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Evaluation of on-site logistics at different types of construction projects

Master's thesis in Design and Construction Project Management

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Cover:
Checkpoint and tents for the ASP-block. The project is explained further in Section 4.2 (Authors' own figure).

Department of Architecture and Civil Engineering
Göteborg, Sweden, 2023

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ABSTRACT

There is a reduced level of attention to logistics in the construction sector according to the literature. Even though studies have shown that improved logistical measures have provided benefits it is still not implemented at a large scale across the sector. Consequently, the same challenges can be found across projects. The aim of the thesis is therefore to find out if a set of solutions can be found to solve multiple logistical challenges in construction projects. This was done by first performing an empirical and literature background study to find out what challenges exist in construction projects. In the empirical study, four ongoing construction projects, with different characteristics, were scrutinized. It was found that all sites had challenges regarding the handling of deliveries to the construction site and material handling. As an example of this, all sites reported that there was no system to, for instance, keep track of when deliveries had arrived, where they had been placed, and what they contained. After these challenges had been identified through a systematic analysis, possible solutions were explored. In total, three solutions were studied and included the services provided by TPL providers Myloc and Qlocx as well as the implementation of a logistics plan. With the aim of investigating applicability, the solutions were then presented back to the case company. The study concluded that these solutions would be applicable in practice and provide value to many of the case companies' projects. By adding accessible information to the material flow and providing certainty of when and where material is being delivered the TPL services proved valuable to solve challenges regarding coordination and planning. Further, the CLP was deemed a good tool to initiate projects to organize and structure the intended flow of logistics at construction sites. By documenting the logistical setup, the organization can take steps towards standardizing logistics methods across their future projects.

Key words: Construction logistics, supply chain management, challenges, solutions

Contents

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Albert Andersson & Oscar van Heek

List of acronyms

ADP	Area Disposition Plan
CCC	Construction Consolidation Center
CLP	Construction Logistics Plan
DMS	Delivery Management System
JIT	Just in Time
KPI	Key Performance Indicators
TPL	Third Party Logistics

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1 Introduction

1.1 Background

Construction logistics is a critical aspect of a construction project yet is often overlooked and under-managed (Sullivan et al., 2010). Poor logistics management is one of the leading causes of delays and cost overruns in construction projects (Lundesjo, 2015; Agapiou et al., 1997). Further, inadequate logistics planning can lead to decreased productivity and quality of the final product (Sullivan et al., 2010). A study by Thunberg and Persson (2014) determined that only 38% of all deliveries at a Swedish construction site were delivered according to agreements (in the right amount and condition, on time, to the correct place, and with proper documentation). Further, it revealed that it takes 134 minutes on average to schedule, receive and handle ordered material. In traditional cases, where there is not a centralized logistics function, this is time wasted for the craftsmen who will have to carry out this task instead of their usual value-adding construction work. Strandberg and Josephson (2005), concluded through a case study of a Swedish construction project that 14% of the craftsmens time was spent searching for and handling material. In addition, the case study of a Danish construction project by Agapiou et al. (1997) concluded that the implementation of a logistics model resulted in cost savings equal to about 5% of the total production cost compared to a traditional approach.

With this in mind, and with an increase in demands for sustainability and climate considerations, providing good solutions through the implementation of logistics- and supply chain management can provide positive benefits for the entire supply chain network (Lundesjo, 2015). A major challenge in making the network efficient in terms of logistics is the temporary nature of construction projects (Dubois et al., 2019). As a project starts several temporary supply chains need to be established (Vrijhof & Koskela, 2000) which involves contractors and subcontractors that are used to working in their own supply network, independently from one another (Dubois et al., 2019). Naturally, each actor makes decisions that are beneficial for themselves rather than prioritizing others in the supply chain system. This complex setting with several independent actors is one of the main explanations for the waste that is being produced as little consideration is taken for the holistic value of the project (Vrijhoef & Koskela, 2000). Consequently, to improve logistics within construction the primary challenges that need to be dealt with are improved coordination and communication within the supply network during design and construction (Agapiou et al., 1997; Thunberg et al., 2014).

It is evident that there are multiple logistical challenges that are recurring in different types of projects. For instance, the loss of materials or misunderstandings in the supply chain (Thunberg & Persson, 2014). When two site managers were interviewed, as part of background research for the thesis, they further expressed that there was a potential for improvement in logistics. Since similar challenges seem to occur across projects, could it be possible to create guidelines applicable across projects even though the challenges do not manifest in the same way? This has led to the following research question.

1.2 Aim and research question

Can logistic challenges across projects be solved by a general set of solutions deemed applicable by a contractor, even though the challenges do not manifest in the same way?

To be able to answer the research question it has been deconstructed into three smaller ones, each representing a separate phase of the study.

> **Q1:** What are the logistical challenges recurring across projects independent of the project prerequisites?
>
> **Q2:** What solutions are appropriate to solve those?
>
> **Q3:** Are the solutions realistic to implement from a contractor's perspective?

1.3 Delimitation

A geographical delimitation was set for the empirical part of the study to Västra Götaland County, Sweden. This was because it would be too difficult to physically study active construction projects further away. To complement this the core of the literature study was made up of Swedish research. However, the literature study was not delimited to a specific geographical location as similarities in settings of projects were highly valued regardless of geographical context.

After consulting with site managers at two different projects it became evident that more comprehensive logistic work was needed on-site than upstream. This led to the decision that only on-site logistics would be scrutinized.

Only public-use projects were studied in the empirical part of the research. This was because ByggDialog, which the thesis was in collaboration with, mainly manages these types of projects. Accordingly, the literature study was focused on research within such projects. However, it was not solely based on these types of projects.

Only challenges found frequently in the analysis among all projects will be focused on. The reason for this is to find solutions that have a wide implementation area for all projects.

The solutions investigated for our research question were chosen in line with the results of the thematic analysis. Therefore, the solutions were mainly focused on challenges regarding the coordination of construction site logistics, targeting as many projects as possible.

1.4 Reading guide

This introductory chapter is followed by the method, explaining the abductive strategy in combination with the qualitative data gathering used in this thesis. After this, the findings of the literature study are presented followed by the empirical cases used in

the study. The findings of the thesis are thereafter analyzed and ultimately concluded in the final chapters.

2 Methodology

2.1 Research method

Before determining the research question and research method, two site visits were made. This was to get a general idea of how the construction sites that were studied functioned and what the common logistic challenges were. Semi-structured reviews were held with the site manager at each location. Before the interview, the site managers gave a short presentation of their respective projects. The semi-structured interviews were based on a previously developed interview guide. As the presentation sparked more questions some were added before the interview, and follow-up questions were also asked and added to the guide subsequently. This led to a better understanding of on-site logistical challenges and ultimately resulted in the research question used for the thesis.

The thesis is based on a qualitative research approach containing semi-structured interviews as well as a systematic literature review. The qualitative approach was chosen to get more in-depth knowledge of, for instance, how individuals on different levels of the project experience site logistics as well as how it is compared to other projects. One of the reasons for choosing a qualitative approach is that it can give a better explanation of "whats and hows" (Silverman, 2014). This means that a qualitative research approach can give answers to why certain inputs translate into certain outputs as opposed to quantitative methods where establishing correlations between variables is harder. Furthermore, while a quantitative method can produce a large amount of data, which can be useful, the data can be hard to use when creating grounded theories (Silverman, 2014), which is the purpose of this thesis.

The data collection has been made in accordance with an abductive strategy. As described by Bell et al. (2019) abduction starts with a problem that, through empirical- and theoretical research, is investigated with the aim of acquiring a better understanding. This approach involves moving back and forth between empirical evidence and literature in an iterative process as seen in Figure 2.1.

Background studies and semi-structured interviews were held at all construction sites that were scrutinized in this thesis. All presentations and interviews served as background information for each case. They were also used to determine how the logistics worked at each site and what the challenges were. When these were determined, a discussion regarding them was held with management from ByggDialog. Afterward, a literature study was made to find potential solutions to these challenges. To answer the research question regarding the applicability, the solutions were discussed with both management from ByggDialog and in workshops on some of the construction sites investigated in the background study. The participants of the workshops had various positions from ground workers to site managers and came from the main contractor and subcontractors and gave feedback regarding if they deemed the solutions realistic and applicable or not. Lastly, the empirical study was compared to the literature study and discussed before a conclusion was made on which solutions would be considered the most useful.

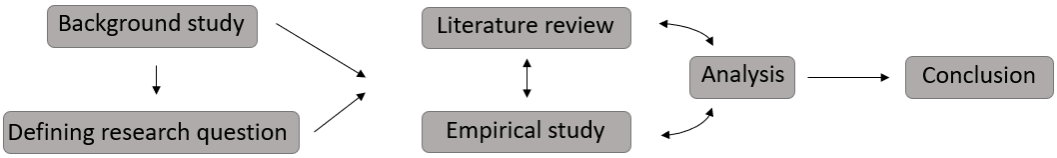

Figure 2.1 Research design (Authors' own figure).

2.2 Systematic literature review

The purpose of a systematic literature review is to accumulate a relatively complete understanding of already existing literature on the topic (Webster & Watson, 2002). This is helpful as prior mistakes made by other researchers can be avoided and it is determined what is still unknown within a topic (Bell et al., 2019). To find relevant literature, Webster and Watson (2002) advise thoroughly searching for sources across databases and methodologies. Leading publications are most likely to present the major contributions, which makes them a good starting point to build on. From there citations from relevant literature both backward and forward can be considered. Greenhalgh and Peacock (2005) call this process *Snowballing,* which is a complement to the initial systematic search. *Snowballing* is a method where reference lists of already relevant literature are scanned and references that seem interesting are further investigated. The method can find highly relevant sources in places that would not be found in the searched databases. Another method is *personal knowledge* where sources already known to the authors are investigated (Greenhalgh and Peacock, 2005). The literature review is near completion once newly investigated articles lack new concepts (Webster & Watson, 2002).

The abductive approach chosen for the thesis made the literature review an ongoing process to complement new empirical findings as they have been made available at different times during the study. A systematic literature study has been conducted and the literature used has been acquired through a number of different methods explained above. The review has been based on systematic searches for literature based on a set of inclusion criteria and has been further complemented with references previously known to the authors, as well as through snowballing studied literature. This process started at an early stage to complement the gathering of empirical data. Keywords such as construction industry, Sweden, logistics management, and supply chain management were used in different combinations within the search engines of the Chalmers- and Gothenburg University library.

Thereafter, the relevance of the literature was examined. First off, the titles were reviewed, followed by checking if the literature was peer-reviewed. Secondly, the abstract and conclusion was read. Lastly, if the source had made it this far and still seemed relevant, it was read in its entirety and later decided if it was suitable for the purpose of the thesis. Inclusion criteria were that the literature had to be applicable to the Swedish construction sector, handling the topic of logistics, and be relevant to Swedish public-use projects.

2.3 Empirical study

Each interview is conducted with the help of an *interview guide*, which is a number of previously constructed questions for the interviewee (Bell et al., 2019). The literature study acted as a basis for the interview guide used during the interviews. Emphasis is put on the interviewee's perspective in contrast to a quantitative approach where it is the researcher's concern that is in focus. The interviewee is hence allowed to take the answers where they please as this gives insights into their perspective on the matter. The interview format allowed the interviewees to reflect upon- and answer the questions from their own point of view, whilst also allowing the researchers to ask follow-up questions as new things were brought to the researcher's attention. The qualitative approach is suitable as it widens the understanding of different points of view and does not limit the interview to only contain the researchers previously set questions. This complements the abductive strategy well as new empirical discoveries could later be involved in the development of the thesis.

Roulston and Choi (2018) claim that qualitative interviews as the main source of data are problematic when aiming at generating facts but work well when trying to learn about perspectives. Within interview research, data triangulation is used to ensure data quality (Roulston & Choi, 2018). Thus, multiple interviews are the base for trying to achieve a holistic understanding of different perspectives that may be present on one topic. Therefore, the selected interviewees have different roles and backgrounds, and a sufficient sample size is one way of attending to the problematic lack of rigor with qualitative interviews as the sole source of data (Roulston & Choi, 2018).

Table 2.1 List of interviews

Company	Reference in report	Role	Project
ByggDialog	SM1	Site manager	AS-Block
ByggDialog	SM2	Site manager	M-block
ByggDialog	SM3	Site manager	Skene
ByggDialog	SM4	Site manager	Rydskolan
Myloc	ML	Business area manager	
ByggDialog	AM	Area manager	
ByggDialog	WS1	Site manager	M-Block
Subcontractor		Electrician	
ByggDialog	WS2	Site manager	Rydskolan

During the interviews, the answers to questions were written down to later be used in the thematic analysis.

2.4 Thematic analysis

In qualitative research coding is a tool to enable researchers to identify, organize and build theory (Williams & Moser, 2019). Coding is based on the need to display the

interdependencies amongst gathered data. Therefore, to analyze the empirical data in this study, a thematic analysis was conducted. It is a nonlinear process done in three steps, open, axial, and selective coding (Williams & Moser, 2019). The initially large amount of data is through the systematic process reduced to a number of codes that represent the whole data set. The first step, open coding, aims at identifying the common characterizing concepts for categorizing (Williams & Moser, 2019). The initial codes in the study were therefore meant to capture the hands-on observations of the empirical study by determining recurring keywords, phrases, and themes such as missing material, difficulties regarding storage, and late information sharing.

The second step, axial coding, aims at aligning and further categorizing the themes (Williams & Moser, 2019). It investigates the dependencies of the initially interdependent codes from the open coding. In this thesis, this was done by defining underlying denominators for the challenges observed in the background study. For example, miscommunication could be a common denominator for several specific challenges such as missing orders and material being delivered to the wrong place.

The final step, selective coding, takes the axial coding a step further as it selects and integrates those categories into higher levels of core categories (Williams & Moser, 2019). These core categories should reflect the experiences and perspectives gathered in the empirical data since the ultimate goal is to enable the researchers to develop a theory explaining the relationships amongst the core categories.

To facilitate the analysis a coding software, Atlas.ti, was used. It enabled the researchers to execute the three-step process whilst also visually providing insights into the correlation between underlying denominators for the experienced logistical challenges on site. Two filters used to investigate this were geographical setting and size of project.

2.5 Ethical conduct

As the study involved several interviews there were a number of ethical aspects that were a part of the collection of data. Before the interviews were held, several steps were taken to ensure that the qualitative research was conducted ethically. To allow all participants to speak freely everyone was anonymous and only the company name has been used in the thesis (Bell et al, 2019). Further, all interviewees were asked if it was accepted that the interview was recorded. At the start of each interview, the interviewees were also informed of the four main requirements of the basic individual protection requirement (Vetenskapsrådet, 2002). This includes the following:

1. Inform the interviewee of their role in the project and on what terms they are participating. That the participation is completely voluntary and that they can abort their participation at any time.
2. A statement regarding the interviewees consent to participate should be collected.
3. The interviewee can decide how long and on what terms they are participating.
4. If the interviewee decides to no longer participate they should not undue pressure or influence.

2.6 Sustainability aspects

The topic of construction logistics, and hence also this thesis, is connected to both environmental and economic sustainability. As stated, the traditional approach to handling logistics in projects has often been overlooked and resulted in waste and cost overruns (Agapiou et al., 1997; Sullivan et al., 2010; Thunberg & Persson, 2014). By the implementation of strategies focused on construction logistics the entire supply chain network can be shaped around a more sustainable approach (Lundesjo, 2015). For example, the suggested solutions support consolidation and could potentially enable the use of fewer vehicles coming in and out of the construction site which would have great environmental benefits for projects and benefit sustainability (Sezer & Fredriksson, 2020). Furthermore, improved logistics can lead to increased efficiency in a project and thereby reduce costs. Building on this, it can also create a safer environment for workers on site (Lundesjo, 2015).

2.7 Quality of the study

Bell et al. (2019) states credibility, transferability, dependability and confirmability as four criteria which need to be met in order to produce a trustworthy thesis. This section addresses how these criteria has been considered in the making of this thesis.

In this thesis, credibility has been ensured by respondent validation in the form of workshops with the contractor (Bell et al., 2019). In the workshops the findings from the initial background study were presented to make sure that the result was consistent with what was discussed in the previous interviews. By also cross-checking the empirical findings with the literature the credibility and quality of the thesis findings have been strengthened.

Transferability is an important criterion to make sure that the findings are relevant to other settings and contexts outside of the case projects (Bell et al., 2019). This was addressed by the contrasting portfolio of case projects as three out of the four was completely different in nature. Further, the size and budget of the projects were varying. This fact, combined with the different perspectives gained from the interviews and workshops, ensure the transferability of the thesis.

Dependability addresses the process of the thesis to make sure that each step taken can be reproduced (Bell et al., 2019). Therefore, each part of the conducted study is clearly described and motivated in this method section. In addition, a peer review specifically aimed at the method of this thesis was conducted at an early stage to ensure that the thesis was conducted in an appropriate manner.

The final criterion, confirmability, refers to the author's objectiveness (Bell et al., 2019). To fulfil this, the study has been audited continuously throughout the thesis by the examiner as well as being peer reviewed. To remain consistent in the gathering of empirical data, both authors have attended all interviews and workshops at site. Further, the thematic analysis helped prevent personal biases when analyzing the empirical data from the background study.

3 Literature study

The literature findings are presented in the following chapter. Supply chain management and construction logistics are introduced in Sections 3.1 and 3.2. Thereafter, a section regarding third party logistics (TPL) providers is presented in 3.3 followed by the construction logistics plan in 3.4.

3.1 Supply chain management in construction

A supply chain is a network made up of all the contractors and suppliers, linked up- and downstream, that are in some way involved in the same project (Lambert & Cooper, 2000). Supply chain management is a relatively new point of emphasis in the construction industry and has the potential for immense improvement (Lundesjo, 2015). The supply chain network in construction is highly influenced by the characteristics of the sector. The temporary setting makes each project unique leading to little repetition (Dubois et al., 2019). Further, it is a fragmented sector with a great variety of companies, often niched at one specific construction process. The combination makes supply chain constellations dynamic as actors change from one project to another.

A supply chain within construction has traditionally been managed by an organization, in many cases a principal contractor, that procure subcontractors to deliver different parts of the project (Lundesjo 2015). It is upon the principal contractor to coordinate and take overall responsibility for the project. Consequently, the principal contractor's supply chain is very large as there are a great number of subcontractors, suppliers, and other stakeholders involved in the project. Subcontractors, on the other hand, are managed by the principal contractor but are responsible for their own supply chain. As such the subcontractor supply chain has traditionally oftentimes been disintegrated with one of the main contractor's, see Figure 3.1 (Dubois et al., 2019).

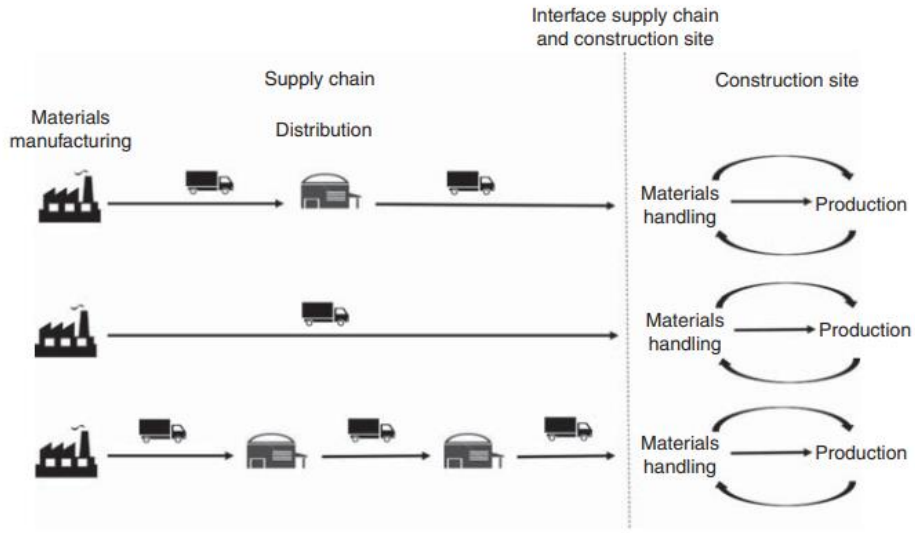

Figure 3.1 Traditional decentralized supply chain configuration picturing independent deliveries arriving at the construction site (Dubois et al., 2019)

3.2 Logistics in construction

The term logistics is referring to the strategic processes that facilitate a company's core activities (Sullivan et al., 2010). In a construction setting, this means that logistics is the function that is responsible for the functionality of services necessary to realize the goal of the construction project (Lundesjo, 2015). These services have a wide range of variety, from hands-on tasks such as handling material or transportation of goods to other things such as distribution of information and on-site safety (Sullivan et al., 2010; Lundesjo, 2015). Logistics can be described as the *"five rights",* referencing the need for services and products to be in the right place at the right time, in the right quantity and quality at the right price (Lundesjo, 2015). Traditionally the field of construction logistics has been underestimated and taken for granted, resulting in low innovation and slow development.

How construction logistics is handled varies depending on the project and setting. The three configurations identified by Dubois et al. (2019), decentralized coordination, on-site coordination, and the supply network coordination, all vary in managing needs and potential upside. The used configuration also decides where in the supply chain and in what stage of the project that the logistics management is handled. A decentralized set-up leaves each subcontractor with the responsibility of managing their own flows on-site whilst a supply network configuration centralizes the task, emphasizing management before it reaches the construction site.

As mentioned the solutions vary but according to Robbins and Thomas (2013) there are a number of solutions that can be considered "best practice". Amongst those is the use of a dedicated on-site logistics team responsible for receiving and distributing deliveries as well as the use of a construction logistics plan (CLP). These are two tools with the intention of managing the organizational problems that occur at a construction site. Even though the best practices mentioned have demonstrated improvements in performance their application in the industry is still limited (Lundesjo, 2015).

3.3 Third-party logistics provider

To achieve better productivity in this complex, temporary environment, Vrijhof and Koskela (2000) claim that a solution is better supply chain management. To improve, clients and contractors have started to hire third-party logistics (TPL) providers (Ekeskär & Rudberg, 2016). This means centralizing the task by outsourcing all or parts of the logistics function to be taken care of by a third party that are experts in the field. Traditionally these services have involved transport, warehousing, and inventory but have developed over time to also offer things such as reengineering of the supply chain and information distribution (Hertz & Andersson, 2003; Ekeskär & Rudberg 2016). According to Kifokeris and Koch (2021) there are a number of companies operating in the Swedish market that all offer digital solutions for handling complex, recurrent, and conflicting flows involved in a construction project. These often have their own digital platforms aimed at organizing the information flows between on-site parties and suppliers.

The driving forces for implementing a TPL arrangement is the assumed lower costs and better overall lead times as well as enabling the contractor to focus on their core value-adding competencies rather than wasting time on logistical tasks (Ekeskär & Rudberg,

2016). This, in combination with a lack of knowledge from contractors, has made TPL a viable solution in the industry (Janné, 2018). However, there are also concerns about outsourcing this function. The loss of control related to the fear of inability or inadequate knowledge from the TPL provider to deal with both basic and emergent issues that are likely to arise at a construction site are among the strongest concerns (Ekeskär & Rudberg, 2016). Another concern is the contractor's lack of knowledge of the actual cost internally when outsourcing the function. It is a hard task for cost estimators to project the true cost as hidden parameters such as time wasted amongst construction workers whilst handling material is hard to calculate (Lindén & Josephson, 2013)

3.4 Construction logistics plan

"No plan survives the first contact with the enemy" is originally a military saying but as stated by Sullivan et al., (2010) works just as well in the context of construction. The complex setting, with designs often not being done at the start of production, makes changes to the logistics plan inevitable. With that in mind, a CLP is still an important tool to ensure both efficient and sustainable construction logistics (Lundesjo, 2015). Logistics planning needs to be considered both on a general- and detailed level and is expected to bring clarity regarding the constraints and procedures of the project and should be made by the main contractor. The CLP should be used as a communicative tool for the management regarding all the necessary logistical aspects of the project. However, it is known that such usage of a CLP is rare in practice and often only considers logistic aspects happening on-site.

There are a number of key topics that need to be documented in a CLP (Lundesjo, 2015; Transport for London, 2013). First, an overview of the project is needed. The overview should give the reader a brief description of the project, the site location and its constraints as well as the development phases and its used techniques (Transport for London, 2013). Visual aids such as the area disposition plan (ADP) are beneficial to include. Secondly, the supply chain constellation should be introduced. The primary products with their respective suppliers and way of transportation are documented. The waste recovery is as important to consider as the material moving to the site. From there the CLP should focus more on in-depth details of the different procedures and policies for an effective construction site. There are several topics important to document in detail including materials, storage, route planning, operation times, material handling policies, unloading locations, and staff travel. cranes and equipment placements. Table 3.1 found below are further examples of what to include in a CLP.

Table 3.1 Checklist for CLP based on Transport of London (2013)

Introduction	- Name of the site - Workplace disposition plan (WDP) - Main challenges
Site information	- Location - Size and nature of the project

	- Parking availability - Site access details (how, when) - Changes to services during construction
Construction details	- Indicative dates for construction phases - Vehicle access arrangements - Vehicle routes - Parking, loading and unloading arrangements - Swept path analysis - Storage details - Safety aspects
Traffic management	- How traffic will be managed during each construction phase - Vehicle types - General traffic considerations
Developing and using policies	- Waste minimization - Alternative modes of transports - Consolidation - Delivery management system - Information sharing
Monitoring, compliance, reporting and review.	- Details for how to monitor, report and review the CLP
CLP Management	- How the CLP will be managed

It is also important to plan how- and who is responsible to manage the CLP (Transport of London, 2013). As previously mentioned, it commonly falls upon the logistics manager to develop this document. To ensure that the working practices agreed upon in the CLP are followed by all involved parties the CLP should be a part of the contractual arrangements.

After establishing this document, it is important for managers and supervisors to actively work towards ensuring that the terms and conditions of the CLP are met by everyone at the site (Transport of London, 2013). Information sharing and gathering of data is important for this process. By using delivery management systems (DMS) information can become broadly available at the construction site, decreasing time waste. The data gathered through this system can later be used to analyze the project and to see if certain rules and conditions have been met by all parties.

3.4.1 Delivery instructions

One type of plan that is recurring in the literature is the delivery instructions (Lundesjo, 2015; Sullivan et al, 2010; Sezer & Fredriksson, 2021). The delivery instructions need to be developed early and established within the supply chain (Lundesjo, 2015). In the case of minimal storage possibilities on site deliveries can be made on a Just-in-Time (JIT)-basis to reduce unnecessary offloading and reloading activities. An important part of minimizing transports is to consolidate the deliveries when possible. A solution to enable this is to use a construction consolidation center (CCC). The CCC is an external location that prepares goods and materials received from suppliers for delivery to the construction sites (Sullivan et al, 2010). To lessen the risk of congestion deliveries should be spread out during different hours of the day. Lundesjo (2015) argues that evenings are ideal for bringing new materials to the site as it provides a safer environment during the day for workers as well as giving easier access to the site. In smaller projects with fewer incoming deliveries, these can be scheduled to come on one or two specific weekdays to minimize the number of transports whilst also saving time for workers on-site.

3.4.2 Area disposition plan

According to Kifokeris and Koch (2021) a common practice among practitioners in Sweden is the implementation of an ADP. It defines the layout of the construction site including roads, storage, and checkpoints amongst other things. Even though these plans are often described as dynamic they are rather static in practice (Kifokeris & Koch, 2021). There is a lack of integration between these plans and other logistics planning such as deliveries, material placement, and other flows at the construction site. Consequently, the use of the area disposition plan is often limited since the provided information may or may not be out-of-date. As previously mentioned, the ADP is an important tool to visually complement a construction logistics plan (Transport for London, 2013).

3.4.3 Delivery management system

Thunberg and Persson (2014) concluded that logistical challenges often arise as a result of a lack of formal procedures for handling incoming materials. Ying et al. (2014) found that this led to purchasing being made through many different channels, resulting in uncoordinated deliveries. The lack of a standardized DMS also makes it hard to track delivery performance (Thunberg & Persson, 2014). A DMS is a platform for managing incoming deliveries to a site (Lundesjo, 2015). It is a scheduling system that offers a clear picture of the deliveries that have been completed and those yet to arrive available to all relevant contractors and managers on site. The contents of such systems differ but the typical information it provides are such as material info, vehicle type, supplier, and recipient. Scheduling deliveries is an important part of an efficient supply chain as it reduces time to waste. In the cases studied by Ying et al. (2014) poorly planned deliveries created conflicts as ad hoc teams for offloading had to be assembled as late as 10 minutes before the arrival of unscheduled deliveries. A DMS can help avoid such problems whilst also offering data collection to help analyze the incoming flows of deliveries for future projects (Lundesjo, 2015)

3.4.4 Labeling

As mentioned in the previous chapter, the lack of formal procedures results in logistical challenges. Another aspect of this is the lack of a common label (Lundesjo, 2015). As contractors use their own channels for purchasing, packages with different kinds of labels and packaging are likely to arrive on the construction site. This results in a risk of "double handling" material. Dubois et al. (2019) exemplify this with the use of a CCC where all incoming material ordered by contractors on-site would need to be repackaged and relabeled if a standardized label is not established with the suppliers. The labeling is deemed extremely important to provide an efficient logistics process (Lundesjo, 2015) and therefore the label system- and design should be a specified part in the purchase contracts at the start of each project.

Labels are usually developed by the party that is the least interested in their design, the manufacturer (SBUF, 2014). The one thing that is important for the manufacturer is that the customer and the freight company accept a standard label for them to save time and money. As special label-design requests from a single customer may become a problem to handle in the usual systems it is evident that a standard is needed to tackle this problem.

BEAst e-Build Label is a Swedish standard specifically aimed at the labels of the Swedish construction industry with the purpose of making it easier for all stakeholders to handle deliveries (SBUF, 2014). Through the SBUF-project "Effektivare varuförsörjning" (SBUF, 2014) the label has shown an upside when used in the internal material handling process in pilot projects at construction sites, albeit at a small scale. Several adaptations have been made to fit the context of a construction site. The label is designed to give info regarding specific delivery destinations on-site, for example, a specific apartment number, see Figure 3.2. Through the pilot projects the labels have also been tested to make sure they are visible for the telehandler drivers moving the packages. To implement this some systematic changes need to be made. For the contractor, this means a change of communication system with the manufacturer as specific info needs to be messaged via the standard of e-Build Supply to complement the label.

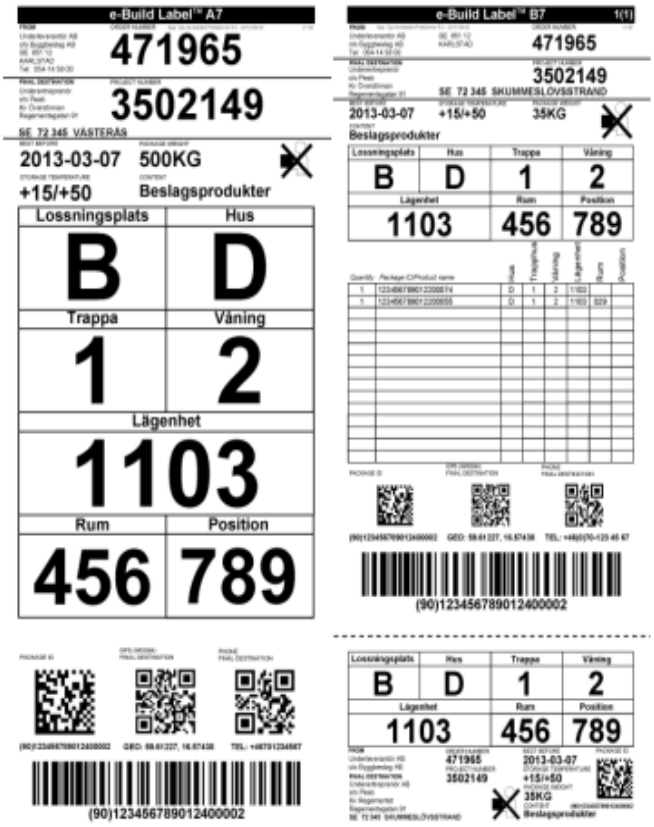

Figure 3.2 Two versions of the e-Build Label, to the left the pallet version and to the right the package version (SBUF, 2014)

4 Empirical study - case backgrounds

4.1 Byggdialog

The company responsible for the projects which were used for the case studies is Byggdialog. Byggdialog was founded in 2006, Karlstad, Sweden, and today has around 280 employees and a turnover of roughly 3,5 billion SEK. They hold numerous ISO certificates including SS-ISO 44001 which is a management system for business relations in cooperation. The company mainly works with public use projects and have their focus on public projects such as hospitals and schools. They emphasized the importance of being able to communicate and collaborate with their clients, especially in projects which affect the general public. (Byggdialog, ND)

ByggDialog has a program where site managers have the possibility to meet up and share experiences. This is partly how ByggDialog works to continuously improve its projects. The company also offers in-house training for managers at different levels. One of their courses focuses specifically on purchasing and logistics but leans more toward purchasing according to SM3.

4.2 The AS- and M-block

Two of the studied cases were part of ByggDialogs project at Skaraborgs Hospital. The hospital is located in Skövde, a mid-sized city of around 57,000 inhabitants located in the county of Västra götaland (Skövde, 2022). Skaraborgs Hospital Skövde has a catchment area of 15 municipal areas which previously made up Skaraborgs county. A total of around 260,000 inhabitants live in these municipalities and in total the hospital has around 4,400 employees and 673 beds. Besides treating patients, the hospital also conducts research, development work, and education (VGRegion, 2022). Byggdialog is contracted by the company Västfastigheter which is owned by Västra Götaland Regionen which is responsible for the health care of the inhabitants of the region (VGRegion, 2022).

The AS-project, which ByggDialog is responsible for, is a large-scale project with a budget of more than 2,3 billion SEK where three new wards will be added to the hospital. The project is divided into three so-called “blocks” where A stands for Akut (Emergency) and the S stands for Service. The building of these wards started in early 2018 and the project as a whole is expected to be finished at the end of 2023. In total, the new wards, together with the P-block, will add up to around 65,000 sqm (GTA) (Byggdialog, 2018) together with the P-block which is also part of the project. The P-block houses the new psychiatric ward and is in itself around 26,000 sqm with a budget of 840 million SEK and was finalized in 2021 according to SM1 While the P-block has already been finalized, the AS-block, is still under construction. Being the larger block of the two, it adds a total of around 39,000 sqm and has a current budget of 1,5 billion SEK. It consists of five levels, two underground and three above ground. The levels underground are mainly for technical installations such as the energy central but also hold locker rooms for staff. The levels above ground facilitate the emergency ward, ambulance station, intensive care unit, operation rooms, radiology, sterilization department, and many more departments. On the highest level of the building, there are more than a dozen ventilation units responsible for the air quality of the operation rooms.

Apart from the ASP-block, Byggdialog is also responsible for the renovation and extension work of the M-block where the M stands for Mottagning. This includes the main entrance of the hospital and the reception areas which are attached to it. Since this project was renovating and extending it was done step-by-step as the hospital still actively used the areas which were being renovated. The project started in 2020 and is expected to be finalized in 2023, it includes around 22,000 sqm and has a budget of around 300 million SEK according to SM2. A large portion of the renovation work was removing dangerous materials such as PCB and asbestos. In total, close to 14000 kg of PCB and 37000 kg of asbestos has been removed. Furthermore, walls have been replaced, insulation has been added, floors have been redone, doors and windows have been changed, and technical installations have been updated.

4.2.1 Logistics at the AS-block

According to AM there was an official logistics plan before the project started. It was part of the tender documents when ByggDialog acquired the project. However, the existence of this document and its implementation of it was never further communicated to the site managers. Hence all the solutions and working methods were never used. There was however a structural plan which was implemented that contained how the work on site should be conducted which led to logistics still being partially taken into account when designing the work site. There was a detailed time plan at the beginning but this was scrapped since deliverables were not ready on time and the schedule constantly had to be moved. As mentioned though, logistics were still taken into account.

For starters, the whole site was constructed from the perspective that trucks could drive through and around the site and not have to stop and turn around. This would decrease the amount of traffic and increase accessibility. One of the goals was to build the roads on the work site in a way so that the ongoing operation of the hospital would not be disturbed, for instance, not getting in the way of ambulances arriving. Except for creating roads to increase accessibility, a checkpoint for goods was also set up close to the entrance gate where trucks could unload deliveries. This was also done to decrease the amount of traffic on site. The checkpoint was a set of large tents, see Figure 4.1, where goods could be stored and were run by a specialist logistics manager. Apart from being in charge of receiving goods, the logistics manager would also gather paperwork relevant to shipments and distribute the materials to their specific location on site. SM1 explained that this was a great system and that the specialist logistics manager relieved some of the workloads. However, after a certain point, workers knew where received goods needed to go on site without the help of the specialist logistics manager.

Except for the logistics manager who manned the checkpoint there was also one who was in charge of booking the arrival of deliveries. It was explained that no shipments could be booked without going through the logistics manager first. One of the reasons for this was that they were unable to receive multiple shipments at once due to their location in the city. This logistic manager was only present at the beginning of the project as ByggDialog later on managed this by themselves as one of their own employees partially manned the checkpoint, accepted deliveries, and distributed them on site. The employee was explained to have a great knowledge of the site and had extensive experience in the construction industry according to the site manager. Apart from this, there was no standardized framework for working with logistics or managing orders, deliveries, and distribution on-site. It was explained that no one on-site really

knew what happened with an order after it was placed. There was no way of telling when it got to the site and/or if it had been distributed on-site. The person who accepted the delivery on-site more often than seldom did not know what it contained. This led to materials getting lost and one specific order worth 50,000 SEK accidentally was ordered twice due to this.

There was also a pilot project where students would transfer the deliveries from the checkpoint to their specific locations at night time when no active work was taking place on-site. This was however not a great success as there was confusion about where the deliveries should be distributed to. Furthermore, it was often placed in spaces where it was in the way of the construction workers and subsequently had to be moved again. The site manager explained that it became more of a burden than a relief to the workload and the pilot project was terminated. Something which further adds to the workload, specifically for the site manager, is that calls regarding deliveries arriving at the sites often go via him.

The site manager said that logistics had still functioned and that his general goal of "nobody should have to wait for someone or something or be in the way" was met. However, as a result of the challenges stated above, specifically regarding orders and deliveries, the site manager expressed that a new system or framework for orders would be welcomed. Furthermore, someone responsible for planning, coordinating, receiving, and keeping track of deliveries would be of great help.

Figure 4.1 Checkpoint and tents for the ASP-block (Authors' own figure).

4.2.2 Logistics at the M-block

Just like the AS-block, the M-block project had no established logistics plan before the building started. However, unlike the AS-block the M-block did not have any logistics managers on-site at any project stage. The M-block has also not had the benefit of a large amount of space that can be used for intermediate storage. The site manager explained that they were aware of this and other logistical challenges before the project started. Limited space on site meant that vehicles with trailers could not enter as there was not enough space for them to maneuver on site. Furthermore, as mentioned, intermediate storage of materials was a challenge. This became evident when they wanted to stock up on materials during the pandemic as there was an international shortage. The M-block utilized some of the space that the AS-block had available but this was not enough for the amount of materials that were needed. Deliveries and materials were as a result of this mixed up and it became hard to keep track of where everything was.

Even though the site had limited space, workers would still have to walk further than normal in order to manage waste, and as a big part of the project was renovation and rebuilding, there was a lot of it. Because the hospital was still operational, patients were still present. The noise made by the disposal of waste disturbed the operations which led to them having to move waste management further away from the hospital.

As there was no logistics manager or employee in charge of taking deliveries or planning them, project management often had to deal with these issues. The site manager expressed that they had been able to handle it but said a logistics manager or a system for logistics probably would have been needed and that it would relieve the workload. Mishaps regarding deliveries could according to the site manager have been avoided and it would be easier to plan deliveries. For instance, the occasion where all doors for the entire project came at once could have been avoided. Furthermore, incidents where forwarding agents placed deliveries at different locations around the hospital could also have been avoided. There was also no one to work actively with logistics as a result of this. The site manager informed that there was no clear goal for the logistics other than “it should work”. No clear subgoals were set and no follow-up was made. He expressed that the logistics of the project could function better and that solutions would be welcomed.

4.3 Skene sewage treatment plant

The third site was located at a sewage treatment plant in a small town called Skene, which has around 10.000 inhabitants (Mark, 2022). Skene sewage treatment is one of several in the municipality of Mark where it is located and is responsible for treating sewage water for five smaller urban areas. It was initially built in 1974 and rebuilt in 1994 to add nitrogen purification to its treatment process. The urban areas have expanded since the treatment plant was initially built and is now in need of expansion in order to handle a larger flow of water. Furthermore, the plant needs to be modernized to meet current standards. Treatment of the water happens in three stages, mechanical-, biological-, and chemical treatment. The project is divided into two stages, renovation of the main office building and expansion and renovation of the process plant itself. Renovation of the main office building is scheduled to be finalized in May of 2023. The

goal was that the design phase for the process part would be completed simultaneously so that construction could start instantly when the office building was finished. However, this has been postponed due to issues with permits on the municipality's part.

Renovation work to the main office building started in October 2022 and is on track to be finished as scheduled. The renovation work includes both the in- and exterior of the building. On the interior, the floor plan has been altered in order to house new technical installations. An additional ventilation unit will be installed along with new appliances, all electric work will be redone, and a new heating system will be installed. The heating system will be a system that will utilize the heat from the pools of sewage water around the plant. Except for modernizing the technical installations, new floors and joints have also been installed while simultaneously removing asbestos and PCB. The roof of the building has also been raised and its angle has been increased. Furthermore, the surface layers of the building have been changed and a new drainage system has been installed. During the time that renovation has taken place, the sewage treatment plant has been fully operational. According to the site manager, this has been a challenge since all the electronic equipment which controls the plant is located in the main office building and has also had to be replaced. The area of the building is in total of 350 sqm with a budget of around 27 million SEK.

Even though construction of the process part of the plant has not started yet, there is still a plan for what will be done. A new 24x15x5m concrete pool will be built that will act as a buffer for when water flows are abnormally high. Functioning parts that are responsible for the treatment process also be changed. This includes grids, pumps, machines which will aerate the sewage water, and other equipment. Renovation work to the concrete in the pools is also set to take place along with the replacement of railings, footbridges, and construction of additional walls in the pools. Furthermore, a new facility housing pumps and other machinery will be built together with a new set of tanks housing the chemicals used in the treatment process. Apart from new tanks, a new brand new facility is to be constructed on-site for the biological treatment process with updated process technology. The budget for the process part has been set to around 230 million SEK.

4.3.1 Logistics at the Skene sewage treatment plant

There was no specific logistics plan made for the project. However, there was a plan describing the different stages of the project and a ADP of the construction site. The ADP does include some aspects which affect logistics. For instance, how trucks will be able to move around with material on site and where cranes will be placed. It also specified where tents should be placed for intermediate storage of materials. Even though this plan exists the site manager emphasized that ADP-plans are often not made in great detail and that it could be improved. It was also stated that these plans never specifically specify how logistics should be managed or specifications for how to work with it, certainly not when sites have limited space. However, there was plenty of space on site for material they needed for the renovation of the main office building. This is unlike many other projects where space has been limited and a constant moving of material takes place. This meant that they could often order in larger quantities and store it on-site in a large tent, see Figure 4.2.

Deliveries of orders were handled by a foreman on site who was responsible for receiving and distributing them on site. This lightened the workload of the site manager and allowed him to focus more on his main tasks which were budgeting and planning. There was however no system where entries were made on when and where shipments had arrived which sometimes could make it hard to keep track if the foreman was unavailable. According to the site manager, some deliveries were sometimes just dumped somewhere on-site by suppliers when the foreman was not available which could also cause confusion.

According to the site manager, there were no clear goals for logistics on site. There had however been an internal discussion on ways to reduce the number of deliveries and order in larger quantities to do so. This was mainly because material suppliers were far away from the construction site which led to higher transportation costs. As mentioned, the site had quite a lot of space for storing material but the site manager explained that this is seldom the case and that it could lead to inefficient work and irritation on-site. Materials constantly having to be moved and difficulty moving around were common challenges as a result of lack of space. Logistics had worked well under the renovation of the main office building according to the site manager. It did not provide any major logistical challenges except for a larger-than-anticipated amount of asbestos being found. This meant that more material had to be sanitized and treated.

The expansion of the process part of the plant could however prove to become more challenging from a logistic aspect. A much larger amount of trucks will be needed to deliver materials such as concrete for the large pool which has to be built. These trucks also have to be flushed which requires space. The site manager explains that meetings regarding the logistics of this are often held beforehand to avoid problems.

Figure 4.2 Material tent at Skene sewage treatment plan (Authors' own figure).

4.4 Rydskolan

The final site studied was Rydskolan in the area of Södra Ryd, Skövde. Around 6500 inhabitants live in the area and the school takes on pupils up to until sixth grade. The building which houses the school was originally a mall but was rebuilt between 2000 and 2005. Up until recently, the school operated in a building that had an area of around 12.000 sqm, part of this area also housed public dental care. However, the school has downsized and is no longer in need of the same amount of space, and public dental care has been moved elsewhere. The building is therefore being rebuilt and renovated and the school will instead operate on an area of around 6000 sqm.

Since the school downsized and no longer needed the space the municipality took the decision to co-locate other operations to the same building. To do this the floor plan has been altered, new technical installations have been installed, and general renovation work is being done. This includes, amongst other things, changing the surface layers on walls and laying new floors, and rerouting ventilation channels. Construction started in May of 2022 and is set to be finished in May 2024. The total budget of the project was initially 53 million SEK but was increased with 7 million SEK to build a new access road to the special aid school.

4.4.1 Logistics at Rydskolan

The site manager explained that logistics on site have been "tricky". There was no dedicated logistics plan at the start of the project and the site has many challenges. For starters, there was no area outside of the school for the project apart from a small area for waste disposal, there were also no sheds for the staff. Instead, the staff was in offices inside of the school, and all material was spread out inside in corridors and rooms. This led to material and other equipment being in the way "a little too often" of work itself according to the site manager, see Figures 4.3 and 4.4. Things often had to be moved and there was no real system to keep track of what was moved to where. They also tried to reuse a lot of the materials in the building which also had to be stored in rooms or corridors where active work was taking place. To minimize the amount of material inside, orders are often placed in smaller quantities.

According to the site manager, this is often the case on smaller construction sites where space is limited and they have to solve problems themselves as they occur. Constant planning takes place and communication is very important according to the site manager. This has worked well during the project but there have been cases in other projects where workers ask for more materials just as they are up instead of planning a few days ahead. The system of planning based on trust that everyone will take responsibility, and place orders without a system to keep track of everything, works well when workers know each other well according to the site manager. Even though this is the case for the project at Rydskolan, orders and deliveries still tend to get lost sometimes. Since there is no real system for information on orders things tend to get lost. According to the site manager, there is no way of knowing when orders have arrived or where on-site they were placed. Larger orders are written down and noted but smaller ones are not. The site manager explained that this often takes unnecessary

time from the project and that this is often the case in construction projects. The only real way of knowing if orders have arrived is when the invoices arrive.

Since the site cannot utilize any space outside of the building, except for waste disposal, there is also no checkpoint for receiving deliveries of materials. Instead, they were dropped off next to the waste disposal at the end of a small parking lot where there was little to no space for large trucks, see Figure 4.3. Truck drivers had to reverse through the parking lot between cars in order to get out of there. When deliveries were dropped off it was carried inside through the corridors of the school to be placed somewhere inside on site. The same goes for all waste which had to be carried quite long distances to be disposed of. To minimize disturbance to the school operation as little as possible the workers would move materials at night-time or after school hours when possible.

Not disturbing the school's operation and providing a safe environment for the pupils has been a goal for logistics at Rydskolan. Apart from this, the site manager explained that logistics had worked fairly well. Mainly because of the long work relationship with co-workers which goes back 10 years in some cases. He did however add that there are challenges, for instance with orders being misplaced, limited space, and confusion due to lack of standardization. These are often, according to the site manager, challenges at smaller projects like Rydskolan where there is a limited amount of resources, and at bigger projects, these challenges do not occur as often.

Figure 4.3 *Area for deliveries (left) and material storage in corridors (right) (Authors' own figure).*

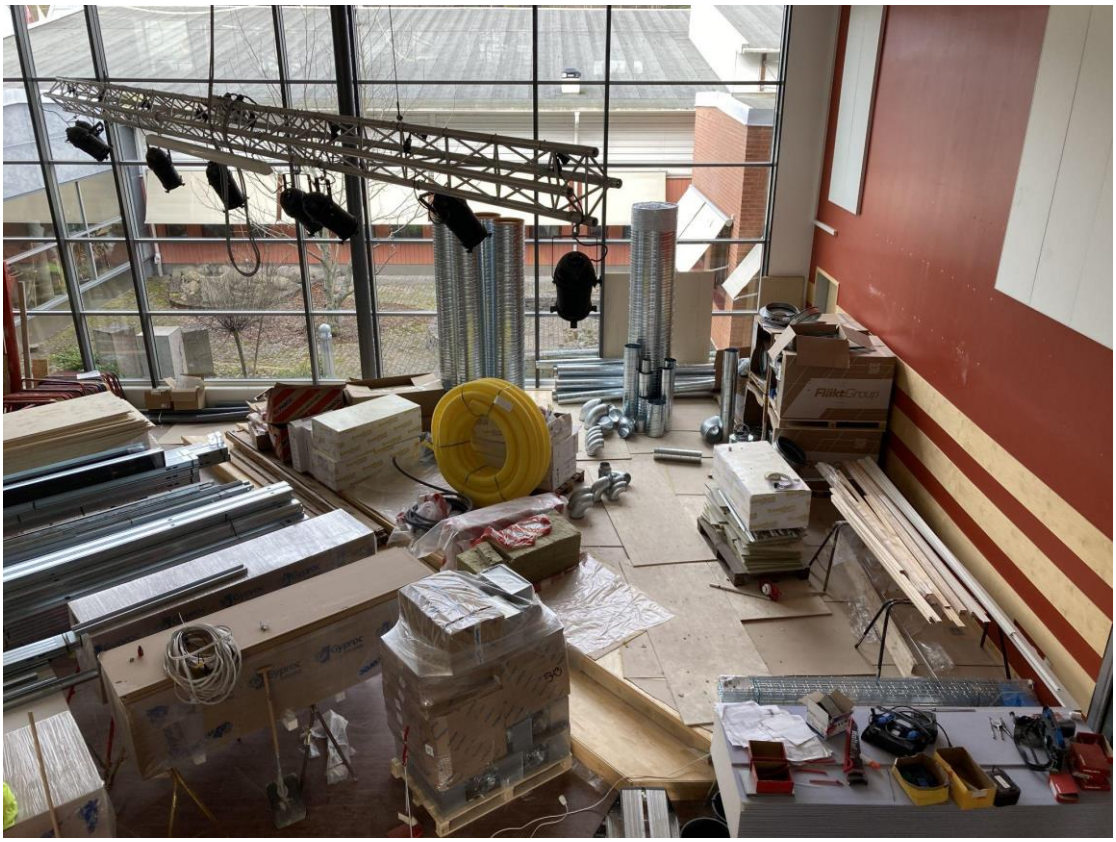

Figure 4.4 Material storage on site (Authors' own figure).

5 Analysis

The following chapter is divided into three parts, challenges, solutions, and feedback on solutions. The chapter aims to analyze the results from the background study by comparing the empirical findings with the literature in order to reach a conclusion to the research question in Chapter 6.

- 5.1 Challenges: What are the typical logistical challenges which are recurring across projects independent of the project prerequisites?
- 5.2 Solutions: What solutions are appropriate to solve the identified challenges?
- 5.3 Feedback on solutions: Are the solutions realistic to implement from a contractor's perspective?

5.1 Challenges

The thematic analysis resulted in a few selective codes representative of the challenges recognized in the case background. The most notable area of challenges, regardless of project type, project size, and geographical setting, were related to the coordination of the supply chain both on- and off the construction site. Other notable areas of challenges, as shown in Figure 5.1, included in the results of the analysis were lack of space, storage, material handling, site layout, and waste management. The four investigated construction sites were all of different natures and therefore they had their own challenges. Apart from site-specific challenges, the empirical data and analysis showed that all sites were also facing similar challenges in regard to logistics, regardless of site-specific elements. The following chapter, therefore, presents both site-specific- and non-site-specific challenges.

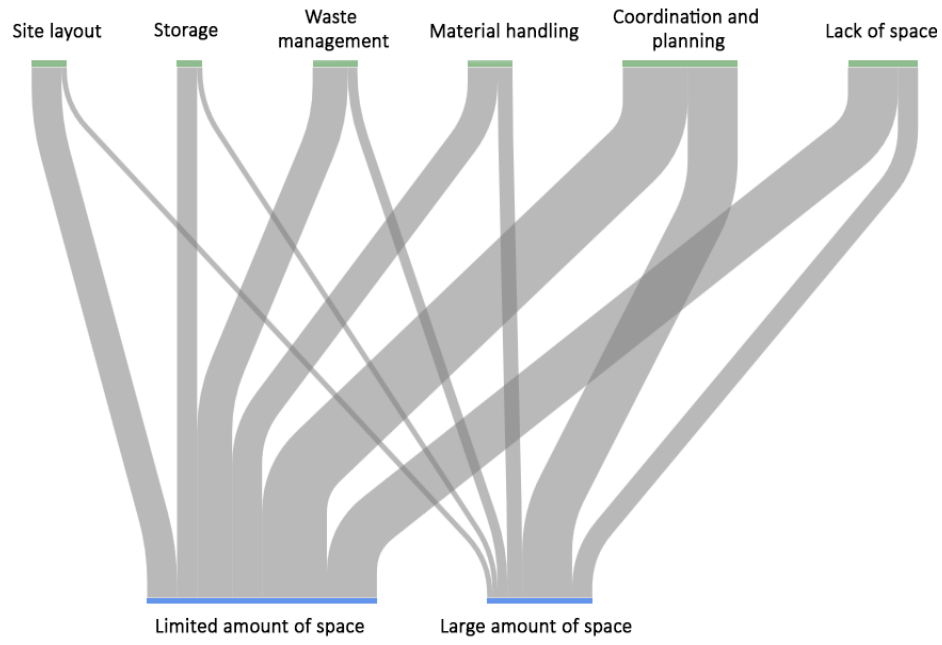

Figure 5.1 *Result of the thematic analysis. Thickness indicates a larger challenge. (Authors' own figure). Coordination and planning were equally recognized as challenging across all studied projects.*

5.1.1 Site-specific challenges

The systematic analysis showed a correlation between the geographical setting, meaning the direct area surrounding the construction site, and the recognized challenges. As both the AS-block and Skene wastewater plant had space available for implementing certain logistics solutions, for example, material tents in the vicinity, they avoided challenges that both the M-block and Rydskolan had to deal with as they had significantly less space to work with. These projects had limited space designated for the construction site both inside and outside of the project. The lack of space, combined with ongoing operations in the hospital and the school, led to several logistical challenges including storage, deliveries, and the layout of the construction site.

Because of the layout, trucks and cars had very little space to move which led to both the M-block project and Rydskolan having significant limitations for handling incoming deliveries. Once delivered there was very little space available for storage which put emphasis on planning deliveries ahead to receive only the necessary amount of material. This was especially challenging in these renovation projects as renovations are often harder to predict and constant operation took place. These challenges put, as mentioned, stress on planning and also coordination and communication which was not always upheld. Because of limited space, constant material handling was also needed as materials and resources were often in the way of work. When materials and resources were moved it was not always the case that all affected parties were informed which led to occasional confusion about where they had been placed.

"Material is being stored where it is and is often, a bit too often, in the way and needs to be moved" - SM3, Rydskolan

Waste management was challenging as it had to be moved long distances as the waste disposal was situated far away from the construction site. This was however due to circumstances involving the operations at both the M-block and Rydskolan which made it hard to adjust. Comparing these projects to the Skene wastewater plant, which was also operated during the project, did not suffer from these same challenges due to the geographical setting which did not limit the construction site in the same capacity as in the two cases above.

5.1.2 Non-site-specific challenges

There were several non-site-specific challenges across all projects. One of the main challenges was that it was hard to keep track of when and where orders arrived at the site. This was the case primarily for the AS-block and Rydskolan. The first had a large flow of deliveries on a large worksite and the second one had a long distance from the actual site to the delivery zone. Furthermore, the ASP-block, Rydskolan, and the M-block had difficulties knowing where, for instance, materials went on-site after they arrived. There were no standardized times for delivery or standards for labels for any of the projects. The only way of getting information regarding where orders had been placed and if they had arrived was through mouth-to-mouth communication with the person who had taken delivery of it. This was problematic because there had been several occasions across sites where forwarding agents left materials on-site without informing anyone. This was a direct result of a change in policy after the pandemic as some deliveries no longer required signatures from the recipients to be delivered. Furthermore, if materials had been moved again, which occurred, there was no way to

keep track of them. A shortcoming in communication and information sharing was the most likely reasons for this.

When orders were received on site they were often received by a specific worker tasked to receive and distribute the orders on site. This system was used by the ASP-block, Rydskolan, and Skene sewage treatment plant. It relied on the worker's general knowledge of where deliveries needed to be distributed and what was in the packages. This system worked decently but since no information was logged it, once again, led to confusion as to where deliveries had been placed and if they had arrived. Even though there was a person who often received orders, all site managers expressed that there was no real system for order management. Orders sometimes could arrive late, early, at the wrong location, and without confirmation. Time was often spent searching for materials and storage became challenging in some cases. There had also been occasions of orders being placed more than once since they were misplaced and lost on site. These challenges are based in lack of, or difficulty in, communicating and sharing information.

A common factor for all sites was that none of the projects had a logistics plan that specified how logistics should be managed and worked with. No standardization of procedures and no specified goals or sub-goals. All projects had an ADP plan which specified the layout of the construction site. This affects logistics since it decides if a checkpoint should exist, how roads for the transportation of materials should go, and where storage should be. However, it does not specify, for instance, how information regarding orders should be handled, when they arrive, or what the procedure is when moving orders around the site. Without standardization, confusion occurs and with that, the challenges stated above.

5.2 Solutions

As mentioned, one of the biggest challenges is the lack of standardization and a system for handling orders and materials. There are ways to improve on this, both with active in-house work by using tools such as a logistics plan and by utilizing services by outside providers. Third-party logistic providers can bring an outside perspective, knowledge, and tools to offer possible solutions to challenges.

5.2.1 TPL-provider, Qlocx

The following section regarding Qlocx as a company and the services it provides are taken from their website.

Qlocx is a company that offers services and products to help with deliveries to work sites. The company aims to digitalize the way orders and deliveries are handled by using a cloud-based system, mobile applications, digital keys, and digital control boxes that can be activated directly through Bluetooth. Qlocx does provide services and products to more than one industry but has some specific tailor-made solutions for the construction industry to help with logistics. These solutions include a smart unloading area, internal lending, supply cabinets, unmanned renting, delivery areas, click and collect, and a digital key platform.

One of the services that Qlocx offers is package cabinets. The package cabinets work in a simple four-step process, the constructor places an order which is then handled by the forwarding agent and delivered to a cabinet on site. As soon as the order arrives the customer gets a notification in the designated app that lets them know the delivery has been made. During the order process, the order can also be followed when being handled and transported. Qlocx handles the integration between the customer, supplier, and forwarding agent. A delivery container uses the same principles as a package cabinet only on a larger scale. It allows deliveries to be dropped off without physical contact while simultaneously informing that an order has arrived. The systems provided use a digital key platform that integrates supplier, forwarding agent, and customer and can be applied and integrated into other applications.

Another solution that Qlocx offers is a smart unloading area is created with the help of a gate to which the forwarding agent can get a time-limited key. Inside the area, a designated zone can be marked by the customer to inform the forwarding agent of where to unload. As soon as a delivery has been made a notification is sent to a designated app so, for instance, the site manager knows if a delivery has been made. A delivery area is just like a smart unloading area in the sense that an area is chosen to which the forwarding agent has access via a one-time or time-limited key. When the delivery has been made a notification is sent to the designated app.

In order to get rid of the continuous ordering of consumable items, such as nails or screws, Qlocx also offers a supply cabinet service. A cabinet is placed on site containing consumable items chosen by an administrator, for instance, a site manager. The cabinet itself keeps track of its inventory balance and automatically places an order for refilling when needed. The chosen administrator gets information regarding this and also when and how much material has been taken from the cabinet as well as by whom.

As stated, Qlocx offers a variety of services for the construction industry. Their package cabinets and delivery containers are targeted at packages of smaller sizes and could potentially eliminate the uncertainty if an order has been placed and if it has arrived on-site or not since all information is available through the app. When a package arrives at the container or cabinet a message would be received through the app. These factors mean that workers and managers can continuously work without interruption and simultaneously have full knowledge regarding deliveries. Smart unloading areas/delivery areas allow for the same benefits but on a larger scale. With the help of this system larger quantities of, for instance, materials, can be brought to the site without physical contact but with full information knowledge. Deliveries can be made at any hour of the day since the system uses one-time and time-limited keys. For sites with active operation during construction, this could be beneficial as it allows for deliveries after work hours in the designated area. It could improve safety for both workers and people in the close vicinity of the worksite.

The supply cabinets that Qlocx offers also offer a solution to worksites where personal responsibility regarding the ordering of consumables does not function. Mouth-to-mouth communication regarding consumables is eliminated and the risk of consumables running out is lower. Since individual responsibility is reduced. This means that a potential stop of active work can be reduced. Unmanned renting which the company also offers also allows for an administrator, for instance, the site manager, to keep track of tools and equipment onsite.

5.2.2 TPL-provider, Myloc

The following section regarding Myloc as a company and the services it provides are based on two interviews with a representative from the company and information available on their website.

Myloc is a Swedish tech company that offers logistical solutions for municipalities, cities, health care, and the construction industry. The segment that is applicable to the construction industry is called Myloc construction and aims to increase logistical knowledge across organizations through information sharing and the introduction of working methods. The service offers the customer a cloud-based system that connects suppliers, forwarding agents, and customers. It offers constant sharing of information between actors in order to coordinate the flow of materials and use resources more effectively. The approach is holistic with the aim to include every step from the supplier to the materials or resources being carried onto the exact location where they are needed. A constant feedback loop with measurable results to be able to benchmark and improve. It is claimed to be applicable to projects of all sizes and has been used in around 450 projects so far in Sweden and Norway. Projects using the system are of different sizes and forms. These include public-use projects, such as hospitals, housing projects, and factories. Around 2000 companies are connected to the service with 2000 individual users every week.

The idea is to make information sharing easier and get rid of unnecessary meetings and information sharing through various amounts of, for instance, excel sheets. Furthermore, to get rid of "the superman trap" where one, or a few individuals, has great competence and knowledge of logistics on-site whereas the rest have little. Instead, all information regarding the flow of materials and resources on-site goes via the Myloc system available through apps or computers. By doing this, the goal is to increase coordination, communication, and information sharing between all connected parties. The pricing of the system is based on square meter of the project when buildings are involved. For infrastructure projects such as roads or bridges, a different model is used for price calculation. To use the system the customer pays a monthly fee per project and gets access to an unlimited amount of licenses to use for that specific project.

In the system, deliveries can be booked with a specified time, date, and place. This would allow workers and managers on-site to get better knowledge of when deliveries arrive. With standardized parcels, information is given on where on-site the deliveries should be placed. It specifies the building/area, floor, room, and more such as the weight and content of the delivery. As a result of this, it will be easier to tell what the shipment contains and where it is supposed to go on-site. As soon as a delivery is received this is noted in the system with the information of who, when, and where it was received. Any anomalies, damages to goods, and other information can also be added to the system. This lets users evaluate delivery performance and key performance indicators (KPI) can be created. When the order has arrived on site, a notification is sent through the app. If the materials or resources are moved after they have arrived on site, this can also be noted. The information regarding this is available to all users of the app and makes coordinating easier since information sharing is not dependent on mouth-to-mouth communication.

A complete overview of shipments can be seen in a calendar with color codes giving information on locations and resources needed. When orders are placed to suppliers, enter information into the system and from there the customer can keep full track of the shipment. All data from a project is available afterward to ensure that the customer can give feedback and improve for future projects.

As stated by Thunberg and Persson (2014) the lack of formal procedures for handling incoming deliveries is often the reason for logistical challenges. One way to tackle this is the implementation of a delivery management system. An example of a company providing such a service is Myloc. The service contains an implementation of working methods that work together with software that connects suppliers, forwarding agents, and customers. It is a cloud service that offers the constant sharing of information between actors in order to coordinate the flow of materials and use resources more effectively.

Its purpose is to solve several of the challenges discovered in the analysis including the information sharing between contractor and sub-contractor, SM1, and relying on mouth-to-mouth communication on breaks for distributing information, SM4. By making information easy to access for everyone on site, all contractors involved would naturally get further integrated into the project's supply chain, which traditionally has been one of the key challenges of the construction sector (Dubois et al., 2019). Furthermore, inefficient information sharing through a large amount of documents would no longer be necessary. Questions regarding if orders have been placed, if they have arrived on site, and where they are on-site, which has been experienced to some degree in all the studied cases can be eliminated. The system allows users to get information on all these factors and stores the data. Time spent searching for materials and resources can instead be spent on continuing work on the project.

Furthermore, the system can also help to get rid of “the superman trap” where, as mentioned, one, or a few individuals, has great competence and knowledge of logistics on-site whereas the rest have little. As stated by SM1 the AS-block was reliant on one person who had all the current information regarding deliveries and distribution on-site without it being documented for sharing with anyone else. Throughout the empirical study, this phenomenon was understood to be industry-wide as it, according to ML and AM, is more or less standard practice for these types of projects. With Myloc making this information available for everyone at the construction site the potential negative effects of this person not being available or disappearing from the project is managed, whereas if this was not the case could be a cause for concern.

Since everyone in the project can have access to the information through the app or computer system, knowledge can be widespread. Information regarding the time of delivery, content, and place of delivery can become common knowledge. Information regarding, for instance, anomalies or damages can also be tracked. All information and gathered data from the project can later be used to create KPI’s which, according to both the empirical study and several literature references (Lundesjo, 2015; Thunberg & Persson, 2014), is an important tool to find what has worked well and eventual improvement areas for future projects.

5.2.3 Logistics plan

Through observation it is evident that there is no such thing as a generic CLP that would fit all the company projects since the prerequisites vary greatly. There are however elements and obstacles that do need to be addressed at every construction project. How to manage deliveries, how to distribute information, responsibilities, storing, waste management, and much more. To ensure efficiency and that tasks are being done in accordance with expectations a CLP is a good tool, even though it may be tweaked to the specific project (Lundesjo, 2015). It can also be of help when evaluating past projects to be able to pinpoint what worked well and what might need to be reconsidered in an upcoming project as policies and procedures are documented in the CLP.

Even with these potential benefits, Lundesjo (2015) stated that the use of a CLP is rare in practice. This is in line with the investigated cases as such documents had not been developed in most of the projects. In the ASP-block, where a CLP was developed, it was disintegrated to the extent that management did not know of its existence. All projects had area disposition plans which worked as a visual aid for some of the most relevant logistical aspects such as roads, material tents, storage, gates, waste disposal, and parking. Depending on the project some ADP's also had smaller instructions or schedules for the project phases. Separate plans with the aim of scheduling the work were implemented at all the projects and in several cases, these included some logistical instructions. SM3 referred to the time schedule which briefly provided information about crane usage and the use of a telehandler for moving material. Compared to the literature, which states the benefits of detailed planning of logistical procedures on- and off-site, the documents used at the construction sites are lacking. Several of the interviewees welcomed the implementation of such plans and some pointed to the ADP as a document that could be expanded to also include more information or policies regarding logistics procedures.

Across the four cases, there were recurring challenges that had been solved with different solutions. SM1, and to some extent SM2, experienced that they got phone calls that could have been made to someone else since their numbers were the ones shared on the delivery documents. For example, when a delivery arrived and the driver needed it signed they could get a call, even though they were not necessarily the right person to contact. SM3 and SM4 had both managed this by appointing a person responsible for managing such calls, with the policy that their phone number would be on all the delivery documents, regardless of who made the order. Such policy could be established across all projects and documented per default in the CLP at the start of each project.

Another challenge, specifically at the AS-block, was the deliveries of incoming material on-site during night-time. These deliveries were often misplaced to the extent that it would force the workers to move the material a second time the next morning as it was in the way of their work. SM1 stated that it was likely the inexperience of the people making the deliveries combined with a lack of instructions on where to put the material that made the arrangement fail. Through observation, it was made clear that there was no effort put into requesting a certain placement of the delivery on behalf of the craftsmen. As suggested by Ekeskär and Rudberg (2016) this type of TPL service has proven to provide value in similar cases but cooperation from the contractor is needed to reach full optimization of the service. Consequently, to improve on the communicative issue, the responsibility of declaring where to put the material could be delegated to someone in the team that is expected to work in that area the following

day. It could be done by marking the floor or putting up a trivial sign. The policy would be documented in the CLP and communicated by management to make it standard practice at the project.

5.3 Feedback on solutions

5.3.1 TPL-providers

The representatives from both Rydskolan and the M-block had previously heard about the services that Qlocx provides as it had been used in another project of ByggDialog. It was even considered as an option for the project at Rydskolan but deemed too expensive. However, only the representative from Rydskolan had heard of Myloc. Representatives from both projects agreed however that the services that both TPL providers offer would be realistic and applicable on-site. It could offer a solution to the challenges regarding uncertainty if deliveries had been made and where on-site they were delivered to. Furthermore, it would help with the uncertainty regarding when deliveries came and where on-site they had been placed. For instance, the occasion where forwarding agents placed goods outside of the construction zone could have been avoided with the help of Myloc's labeling system or Qlocx's unloading area or container system. According to the representative from Rydskolan, the solutions that Qlocx offers would suit smaller projects better. It would offer a solution to the uncertainty regarding the arrival of deliveries and keep the materials safe and protected from the weather. The solution with a delivery container would also be suitable for projects where space is limited. It was argued that this solution together with a larger storage option for larger deliveries would make a great combination to keep track of everything.

For bigger projects, Myloc would be suitable according to all representatives. Since bigger projects often involve more deliveries it would make it easier to keep track of them. The representatives of the M-block informed that weeks were spent looking for the lost materials, but they could easily have been found or been placed at the correct location with the help of one of these services. Another positive of the TPL-provided solutions was the notification systems they provide. This could help with the challenges regarding the knowledge if deliveries had arrived or not. The ability to spread information and logistical knowledge through Myloc's services was also something that the representatives from the M-block found very positive. It could help with the challenges regarding coordination and communication since everyone on site would have access to information. The representative from Rydskolan agreed on the positive possibilities with Myloc but the cost would probably outweigh the benefits, which was also something that the regional manager at ByggDialog mentioned. They added however that Myloc would be a suitable solution for bigger projects.

When asked about possible challenges of implementation of TPL services the representatives from the M-block specifically highlighted one. This was the possible resistance from older generations as they could possibly have an objection to change or that the systems are too complicated. However, as long as the systems are relatively easy to use this would not be an obstacle. Furthermore, in 10 years this would not be a challenge at all according to the representatives due to younger generations entering the

industry. They could see clear advantages and time savings by not having to constantly look for materials, thereby improving site efficiency.

5.3.2 Logistics plan

A logistics plan was something that the representatives from the M-block would find a realistic and applicable solution as well. However, it would most likely be a tool primarily used at the beginning of projects and during the design phase which is something that the representative from Rydskolan agreed upon. It could add more information to how a work site should be constructed and how material handling should be conducted. It could prevent the loss of materials and give more insight into how and where materials should be moved on-site. It could also clarify how traffic should move and when.

Through the workshop, it became evident that the purpose of using the logistics plan actively in the production phase would be hard to accomplish, as neither of the representatives thought it would be likely to be used in such a way. It was stated to have the potential to be a good tool, but it must be specific and also concise. This is so that all parties and personnel involved in the project can easily read and understand it. It should not be too long and involve too much text but rather straightforward guidelines and explanations. The representative from Rydskolan added to this by saying that it should not only be a paper product but, it should be something that translates into reality. For this to be able to work, all workers should be able to work with the document and not only those with an interest in logistics. A clear template for a logistics plan would be highly appreciated according to both representatives from the M-block and Rydskolan as well as the regional manager from ByggDialog. They all expressed that it would lead to higher usage and a standardized way to work. Once again they emphasized the importance of keeping it concise and relevant so that everyone can understand and use it.

6 Conclusion

This chapter aims at drawing conclusions based on the analysis in Chapter 5. The three initial questions are discussed and answered before determining the conclusion to the research question of this thesis. Finally, research contributions and proposals for future research are presented.

6.1 Answering research question

- **Can logistical challenges across projects be solved by a general set of solutions deemed applicable by a contractor, even though the challenges do not manifest in the same way?**

To answer this, three sub-research questions have been created and answered which are stated below.

- **What are the typical logistical challenges and which are recurring across projects independent of the project prerequisites?**

Generally, there are several logistical challenges reminiscent of one another across all the studied projects regardless of their specific prerequisites. The most common are the ones connected to coordination and planning such as delivery management and information sharing within the supply chain network. One reason for this is that the network is disintegrated and communication between each actor is often limited. Another is the lack of attention to logistics as a major contributor to project success. As a consequence, projects often do not have an established logistics plan or standard procedures for how to handle regular logistical tasks. Information regarding delivery placements or moved material is dependent on mouth-to-mouth communication and specifically the disintegration between forwarding agent and contractor often leads to the latter not knowing when deliveries have- or will arrive at the site.

Furthermore, there are challenges that occur due to the project setting. Two of the cases were limited in terms of the surrounding space and ongoing operations which put restrictions on for example deliveries, parking, and waste management. The lack of space for storage imposed a JIT-approach upon the projects which puts more demand on planning the logistical flow ahead of time for the supply chain to work and not hinder the production phase.

- **What solutions are appropriate to solve those?**

After a background study was performed, three solutions were chosen based on challenges found at the different construction sites. The first solution chosen was Myloc construction, a system that connects customers, suppliers, and delivery agents. It enables contractors to organize and clarify deliveries, share information, and implement logistical working methods throughout an organization. The integration of such a service can remove uncertainties regarding if deliveries have arrived or not, clarify their content, store information, and much more. The second solution was Qlocx which offers contractors the possibility to keep track of when deliveries have arrived, their

location, and that they are stored safely. Lastly, a construction logistics plan which is a tool to ensure that all projects within the organization have an intentional approach to logistics. It helps centralize knowledge and experience sharing amongst current and future projects. Examples of details specified in such a plan can be access details, traffic management, and storage information. Further, it should contain policies that are followed on-site, for example, the use of a DMS or how waste is managed.

- **Are the solutions realistic to implement from a contractor's perspective?**

To answer this, the solutions were presented during workshops to representatives from two of the case projects as well as the regional manager at ByggDialog. The conclusion from these workshops was that the solutions, Myloc, Qlocx, and a logistics plan, are deemed to be realistic to implement and applicable to construction projects. However, not all solutions would be ideal for all projects. The cloud service, Myloc, was deemed a great solution by all who participated in the workshops but not for all projects. For smaller projects, like Rydskolan, the representatives were skeptical if the benefits would outweigh the cost of the service. For bigger projects on the other hand, such a system was deemed to be a good way of implementing working methods throughout the organization. Meaning that everyone has access to information regarding logistics. It would eliminate several of the challenges including finding a suitable system for deliveries.

A logistics plan was, as mentioned, also deemed to be a realistic solution to implement in projects even if it had not been used before by those participating in it. However, a clear template for it is needed according to all representatives who participated in the workshops. Furthermore, the information included must be relatable, relevant, and put together in a way so that both managers and workers on site can work with it. To add to this, the documents cannot be too long and should be easy to understand without significant knowledge of logistics.

To conclude, a general set of solutions can be used across projects and could potentially be used as a toolbox to increase efficiency and safety. The solutions presented have been deemed applicable by the case company and have been met with a positive reaction. The reason for this is most likely that regardless of the project, the logistical challenges have been similar, even though they have not manifested in the same way. However, how effective and suitable these solutions are depends on, for instance, the size and location of the project.

6.2 Contribution

This master thesis has contributed scientifically by investigating the downstream and on-site logistical flows of several public-use projects through the lens of a general contractor. By conducting this study it was found that all four construction projects which were scrutinized had similar logistic challenges. It showed that regardless of factors such as the size of the projects, resources, geographical location, and budget, there are similar challenges that occur in all projects. These challenges include a lack of organization of deliveries, uncertainty regarding the location of materials and resources on site, and communication about the prior two. A common example of this was forwarding agents delivering items to the construction sites but with no information regarding this available to workers or managers. There were occasions when it took

weeks to find deliveries, and some had been ordered twice as a result of this. Furthermore, when items were moved on site there was no information available regarding this. By showcasing this, the study contributes with the information that there are common logistical challenges across construction projects, regardless of for instance size of the project or physical space available.

After determining common denominators for logistical challenges across projects a set of solutions have been developed. These solutions include services from TPL providers and a structured logistics plan. The services provided by TPL providers introduce a standardized way of booking and receiving deliveries, getting clear information about them, and specifying locations of materials and resources, these solutions help solve the challenges stated above. The final solution, a construction logistics plan, targets the early phases of construction projects. It ensures that all projects start off with an intentional approach to on-site logistics making it easier to process as the project progresses compared to implementing policies and strategies in an already established project. By using such plans knowledge and experience sharing can be improved to ensure that the organization learns what works well and what does not for future projects further improving logistics on-site.

The thesis presents the solutions to management and workers of different levels of the case company and its projects. By doing this, it showcases how realistic and applicable solutions are according to the different levels of a construction company. It presents the opinions and feedback of several different representatives at different levels of projects and thereby enables a holistic perspective. As a result, the thesis can help to understand why these solutions are likely to have a positive impact and why they are adaptable in projects.

6.3 Future research consideration

In the process of making this thesis, several areas of future research have been identified. This includes, amongst others, exploring the success rate of the implementation of the solutions. Amongst other things, it could investigate the effects they have on the financial, environmental, and social factors of a project. Furthermore, how well the template for the logistics plan works in regard to usability and easiness to use. It would also need to be specified further on what specific details to include. Finally, to fully understand how the investigated solutions would affect the supply chain network, the perspectives of suppliers and forwarding companies would need to be investigated.

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