T	NVA	50
8	Add information in Myloc	A	NNVA		Search for delivery part	A	NNVA	
9	Print label	A	NNVA		Track package	A	NVA	
10	Walking from office	T	NVA	50	Register in Myloc	A	NNVA	
11	Label package	A	NNVA		Print label	A	NNVA	
12	Scanning	A	NVA		Walk from office	T	NVA	50
13	Load forklift truck	H	NNVA		Label package	A	NNVA	
14	Drive to gate	T	VA	50	Scanning	A	NVA	
15	Unload forklift truck	H	NVA		Sort packages before delivery	H	VA	
16	Storage	S	NVA		Load forklift truck	H	NNVA	
17	Scanning	A	VA		Transportation	T	VA	50
18	Load hand pallet truck	H	NVA		Unload forklift truck	H	NVA	
19	Walk to delivery point	T	VA		Storage	S	NVA	
20	Unload deliver	H	VA		Scanning	A	VA	
21	Scanning	A	VA		Load hand pallet truck	H	NVA	
22					Walk to delivery point	T	VA	
23					Unload deliver	H	VA	
24					Scanning	A	VA	
25								
26								
27								
28								
	H	8			**H**	8		
	A	8			**A**	9		
	S	2			**S**	2		
	T	5			**T**	5		
	Summary	**23**		**200**	**Summary**	**24**		**200**
	VA		5		VA		6	
	NVA		8		NVA		10	
	NNVA		8		NNVA		8	

I. Categorization of activities at CCC

There are two columns with activities and categorizations for the CCC warehouse. These two represents the two different routes, presented in VSM, the parcels can be transported inside the CCC Warehouse.

Table I 1: Categorization of the material handling activities at the CCC for full delivery planning.

CCC - Full delivery planning												
Activities	**1. CCC Warehouse**	**HATS**	**Value**	**Distance [m]**	**2. CCC Warehouse**	**HATS**	**Value**	**Distance [m]**	**3. CCC Tent**	**HATS**	**Value**	**Distance [m]**
1	First sorting	H	NVA		First sorting	H	NVA		First sorting	H	NVA	
2	Call BLC	A	NVA		Call BLC	A	NVA		Call BLC	A	NVA	
3	Storage	S	NVA		Storage	S	NVA		Storage	S	NVA	
4	Transport	T	NVA	270	Transport	T	NVA	270	Transport	T	NVA	80
5	Unload truck	H	NNVA	15	Unload truck	H	NNVA	15	Unload truck	H	NNVA	15
6	Scanning	A	VA		Scanning	A	VA		Storage	S	NVA	
7	Storage	S	NVA		Storage	S	NVA		Walk to tent	T	NNVA	250
8	Load Forklift	H	NVA		Load Forklift	H	NVA		Scanning	A	VA	
9	Transport	T	NVA	65	Transport	T	NVA	65	Load Forklift	H	NVA	
10	Unload forklift	H	NVA		Unload forklift	H	NVA		Transport	T	NNVA	50
11	Storage	S	NVA		Storage	S	NVA		Place at storage location	H	VA	
12	Load forklift	H	NVA		Load Forklift	H	NVA		Scanning + storage location	A	VA	
13	Transport	T	NVA	50	Transport	T	NNVA	50	Walk from tent	T	NNVA	250
14	Unload forklift	H	NVA		Place at storage location	H	VA		Storage	S	VA	
15	Storage	S	NVA		Scanning + storage location	A	VA		Walk to tent	T	NNVA	250
16	Load forklift	H	NVA		Storage	S	VA		Load forklift	H	NNVA	
17	Transport	T	NNVA	40	Load Forklift	H	NNVA		Transport	T	NNVA	50
18	Place at storage location	H	VA		Transport	T	NNVA	115	Unload forklift	H	NNVA	
19	Scanning + storage location	A	VA		Unload forklift	H	NNVA		Scanning	A	NNVA	
20	Storage	S	VA		Scanning	A	NNVA		Walk from tent	T	NNVA	250
21	Load forklift	H	NNVA		Email	A	NNVA		E-mail	A	NNVA	
22	Transport	T	NNVA	125	Storage	S	NVA		Storage	S	NVA	
23	Unload forklift	H	NNVA		Scanning	A	NNVA		Scanning	A	NNVA	
24	Scanning	A	NNVA		Load Truck	H	NNVA	15	Load truck	H	NNVA	15
25	Email	A	NNVA									
26	Storage	S	NVA									
27	Scanning	A	NNVA									
28	Load Truck	H	NNVA	15								
29												
30												
31												
32												
33												
34												
35												
25												
25												
25												
25												
25												
	H	11			**H**	9			**H**	7		
	A	6			**A**	6			**A**	6		
	S	6			**S**	5			**S**	4		
	T	5			**T**	4			**T**	7		
	Summary	**28**		**580**	**Summary**	**24**		**530**	**Summary**	**24**		**1210**
	VA		4		VA	4			VA		4	
	NVA		15		NVA	11			NVA		7	
	NNVA		9		NNVA	9			NNVA		13	

Table I 2: Categorization of the material handling activities at the CCC for light delivery planning.

	CCC - Light delivery planning											
Activities	**1. CCC Warehouse**	**HATS**	**Value**	**Distance [m]**	**2. CCC Warehouse**	**HATS**	**Value**	**Distance [m]**	**3. CCC Tent**	**HATS**	**Value**	**Distance [m]**
1	First sorting	H	NVA		First sorting	H	NVA		First sorting	H	NVA	
2	Call BLC	A	NVA		Call BLC	A	NVA		Call BLC	A	NVA	
3	Storage	S	NVA		Storage	S	NVA		Storage	S	NVA	
4	Transport	T	NVA	270	Transport	T	NVA	270	Transport	T	NVA	80
5	Unload truck	H	NNVA	15	Unload truck	H	NNVA	15	Unload truck	H	NNVA	15
6	Check delivery note	A	VA		Check delivery note	A	NNVA		Storage	S	NVA	
7	Walk to computer	T	NVA		Walk to computer	T	NVA		Walk to tent	T	NNVA	
8	Search for delivery part	A	NNVA		Search for delivery part	A	NNVA		Check delivery note	A	NNVA	
9	Add information in Myloc	A	NNVA		Add information in Myloc	A	NNVA		Walk back	T	NVA	250
10	Print label	A	NNVA		Print label	A	NNVA		Search for delivery part	A	NNVA	
11	Walk back	T	NVA		Walk back	T	NVA		Add information in Myloc	A	NNVA	
12	Label parcel	A	NNVA		Label parcel	A	NNVA		Print label	A	NNVA	
13	Scanning	A	NVA		Scanning	A	NVA		Walk to tent	T	NVA	250
14	Storage	S	NVA		Storage	S	NVA		Label parcel	A	NNVA	
15	Load forklift	H	NVA		Load forklift	H	NVA		Scanning	A	NVA	
16	Transport	T	NVA	65	Transport	T	NVA	65	Load forklift	H	NVA	
17	Unload forklift	H	NVA		Unload forklift	H	NVA		Transport	T	NNVA	50
18	Storage	S	NVA		Storage	S	NVA		Place at storage location	H	VA	
19	Load forklift	H	NVA		Load forklift	H	NVA		Scanning + storage location	A	VA	
20	Transport	T	NVA	50	Transport	T	NNVA	50	Walk back	T	NNVA	250
21	Unload forklift	H	NVA		Place at storage location	H	VA		Storage	S	VA	
22	Storage	S	NVA		Scanning + storage location	A	VA		Walk to tent	T	NNVA	250
23	Load forklift	H	NVA		Storage	S	VA		Load forklift	H	NNVA	
24	Transport	T	NNVA	40	Load forklift	H	NNVA		Transport	T	NNVA	50
25	Place at storage location	H	VA		Transport	T	NNVA	115	Unload forklift	H	NNVA	
26	Scanning + storage location	A	VA		Unload forklift	H	NNVA		Scanning	A	NNVA	
27	Storage	S	VA		Scanning	A	NNVA		Walk back to CLC	T	NNVA	250
28	Load forklift	H	NNVA		E-mail	A	NNVA		E-mail	A	NNVA	
29	Transport	T	NNVA	125	Storage	S	NVA		Storage	S	NVA	
30	Unload forklift	H	NNVA		Scanning	A	NNVA		Scanning	A	NNVA	
31	Scanning	A	NNVA		Load truck	H	NNVA	15	Load truck	H	NNVA	15
32	E-mail	A	NNVA									
33	Storage	S	NVA									
34	Scanning	A	NNVA									
35	Load truck	H	NNVA	15								
25												
25												
25												
25												
25												
	H	11			**H**	9			**H**	7		
	A	11			**A**	11			**A**	11		
	S	6			**S**	5			**S**	4		
	T	7			**T**	6			**T**	9		
	Summary	**35**		**580**	**Summary**	**31**		**530**	**Summary**	**31**		**1460**
	VA		4		VA		3		VA		3	
	NVA		18		NVA		14		NVA		10	
	NNVA		13		NNVA		14		NNVA		18	

Table I 3: Categorization of the material handling activities at the CCC for no delivery planning

	CCC - No delivery planning											
Activities	**1. CCC Warehouse**	**HATS**	**Value**	**Distance [m]**	**2. CCC Warehouse**	**HATS**	**Value**	**Distance [m]**	**3. CCC Tent**	**HATS**	**Value**	**Distance [m]**
1	First sorting	H	NVA		First sorting	H	NVA		First sorting	H	NVA	
2	Call BLC	A	NVA		Call BLC	A	NVA		Call BLC	A	NVA	
3	Storage	S	NVA		Storage	S	NVA		Storage	S	NVA	
4	Transport	T	NVA	270	Transport	T	NVA	270	Transport	T	NVA	80
5	Unload truck	H	NNVA	15	Unload truck	H	NNVA	15	Unload truck	H	NNVA	15
6	Check delivery note	A	NNVA		Check delivery note	A	NNVA		Storage	S	NVA	
7	Walk to computer	T	NVA		Walk to computer	T	NVA		Walk to tent	T	NNVA	250
8	Search for delivery part	A	NNVA		Search for delivery part	A	NNVA		Check delivery note	A	NNVA	
9	Track package	A	NVA		Track package	A	NVA		Walk back	T	NVA	250
10	Walk back	T	NVA		Walk back	T	NVA		Search for delivery part	A	NNVA	
11	Note package information	A	NNVA		Note package information	A	NNVA		Track package	A	NVA	
12	Walk to computer	T	NVA		Walk to computer	T	NVA		Walk to tent	T	NVA	250
13	Register in Myloc	A	NNVA		Register in Myloc	A	NNVA		Note package information	A	NNVA	
14	Print label	A	NNVA		Print label	A	NNVA		Walk back to CLC	T	NVA	250
15	Walk back	T	NVA		Walk back	T	NVA		Register in Myloc	A	NNVA	
16	Label parcel	A	NNVA		Label parcel	A	NNVA		Print label	A	NNVA	
17	Scanning	A	NNVA		Scanning	A	NNVA		Walk to tent	T	NVA	250
18	Storage	S	NVA		Storage	S	NVA		Label parcel	A	NNVA	
19	Load Forklift	H	NVA		Load Forklift	H	NVA		Scanning	A	NNVA	
20	Transport	T	NVA	65	Transport	T	NVA	65	Load forklift	H	NVA	
21	Unload forklift	H	NVA		Unload forklift	H	NVA		Transport	T	NNVA	50
22	Storage	S	NVA		Storage	S	NVA		Place at storage location	H	VA	
23	Load Forklift	H	NVA		Load Forklift	H	NVA		Scanning + storage location	A	VA	
24	Transport	T	NVA	50	Transport	T	NNVA	50	Walk back	T	NNVA	250
25	Unload forklift	H	NVA		Place at storage location	H	VA		Storage	S	VA	
26	Storage	S	NVA		Scanning + storage location	A	VA		Walk to tent	T	NNVA	250
27	Load forklift	H	NVA		Storage	S	VA		Load forklift	H	NNVA	
28	Transport	T	NNVA	40	Load forklift	H	NNVA		Transport	T	NNVA	50
29	Place at storage location	H	VA		Transport	T	NNVA	115	Unload forklift	H	NNVA	
30	Scanning + storage location	A	VA		Unload forklift	H	NNVA		Scanning	A	NNVA	
31	Storage	S	VA		Scanning	A	NNVA		Walk back to CLC	T	NNVA	250
32	Load forklift	H	NNVA		E-mail	A	NNVA		E-mail	A	NNVA	
33	Transport	T	NNVA	125	Storage	S	NVA		Storage	S	NVA	
34	Unload forklift	H	NNVA		Scanning	A	NNVA		Scanning	A	NNVA	
35	Scanning	A	NNVA		Load truck	H	NNVA	15	Load truck	H	NNVA	15
25	E-mail	A	NNVA									
25	Storage	S	NVA									
25	Scanning	A	NNVA									
25	Load truck	H	NNVA	15								
25												
	H	11			**H**	9			**H**	7		
	A	13			**A**	13			**A**	13		
	S	6			**S**	5			**S**	4		
	T	9			**T**	8			**T**	11		
	Summary	**39**		**580**	**Summary**	**35**		**530**	**Summary**	**35**		**2210**
	VA		3		VA		3		VA		3	
	NVA		20		NVA		16		NVA		12	
	NNVA		16		NNVA		16		NNVA		20	