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Mitigation strategies for challenges to achieving high performing on-site construction logistics

A case study with insights from a large Swedish construction company

Master's thesis in Design and Construction Project Management

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SUMMARY

The construction industry has difficulties achieving high performance and well-functioning construction logistics is a key aspect for improving project performance and increasing productivity. The aim of this study was therefore to expand the understanding of the poor performance of on-site construction logistics and map out the main logistics challenges, their causes, effects and possible mitigation strategies. The study consisted of a case study of two construction projects in a large Swedish construction company, with common logistics conditions experienced in commercial building projects in dense urban areas. The findings were based on a literature review, interviews with 25 respondents and a review of company documents. The study focused on investigating challenges related to on-site logistics. The four main challenges to high performing on-site logistics found in this study were: lack of space, constrained conditions for efficient material handling, construction documents provided late and late changes of construction documents. Identified causes of the challenges included poor communication, timeliness of deliveries, the planning and design process falling behind and multiplicity and variety of concurrent activities. The main effects caused by the challenges was waste of resources in form of time and money, stressful work environment and adoptions of reactive ad-hoc practices. The results emphasised the importance of logistics planning and management, logistics setups and a structured procedure for integrated information sharing between projects, in order to mitigate the challenges. The theoretical implications explains that the general view found in this study regarding the urging of concurrency in operational and strategic activities is not generating high performing logistics. The contribution of this study includes practical implications regarding an awareness of common challenges and performance benefits of planning for construction logistics and sharing lessons learned within the construction industry.

Keywords: on-site construction logistics, construction logistics, logistics challenges, mitigation strategy, causes, effects, logistics solution.

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Terminology

Planning phase

Planning stands for that phase of the work before construction starts. It includes financial management, time planning and logistics planning.

Design phase

The design process includes developing the construction documents with the technical specification required.

Site disposition plan

A map of the construction site where different areas and facilities are drawn out, such as electricity, taps, gates, unloading zones and transport connections.

Site manager

The person responsible at the site to make sure the project is completed safely, on time and within budget.

Supervisor

A person responsible for material flow and production personnel in an assigned area of the project.

Production personnel

The personnel performing the construction work.

Logistics set up

The range of tools, partners, solutions and aids that the market offers to facilitate the on-site logistics. From this, each project can put together its own specific logistics setup.

1. Introduction

The construction industry encounters challenges to achieving high performance (e.g., cost efficiency and productivity; Vrijhoef & Koskela, 2000). Well-functioning construction work relies heavily on successful logistics activities (Brusselaers et al., 2020). Construction logistics is defined as “... planning, organisation, coordination, and control of the materials flow from the extraction of raw materials to the incorporation into the finished building” (Agapiou, 1998, p. 132). Improving logistics activities can enhance construction project performance (Wegelius-Lehtonen, 2001). For example, a project studied by Agapiou et al. (1998) proved 5 % cost savings when establishing a logistics model, achieved through reduced waste, damages, and earlier completion. However, the construction sector still suffers from considerable waste, unnecessary costs due to the poor handling of materials and tools and ad hoc work practices based on intuitions (Sundquist et al., 2018). Thunberg and Persson (2014) demonstrated that less than 40 % of the construction site deliveries arrive on time, in the right amount, undamaged, and at the right location. In commercial building projects, there may be several end-customers with different businesses, which means more types of materials and more changes, which leads to problematic issues for construction logistics (Ying et al., 2018). The conditions for implementing high-performing logistics becomes increasingly challenging when construction projects occur within dense urban areas due to heavy traffic flow outside the projects and the lack of space at the site (Kooragamage, 2015). Therefore, projects within large urban areas require logistics solutions to be successful (Janné & Fredriksson, 2019).

Construction logistics can be divided into supply logistics and site logistics (da Silva & Cardoso, 1999) also called on-site and off-site logistics (Dubois et al., 2016). Resolving on-site logistics issues is the first step to improving construction logistics performance (Ying et al., 2014). Even if there is a distinction between on-site and off-site logistics, there is still an interface between them (Havenvid et al., 2019) and there is a need for coordination between the supply chain and the on-site operations (Zheng et al., 2020).

Previous research within the construction field has addressed logistics and performance from different perspectives. Janné (2018) investigated how construction logistics affect the performance and the coordination of stakeholders, with a focus on the supply chain. Thunberg and Persson (2014) have looked into suggestions for improving construction logistics, but with a focus on a supply chain operations reference model. Sundquist et al. (2018) focuses on improving the construction performance by integrating the on-site and off-site logistics. Tsaxiri (2018) has identified logistics challenges and solutions, however focusing exclusively on Construction Logistics Centres. There are still limited insights regarding common challenges and solutions to achieve high performing on-site construction logistics for commercial buildings, with inputs from both the main contractor and subcontractors.

1.1 Aim

This study aims to expand the understanding of the poor performance of on-site construction logistics by mapping out the main logistics challenges, their causes and effects. The results strive to improve the performance of construction projects by inspiring the use of more strategic logistics solutions.

1.2 Research questions

The research questions for this thesis are stated as follows:

RQ1 - What are the challenges, and their causes and effects, for achieving high-performance construction logistics on site?

RQ2 - How can the challenges be mitigated by possible solutions?

To answer the research questions, the approach of this study was to conduct a multiple case study. The case study consisted of two construction projects with similar features, within one building department of a construction company.

1.3 Delimitations

The study focused on the challenges regarding on-site logistics activities in relation to what may hamper the productivity in two construction projects within one building department. As such, the study addressed two large commercial construction projects. The on-site challenges comprise only the challenges occurring within the specific location and during the construction phase of that one project.

1.4 Outline of the thesis

Chapter 1 introduces the study, providing a background of the topic, the aim and delimitations of the study and the research questions.

Chapter 2 consists of the literature review presenting the theoretical framework and ends with the conceptual framework.

Chapter 3 describes the method of how this study was conducted. This chapter provides a detailed description of the study process.

Chapter 4 presents a case description of the two studied projects.

Chapter 5 demonstrates the result from the empirical study, divided under the four logistics challenges and categorised under causes and effects, and possible solutions.

Chapter 6 discusses the findings of the empirical result in relation to the research question and theoretical findings, implications and sustainability.

Chapter 7 presents the conclusion of the study, its limitations and proposes future research.

2. Literature review

This chapter is providing a broader context of the chosen topic. First, the concept of construction logistics is explained. The next section is describing the four most common challenges discovered in this case study: lack of space, constrained conditions for efficient material handling, construction documents provided late and late changes of construction documents. Thereafter, possible mitigation strategies that the literature considers as beneficial are reviewed.

2.1 Construction logistics

Logistics was from the start limited to the military, and it was not until the industrial revolution that logistics was taken to a wider context (Agapiou et al., 1998). According to the Concise Oxford Dictionary, logistics is defined as the “art of moving, lodging and supplying troops and equipment” (Agapiou et al., 1998, page 132). Christopher (1998) defines logistics as the “process of strategically managing the procurement, movement, and storage of materials, parts and finished inventory “ (page 2). Agapiou et al. (1998) relate logistics to business, emphasising that its purpose is to have “the desired object of flow at the right place at the right time“ (page 132). Janné and Fredriksson (2019) share the description and express it as “activities dealing with supplying the right materials and resources to the correct customer and construction site to meet the customer’s requirements” (page 90). On-site logistics include handling material and planning the physical flow at the construction site (Fadiya et al., 2015). The on-site logistics entails activities such as delivery control, inbound transport, movement of material to assembling areas, and waste management (Havenvid et al., 2019). In terms of measuring whether or not construction logistics is successful, seven rights are suggested: “the right product has to be delivered in the right quantity, at the right time and place, with the correct documents and in the right condition” (page 1071). If one of these criteria is not met, delivery is not considered perfect (Thunberg & Persson, 2014).

Few in the construction industry understand logistics costs fully, and it is hard to understand since a lot of the non-construction costs are hidden (Sullivan et al., 2011). Hidden costs for on-site logistics are for example, handling material, material transport wagons, disturbances, and damage of materials (Lindén & Josephson, 2013). Meantime the workflow on-sites is dependent on logistics when it comes to factors such as availability of resources, production personnel, tools, and machinery at the right time. These factors impact the production productivity and the hidden costs make it hard to predict and measure these costs (Lindén & Josephson, 2013; Sullivan et al., 2011). The main contractor usually has difficulty calculating the logistics budget due to the hidden costs even after a finished project. However, it will never be possible to measure what it would have cost if the various logistics measures had not been implemented (Sullivan et al., 2011).

2.2 Logistics challenges

The brief interviews framed what challenges the literature review has investigated and the description of the challenges in table 1 presents how the literature define them.

Table 1: Summary of challenges investigated in the study

Challenge	Description	Source
Lack of space	Construction sites in dense urban areas tend to have very limited storage areas, which complicates production and the material flow.	Agapiou, 1998; Misron et al., 2018; Nolz, 2021
Constrained conditions for efficient material handling	The circumstances on the construction site makes material handling more difficult, resulting in time spent on moving materials etc.	Challa & Das, 2019; Kasim et al., 2019; Strandberg and Josephson, 2005; Tetik et al., 2021
Construction documents provided late	Construction documents are provided late to production due to limited resources in the design phase.	Assaf & Al-Hejji, 2006; Hanna et al., 2002; Khalifa & Mahamid, 2019; Platen, 2009
Late changes of construction documents	A change in the documents represents a difference from the original scope and usually occurs when developers/clients change requirements.	Al-Emad & Nagapan, 2015; Al-Momani, 2000; Assaf & Al-Hejji, 2006; Hanna et al., 2002; Ibn-Homai et al., 2011; Khalifa & Mahamid, 2019

2.2.1 Lack of space

Lack of space is a challenge for high-performing logistics. Construction projects located in dense urban areas are often impacted by congested sites and limited material storage possibilities (Misron et al., 2018). A construction site also has a limited possible amount of deliveries due to lack of space (Nolz, 2021), which may hamper the work process and the material flow. The lack of storage space at the site is complicated by the material being ordered sporadically in too large quantities, which causes waste of resources and high costs (Agapiou, 1998). Challenges regarding storage need to be addressed in order to have well-functioning material storage management.

2.2.2 Constrained conditions for efficient material handling

A correlation between poor material handling and project delay has been found in literature where material management has been found time-consuming due to the use of convenient and analogue methods (Kasim et al., 2019). Poor material handling increases time spent on moving materials which causes additional costs and time delays. Material availability is critical to optimise production. Misplaced material can increase costs, lead to safety problems, and cause delays (Tetik et al., 2021). The material not being in the right places causes construction production personnel to spend 13,9% of their working hours on moving materials, according to Strandberg and Josephson (2005). Inadequate material management also leads to production personnel spending nearly 20% of their time searching for the right materials (Challa & Das, 2019). Instead, implementing proper material management can positively impact productivity by 6% or more, according to Challa and Das (2019). Improper material handling entails extra costs. Two primary cost drivers that require minimization include the direct labour cost investment in connection to delayed deliveries of materials and the material inventory cost related to double handling and storage due to early and excessive material supply (Challa & Das, 2019).

2.2.3 Construction documents provided late

In construction projects, late construction documents which deviate from the planned construction, are common (Assaf & Al-Hejji, 2006; Khalifa & Mahamid, 2019). That is because every project is unique and has limited resources for the planning and the design phase (Hanna et al., 2002). A study by Assaf & Al-Hejji (2006) showed that there is a connection between project delays and the design phase. The impact on the delay was related to the complexity of project design, mistakes and discrepancies in design documents and delays in producing design documents. Al-Momani (2000) conducted another study that also investigated causes of delays in construction, which showed that the main reason for the project delay was due to poor design. Project delays lead to costs and potentially legal issues and therefore it is important to focus on the design phase. Late design documents occur when there are insufficient resources in terms of money and time for the planning and design phase (Hanna et al., 2002). In some projects the construction phase begins with only 20% of the design being completed, implying a risk that the production could catch up (Sullivan, 2011). The impact of influencing the design of a construction project is initially low. However, in later stages, such as after the start of production, the impact of the changes quickly increases (Platen, 2009).

2.2.4 Late changes of construction documents

Changes in design documents represent one of the most common reasons for project delays (Al-Momani, 2000; Khalifa & Mahamid, 2019; Al-Emad & Nagapan, 2015; Assaf & Al-Hejji, 2006). When there is a change in the design documents, a change request must be sent to the contractor (Khalifa & Mahamid, 2019). A change request is “a written order to the contractor, signed by the owner, and issued after execution of the contract, authorising a change in the work or an adjustment in the contract sum or contract time” (Khalifa & Mahamid, 2019, page 4956). Changes create issues in terms of variation of the project scope, unit rate changes, material quantities, material handling and design errors (Khalifa & Mahamid, 2019). A change is defined as a result of a modification from the original scope (Hanna et al., 2002), and late changes are customarily due to the client’s change of requirements such as additional work or changes in the design (Ibn-Homai et al., 2011; Khalifa & Mahamid, 2019). Furthermore, late changes can arise from omissions in design, lack of coordination between construction parties, and requests made by a consultant due to design errors, new findings or defective workmanship (Khalifa & Mahamid, 2019).

Late changes in design documents inhabit the control over the project’s schedule and negatively affect both price and time (Khalifa & Mahamid, 2019; Hanna et al., 2002) and cause rework of completed items (Al-Emad & Nagapan, 2015). Changes negatively impact labour productivity, and the contractor may achieve lower productivity than planned (Hanna et al., 2002). Ibn-Homai, et al. (2011) found that construction projects’ average increase in total cost due to changes was 11.3%. Changes can increase contractual disputes and negatively impact the relations between contractors, subcontractors, engineers, clients, and other parties involved in the construction process (Khalifa & Mahamid, 2019).

2.3 Mitigation strategies

In table 2 the mitigation strategies towards logistics challenges are presented. The mitigation strategies investigated were found in the literature and from the interviews and were evolved through systematic combining.

Table 2: Summary of challenges investigated in the study

Mitigation strategies	Description	Source
Logistics plans and Logistics Managers	Planning of logistics is the key to efficient on-site production. The planning includes an on-site layout and material management plan. An assigned Logistics Manager that is in charge of the on-site logistics reduces the waste of resources.	Sundqvist et al., 2018 Olivera, 2003; Sullivan et al., 2011
Material handling services	Material specialists move material and perform related activities through deploying specialised knowledge and efficient processes at the site.	Lindén & Josephsson, 2013; Ekeskär & Rudberg, 2011; Marasco, 2008
Construction Logistics Centres	Facilities that receive and redistribute material deliveries outside construction sites can ensure timeliness and order.	El Moussaoui et al., 2021; Hamzeh et al., 2007
Smart Delivery Container	The smart delivery container is enabling deliveries of smaller packages without occupying the space and personnel on site.	Rudberg & Gholami, 2019
Preventive work to minimise changes	Identifying the causes of changes, having a clear picture of clients' and end-users' requirements, and avoiding delays in reviewing and approving documents can help avoid unnecessary changes.	Khalifa & Mahamid, 2019; Ibn-Homai et al., 2011
Communication in construction projects	Communication is an important factor for enhancing logistics performance within projects. Updating all actors on site with information will improve many challenges.	Emmitt & Gorse 2009; Chen & Kamara 2008
Information sharing between projects	By sharing information within the organisation and its project, organisational learning can be achieved and knowledge will be kept within the organisation.	Wiewiora et al., 2009; Berg et al. 2012

2.3.1 Logistics plans and Logistics Managers

Well-performing logistics on-site is heavily dependent on how logistics are considered in the design phase before the production stage. Proper planning and organisation in an early stage of material handling, delivery, and storage enhances the logistics performance (Sundqvist et al., 2018). Planning is needed in order to reduce fire fighting, which is good for not wasting resources (Sullivan et al., 2011). The production plan and on-site layout support the planning, procedure, and monitoring of the

construction logistics, helping to indicate where, how, and when specific activities will occur and what material is needed (Olivera, 2003). The site layout design is a vital part of on-site logistics as it affects the productivity, safety, and cost of a project (Sundqvist et al., 2018). The site disposition plan should consider areas for material storage, production areas, and facilities for the production personnel (Olivera, 2003).

The site design layout should define the size, shape, and location of the work areas and circulation routes in line with the production design. Logistics solutions are necessary for many urban projects since they often have limited space, a need to reduce environmental impact and improve accessibility, and noise restrictions (Janné & Fredriksson, 2019). Since every construction project is unique, every project requires its own logistics plan that is adapted to the circumstances of the specific project (Janné & Fredriksson, 2019). A logistics solution should not be general; rather, it should be adapted to the specific condition of the construction site (Janné, 2018). Therefore, mapping the construction project is the first step when initiating construction logistics setups. After investigating the project context, necessary services can be defined and should also be developed to consider customer needs (Janné, 2018). The layout should regard specific conditions for the safety and health of the production personnel and support a rational production execution (Ferreira, 1998). According to Olivera (2003), there are multiple benefits arising from using a logistics plan and site layout. Some of the benefits mentioned are improved management of the physical flows, significant reduction of wastage due to a better organised construction site, and a general minimisation of the problems that typically appear at the interface between the different parties during the production phase. A proper logistics plan also enables a reduction of non-value-adding activities such as the movement of materials (Olivera, 2003). If the construction company uses a delivery calendar, they can book a time slot for unloading and transporting of upcoming material delivery. In the calendar the company can also book the required equipment for unloading the material such as a forklift. But in some projects only 50 % of the deliveries are pre-booked in the delivery calendars (Sezer & Fredriksson 2020). Everyone at the project needs to know the delivery plan and one way to achieve this is to print a delivery plan for everyone to study, this can improve the communication by everyone knowing that the plan exists (Thunberg & Persson, 2014). Subcontractors can ignore the plan leading to delivery collisions, and information shared about delivery information among the main contractor and subcontractors is important to reduce time spent on material handling (Thunberg & Persson, 2014). The site disposition plan for the project includes for example, inventory-holding areas and the plan needs to be updated and communicated to everyone on site (Thunberg & Persson, 2014).

The responsibility of planning and operating logistics activities often belongs to the site manager role; preferably, this should be assigned to a specialist position, the so-called Logistics Manager. Logistics operations require a logistics expert to manage the activities properly (Sullivan et al., 2011). When a Logistics Manager is involved in a construction project, risks can be mitigated, and costs can be decreased through increased productivity and predictability of the schedule. Benefits within the logistics plan can be realised when the activities concerning material handling are streamlined and held within one particular management role (Sullivan et al., 2011). The responsibility within the Logistics Manager role is to manage the distribution of material from the factory to the assembly. The Logistics Manager needs to create a plan for receiving and unloading deliveries and what tools are needed to do so, such as vehicles, cranes, and hoists. A well-performing Logistics Manager can remake the theoretical plan when it is not working in practice. Therefore, a Logistics Manager's flexibility and responsiveness are critical abilities when changes occur. Some construction projects start when only 20 % of the design is finished, and the Logistics Manager needs to be prepared for potential design changes and unforeseen events (Sullivan et al., 2011). The Logistics Manager should

also foster collaboration between different actors involved in the project and is responsible for logistics meetings on-site. It is good to have a Logistics Manager in all different projects, but the most significant benefits can be gained in large and complex projects (Sullivan et al., 2011).

2.3.2 Material handling services

Lindén and Josephsson (2013) claim that outsourced services regarding material handling generally reduce the non-value adding activities at a construction site. Traditionally, material handling (e.g., unloading and moving material to the assembly area) is done by production personnel during their daily work. This activity reduces the portion of value-adding working hours for the production personnel, i.e., material installation. An alternative is that a material handling specialist focuses on material handling and moving activities. The advantages of a material handling specialist are increased amount of material in the right place at the right time, fewer damages, and reduced movement of equipment and people (Agapiou et al., 1998; Lindén & Josephsson, 2013). If the material service is performed after regular working hours, the space at the site and the moving of equipment (e.g., cranes, elevators) can be used more efficiently during the whole day (Lindén & Josephsson, 2013). Overall, Lindén and Josephsson (2013) study proved 20 % cost savings when the handling of gypsum boards was outsourced.

Third-Party logistics (TPL) is defined by Marasco (2008) as “an external organisation that performs all or part of a company’s logistics function”. TPLs can be used for several logistics services but are referred to as on-site material handling service providers in this thesis. In the case study of TPL conducted by Ekeskär and Rudberg (2016), the service providers were responsible for material handling and construction site disposition plans, placement, and planning of scaffolding and cranes and elevators used. Positive effects were uncovered, like mitigated traffic disturbances. However, challenges regarding cost calculation, following up budgets, and resistance against the new setup among stakeholders were observed. When outsourcing material services, the contractor transfers a business opportunity to the TPL (Ekeskär & Rudberg, 2016).

The material handling service in the study of Janné and Rudberg (2022) resulted in material being available for production when required and a cleaner and more structured construction environment. This result was achieved after regular hours deliveries and given a limited amount of on-site materials. Negative consequences of the material handling services consisted of coordination difficulties and failures in the labelling of material and in planning. There are benefits gained with TPL, but it comes with a cost. A long-term learning process is needed to unlock the TPL’s full potential. For example, subcontractors and suppliers must accept and understand the purpose of the solution in order for it to be successful (Janne & Rudberg, 2022).

2.3.3 Construction logistics centres

A Construction Logistics Centre can be useful to mitigate the issues related to poor material handling and lack of storage. A Construction Logistics Centre (CLC) is a facility outside the construction site where deliveries of materials are received and then redistributed to the construction site at the time and in the order needed (El Moussaoui et al., 2021). A CLC could also be described as a central point for the material flow in a logistics supply chain, which provides the possibility of many value-adding services, different shipment methods, and a wide range of logistics functions for different users. The CLC provides the opportunity for temporary storage to better accommodate the supply and demand, which also facilitates the use of Just in Time (JIT) deliveries to the site (El Moussaoui et al., 2021).

JIT is a lean principle that implies having the material delivered immediately installed, meaning a smaller inventory of on-site material (El Moussaoui et al., 2021).

Additional storage space will impose additional costs for the project. However, not receiving material deliveries on time causes delays, resulting in added costs and negative consequences on the project progression (Hamzeh et al., 2007). Damaged material due to improper storing conditions on-site also results in waste and additional costs for the project (Hamzeh et al., 2007). The application of a CLC can reduce supply chain costs regarding less inventory. Projects tend to use the safety stock of some materials to reduce their liabilities and compensate for variations and changes. Using a CLC to accommodate several different projects enables the possibility to combine the safety stock inventory for the different projects, thus saving the total inventory costs (Hamzeh et al., 2007).

2.3.4 Smart delivery container

The smart delivery container solution can improve the efficiency of construction logistics on-site (Rudberg & Gholami, 2019). This container enables deliveries of packages to site without entering the gates or time booking, which reduces the resources spent on handling material. The container is attached to the site fence, since it is supposed to be loaded from outside the fence from the delivery company and unloaded from the construction site when materials are needed. The doors to the containers are supplied with smart bluetooth locks, and they can be opened with an app (Rudberg & Gholami, 2019). The app is also keeping track of inventory levels and when deliveries have arrived to the site. Only planned deliveries can enter through the container, since every delivery has its unique digital key for opening the container. The pick up of the delivered goods can thereafter occur when the on-site personnel has time. Information regarding the delivery and confirmations is handled through the app. Important factors of achieving the benefits of the smart container is to ensure that production personnel receive education of how to use the solutions and to make sure that commitment for the container is present at the construction site (Rudberg & Gholami, 2019).

2.3.5 Preventive work to minimise changes

Late changes and late approval of construction documents are often inevitable (Khalifa & Mahamid, 2019; Hanna et al., 2002), but some preventive work can be done to avoid potential changes or minimise their effects (Khalifa & Mahamid, 2019). There is often an adversarial atmosphere between parties in construction projects. Therefore, the changes must be managed well to support the different relations between actors, minimise their cost and schedule impacts, and avoid consequential effects such as substantial cost and schedule overruns (Khalifa & Mahamid, 2019). An important aspect to avoid potential changes and minimise the effects is identifying the causes of the changes. Therefore, attention to this problem must be given in an early stage of the construction project (Khalifa & Mahamid, 2019). Ibn-Homai et al. (2011) argue that the best practices for project change management include defining the clients' and end-users' requirements clearly before the beginning of the project design and reviewing the design drawings before construction to achieve the overall project objectives. These practices can be realised by the client preparing well-defined documents about the needs before the design stage starts (Khalifa & Mahamid, 2019) (e.g., through a survey study, a questionnaire for the project's end-users, and carefully studying the project's final intended use).

Furthermore, the client should work with well-experienced technical staff members to get the help they need to make the decisions on time (Khalifa & Mahamid, 2019). Assaf and Al-Hejji (2006) also mention that the owner should avoid delays in reviewing and approving design documents and

investigating resources and capabilities before offering the contract to the lowest bidder. When it comes to the architect and design engineer, they should focus on issues such as delivering design documents on time and avoiding mistakes and discrepancies in design documents to avoid the need to redo design documents (Assaf & Al-Hejji, 2006).

2.3.6 Communication at the construction site

Emmitt and Gorse (2009) have a concern for the lack of effective communication during the construction process and describe how the construction industry is known for failing in communication and cooperation. Communication in the construction industry needs to become more productive, and well-functioning communication is key for the quality of the end product and to avoid conflicts (Emmitt & Gorse, 2009; Hoezen et al., 2006). The construction site is an information intensive environment (Chen & Kamara, 2008) and the information can flow in formal and informal communication routes (Emmitt & Gorse, 2009). The project based industry entails that every new project consists of unfamiliar organisations with their own culture and people with their own personalities. Temporary and ad-hoc arrangements create a need for relationships and communication channels to be recreated for every new project, sometimes even within a project if the participants are changing and the participants usually do not have an overall goal or a shared deadline. The production environment at a construction site reflects a very tight time schedule with complete focus on coordination and planning in order to complete the building activities in time (Wikforss & Löfgren, 2007). This environment requires extra effort and time to achieve effective communication at construction sites (Emmitt & Gorse, 2009).

The lack of communication and coordination creates inefficient planning and problems regarding logistics in the construction industry (Ying et al., 2014). How efficient and effective the construction process is strongly depends on the quality of communication (Hoezen et al., 2006). There are various sources of information and communication mediums at construction sites. Sources to receive information from at site can be supervisors, clients, consultant, design team, subcontractors, engineers, suppliers and so on. The mediums to communicate the information are usually meetings, telephone, email, computer disc, cloud data etc. (Chen & Kamara 2008). Problems with information sharing at a construction site usually arise from lack of updating the information channels and the information flow stagnates creating challenges in overcoming problems and the problems remain on the construction site. One way to improve on-site communication is to use technologies as communication systems, creating access and mobility of information (Wikforss & Löfgren, 2007) and hindering information to be bound to paper or people (Chen & Kamara 2008).

The communication and information sharing between the main contractor, subcontractors, suppliers and transporters are important factors for the on-site logistics performance concerning the material flow (Thunberg & Persson, 2014) and improved connection between off-site and on-site activities supports well functioning logistics (Sundquist et al., 2018). Inaccurate order communication leads to deliveries needing to be solved on an ad-hoc basis, entailing more truck movements (Ying et al., 2014). Effective communication between participants in construction projects will limit time spent waiting and remodelling work, improve the quality of the final building and save costs (Sørensen, 2014).

2.3.7 Information sharing between projects

Knowledge is seen as one of the primary competitive organisational advantages indicating that knowledge management should be an essential activity (Landaeta, 2008; Love et al., 2005). Managing knowledge implies dealing with two key elements: information and knowledge. The difference between what information and knowledge are can be challenging to distinguish since they are abstract and intertwined (Savolainen, 2017). The abstractness of information and knowledge also implies the difficulty of separating what information sharing and knowledge sharing are. Some authors suggest that information and knowledge can be shared and that the two terms can be viewed as interchangeable. The application of information sharing can be conducted in real-time through personal communication and passively by uploading documents in an archive for future usage (Savolainen, 2017).

In practice, knowledge sharing has shown to be challenging to accomplish in the construction industry due to its specific characteristics with geographically spread, temporary project organisations without natural systems of learning (Argote et al., 2000; Love et al., 2005). Projects' discontinuous and temporary nature imposes difficulties for project-based organisations to assimilate and distribute knowledge (Landaeta, 2008). The construction industry's poor performance and productivity are connected to new projects not utilising the learnings from former projects (Wiewiora et al., 2009). With projects being temporary, the knowledge is often bound to the individuals in the different projects rather than implemented in the core organisation (Berg et al., 2012).

In order for knowledge sharing to occur, a knowledge management strategy needs to be set within the organisation (Leal et al., 2017). In the study of Almeida and Soares (2014) regarding information sharing in project based organisations, it was suggested that social relationships between the projects and the main organisation should be enhanced to enable knowledge sharing. Sharing of information and knowledge by informal social meetings such as chit-chatting is an important part of the knowledge sharing process. The authors (Almeida & Soares, 2014) stress that people tend to share knowledge with those they have a relationship to. Therefore, in order to enable knowledge sharing between projects, connections and networks between projects should be established (Leal et al., 2017). The organisation should allow for and enable stronger inter-project communities where relationships can be created, and thereafter there is an opportunity for information to be shared (Almeida & Soares, 2014). Furthermore, the behaviour of people implies that people tend to share knowledge to a large extent if they receive knowledge back (Leal et al., 2017). If top managers are willing to play an important role in setting the knowledge sharing environment, people are more willing to follow its procedures (Leal et al., 2017).

The development of today's technology could improve the issues regarding gathering and sharing information, if the construction industry applied these information technology systems (Leal et al., 2017). Storing and codifying knowledge by using digital tools is a useful strategy for enabling information sharing (Almeida & Soares, 2014). Even though informal information such as chit-chatting is shared frequently and sporadically, this knowledge could be easily lost since it is not automatically documented and available for the whole organisation outside the relationship. A strategic procedure of organising and collecting the information is therefore required to assure that produced knowledge is saved in order to fulfil the organisational needs of learning after a project ends. Platforms for saving documents and lessons learned are suggested (Almeida & Soares, 2014). The IT platforms should be used to store and sort knowledge in documents so it is easy for everyone to have access to it. However, establishing a new information platform in an organisation can be

challenging due to resistance towards change and extra costs. It is therefore of importance that the IT platform is user friendly to gain acceptance for it (Almeida & Soares, 2014).

2.4 Conceptual framework

The conceptual framework structures the analytical thinking and guides the literature findings. The arrows show how the challenges negatively affect the performance and how mitigation strategies can positively affect the challenges. The conceptual framework for this study is shown in figure 1.

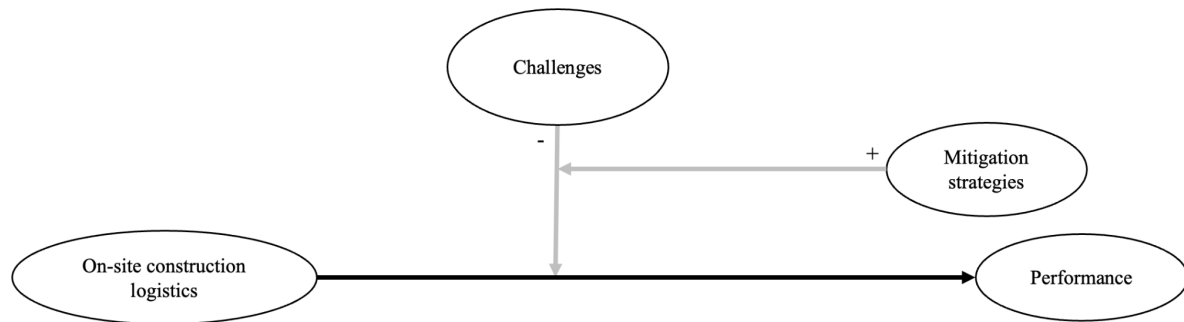


Figure 1: *Illustration of the theoretical conceptual framework.*

3. Method

This chapter presents the research design and how the data were collected and analysed. Then, the reliability and validity of the study are discussed.

3.1 Research design

The research design was developed to answer this study's aim and research questions. The research questions were answered by establishing an understanding of individuals' experiences. This study is based on a qualitative methodology to collect empirical data due to the exploratory nature of the aim and research question. In order to get an in-depth conceptual and individual understanding of people's behaviours, experiences, and attitudes, qualitative inquiry is required (Patton, 2014). According to Collins (2018), the interpretivism view includes understanding individuals' differences and subjective perceptions in a socially constructed world. The study adopted an abductive approach since the collected empirical data evolved the theory and vice versa to generate new knowledge.

This study consisted of a multiple-case study. A case study is a unit of analysis and it is possible to study an issue from different cases within the same firm (Voss et al., 2002). The analysis units were two commercial building projects in a large construction company in Sweden. The two cases were selected since they are both facing somewhat similar logistics challenges but consist of a different set of people. The study is based on an exploratory approach allowing to highlight the similarities and differences observed in the projects (McCutcheon & Meredith, 1993) Therefore mutual barriers but different perceptions and working procedures could be identified when comparing them. Case studies are appropriate when looking at how and why contemporary events occur, and a case study allows for a holistic view of organisational and managerial processes (Yin, 2018). Multiple-case designs contribute to analytical benefits since the conclusions from two cases will be stronger than when using a single case-study design (Voss et al., 2002). Case studies enable investigating greater depth over breadth (Yin, 2018), which is in line with the need of this study that sought to generate deep insights into how the building department can improve its logistics solutions. Therefore, depth is prioritised. Depth enables capturing of social relations and mindsets of the people involved to help understand the issues fully. Two projects enabled a comparative analysis, considering various project scopes and budgets. Above all, the selected projects shared some aspects that ensure multiple case homogeneity since the cases need to be relatively similar to compare them (Yin, 2018). They are both commercial buildings with a central location, which complicates on-site logistics. The homogeneous and heterogeneous characteristics made the projects easier to analyse and draw patterns. The homogeneous characteristics allow for comparability and identifying patterns, and the heterogeneous characteristics highlight the differences and allow for lessons learned (Voss et al., 2002).

The study started with developing research questions that contribute to the aim. The next step was an iterative process between the literature review and in-depth interviews focusing on identifying and explaining logistics barriers and mitigation strategies. The iterative combining of empirical and theoretical data resulted in a suggested framework. Thereafter, the findings were compiled into a practical guide concerning how the investigated logistics challenges could be handled to improve project performance. Figure 2 illustrates the research process.

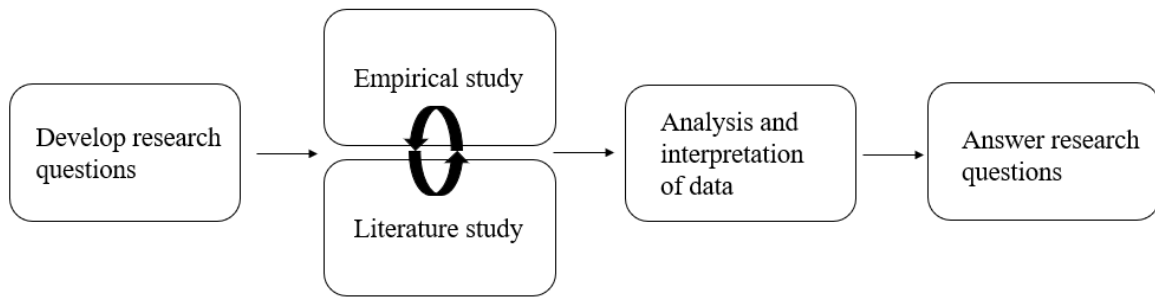


Figure 2: Illustration of the research process

3.2 Data collection

The primary data source was people. Opinions and perceptions were captured using interviews in two steps. The first step consisted of brief interviews with employees representing the two projects to map out the most recurrent logistics barriers. The second step was to conduct in-depth semi-structured interviews with the employees from the two projects, a Logistics Expert from the construction company, and a Logistics Researcher. The interviews focused on the most common logistics problems, how the respondents experienced those problems, how the respondents wanted the problems to be handled in the future, and possible mitigation strategies. The information about the interviews is found in Table 3.

Table 3: Summary of in-depth interviews

Project 1			Project 2			Non project specific	
Interviewees	Abbreviation	Time [min]	Interviewees	Abbreviation	Time [min]	Interviewees	Time [min]
Main contractor, site manager	SC1-MC-SM	60	Main contractor, logistic manager	P2-MC-LM	60	Logistic expert in the company	50
Main contractor, supervisor 1	P1-MC-S1	10	Main contractor, supervisor 1	P2-MC-S1	10	Logistic researcher at a University	50
Main contractor, supervisor 2	P1-MC-S2	40	Main contractor, supervisor 2	P2-MC-S2	40		
Main contractor, supervisor 3	P1-MC-S3	10	Main contractor, supervisor 3	P2-MC-S3	40		
Main contractor, supervisor 4	P1-MC-S4	40	Main contractor, supervisor 4	P2-MC-S4	40		
Main contractor, supervisor 5	P1-MC-S5	10	Main contractor, supervisor 5	P2-MC-S5	40		
Main contractor, supervisor 6	P1-MC-S6	10	Main contractor, supervisor 6	P2-MC-S6	40		
Main contractor, supervisor 7	P1-MC-S7	10	Subcontractor, supervisor 1	P2-SC-S1	20		
Main contractor, supervisor 8	P1-MC-S8	40	Subcontractor, supervisor 2	P2-SC-S2	20		
Subcontractor, supervisor 1	P1-SC-S1	10	Subcontractor, supervisor 3	P2-SC-S3	20		
Subcontractor, supervisor 2	P1-SC-S2	20					
Subcontractor, supervisor 3	P1-SC-S3	20					
Subcontractor, supervisor 4	P1-SC-S4	20					

The respondents were selected to represent different perspectives. The Logistics Manager and Logistics Expert were chosen to represent the perspective of the people who set the framework for logistics solutions. The supervisors from the building department and the subcontractors were interviewed to include the perspective of the people who adopt logistics solutions. The respondents also represented both the internal perspective (i.e., the building department) and the external perspective (i.e., the subcontractors). The interviewed subcontractors represented actors at different types of project stages and handling materials of different sizes. The selected subcontractors covered the handling of large volumes of materials, large amounts of smaller components, and heavy and ungainly materials, thus facing different problems. The supervisors from the building department were chosen to represent different stages and parts of the production in order to cover different perspectives of the barriers. They had all been working on the respective projects for a substantial amount of time, meaning they knew the project process well and could provide valuable insights. Lastly, a Construction Logistics Management Researcher was included to complement the interview study with more theoretical knowledge and provide an external point of view.

The semi-structured interview template was based on the conceptual framework synthesised using relevant literature. The template enabled the possibility of follow-up questions and the opportunity for the respondents to speak freely about their experiences and opinions. To avoid ethical transgressions, the interviewees were kept anonymous. All the respondents participated voluntarily, and the interviews were recorded if their permission was obtained.

The secondary data source in this study was a review of company documents. The company documents included delivery instructions, the logistics strategy, and a logistics checklist. The company documents provided further information about the logistics work, both on the specific projects and generally at the company. The documents were also used to see what information brought up during the interview study could be validated or contradicted.

3.3 Data analysis

The study used a systematic combining approach where the empirical data guides the theory collected in a non-linear process (Dubois & Gadde, 2002). The matching process was affected by theory versus empirics and the conceptual framework versus the evolving case (Dubois & Gadde, 2017). The selection of the theory collected in the literature review was governed by how the interviews evolved the case. When new aspects emerged in the interviews, the literature expanded simultaneously with corresponding theories.

The initial step of the analysis was to identify the most common logistics challenges. The claims from the brief interviews were counted and the results were compiled into pie charts based on percentage for the most common answers (see figure 4 and 5). The data from the interviews consisted of recordings of all the interviews, notes taken by two different people, and the company logistics documents. In order to understand the presumptions for the projects, company logistics documents were used in order to map the planned situation and course of action. The company logistics documents were also used to verify the answers from the interviews. The data analysis process followed the structure illustrated by Yin (2011); see Figure 3. The first step was to compile the interview notes and recordings to gain an overview of and initially sort the empirical data. Identical or similar answers were grouped, and frequently occurring answers were highlighted to facilitate the analysis process. The second step was to disassemble the data into smaller parts and further sort the information. Consequently, categories were organised depending on possible associations between the

data and challenges, their causes and effects, and mitigation strategies. The third step (i.e., reassembling the data) mainly coincided with the second step (i.e., disassembling the data). Patterns could be identified in these two steps, which led to some adjustments to the initial sorting. An example illustrating this was that the two categories ‘causes’ and ‘effects’ were merged into one combined category since it appeared they were strongly interconnected. Once the data was sorted and decomposed, interpretations (step 4) and drawing conclusions (step 5) were performed. As illustrated by the double-sided arrows in Figure 2, the analysis was an iterative process going back and forth between the different steps as the process evolved and new/extended perspectives unfolded.

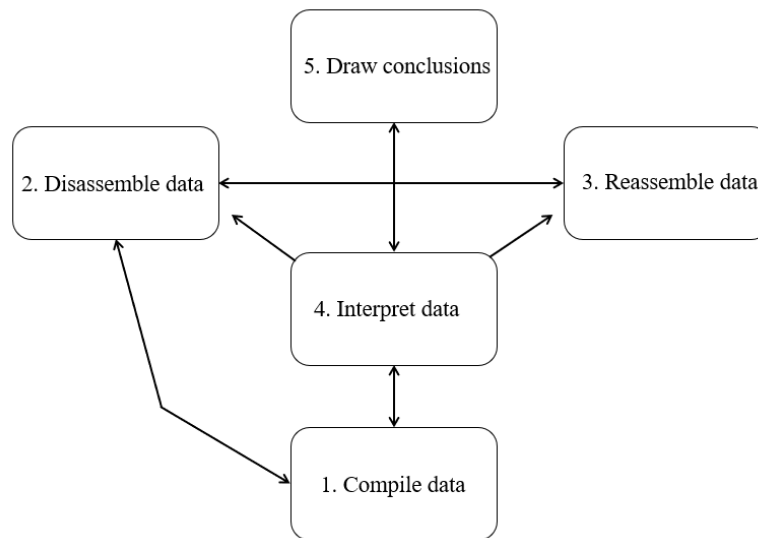


Figure 3: *Data analysis process by Yin (2011)*

3.4 Reliability and validity

The external validity describes whether the result can be generalised outside the case context (Yin, 2018) and case studies help guard the result against observer bias boosting the external validity (Voss et al., 2002). Although case studies have limitations concerning generalisations, they provide rich stories and narratives and thereby put more attention to the research (Dubois & Gadde, 2017). A case study relies on analytical generalisations (Yin, 2018), and in this case, the study tries to analyse data into a broader theory in the shape of recommendations. The data were collected from more than one project in order to specify that the same result occurs in both as a direct replication of the result (Yin, 2018). The projects were chosen because they are in the general context of commercial buildings in dense urban areas. The two projects’ homogeneous and heterogeneous characteristics facilitated the analysis and the possibility of drawing parallels between them. Large construction companies in Sweden are pretty similar and operate within the same context with the same or similar customers. The similarities allow other construction companies to use the study results since they can recognize themselves in the selection and context. The cases must be chosen carefully; in this case, they were two building projects since they predict the same result, called literal replication (Yin, 2018).

The internal validity characterises the confidence that the causal relationship being tested is reliable and not affected by other variables or factors and this aspect is an extra concern for explanatory case studies (Yin, 2018). Although this study adopted an exploratory approach, collecting and interpreting data in a structured, reliable setting was essential to enable drawing direct and correct conclusions from the result and ensure that the result reflected the reality under study (Yin, 2018). The interview

template consisted of open-ended questions to guide and not lead the interviewee and offer them an opportunity to describe their view of reality.

Several respondents representing various key actors in several project phases were selected to explore answers to the research question from different perspectives and thereby strengthen the validity. Furthermore, data triangulation was applied by collecting data from different sources, enabling multiple sources of evidence for the result (Voss et al., 2002). The data sources comprised the building department's and the subcontractors' perspectives combined with previous research, a Logistics expert, a Logistics Researcher and company documents. The combination of different sources helps cross-check the validity of the findings and a sound comparison of the data (Yin, 2018; Voss et al., 2002). Testing the research question by various sources ensured that the study measured what it was intended to measure. This aspect ensured that the outcome would be the same if the study were carried out again, featuring enhanced reliability (Yin, 2011).

4. Case description

A multiple case study was used to gather data in this thesis. This section presents the characteristics of the two studied cases and provides an overview of the respective logistics solutions already implemented. The investigated cases consist of two commercial building projects, both located in the same city in Sweden within the dense urban area. The two projects are held within the same building department at a construction company i.e. the focal organisation of this study.

The logistics procedure of both projects takes its starting point from the logistics checklist provided by the companies' production development unit. The logistics solutions used by both the projects are summarised in Table 4. The work begins before the production starts during the planning phase, where the area's conditions are mapped, such as access roads, surrounding construction projects, and allocated on-site areas. All subcontractors and suppliers have signed and approved the project management's logistics and delivery plans. All deliveries in the two projects need to be booked in advance in a delivery calendar. In addition to booking, the purchaser needs to include information about what is ordered, the end location of the order, the person responsible on-site, and other relevant information.

Table 4: Summary of the logistics solutions used by the projects

Logistic solutions	Project 1			Project 2		
	Yes	Partly	No	Yes	Partly	No
Calendar for unloading slots	x			x		
Logistic manger at site	x			x		
Forklift for everyone on site	x			x		
Third party logistics	x			x		
Consolidation centre			x			x
Storage area outside the site	x			x		
Labeled storage space for the disciplines		x			x	
Delivery container	x					x
Regular logistics meetings		x			x	
Written logistics plan	x			x		
Kitting deliveries		x			x	
Check point			x			x
Material marked with bar code or QR code			x			x

4.1. Project 1

Project 1 is a commercial building where a hotel, offices, restaurants and a pool will be included. The building will have around 30 floors and every floor will be around 1000 square metres. The duration of the construction process is estimated to be 3 years and the project has reached the later phases of the construction. Project 1 is operated in collaboration between the focal construction company and a real estate company.

Project 1 have a logistics plan that includes logistics instructions and an overall site disposition plan. For organising deliveries, an unloading calendar was used, where deliveries must be registered five days in advance. The project also has a responsible Logistics Manager on-site. A forklift is available

on site, for all actors to book and use. The project has also employed a third party logistics provider that is handling material every day, and during after hours. Project 1 also have the possibility to store material outside the site in a warehouse when special circumstances occur. Further, the project uses a smart delivery container for small package deliveries.

4.2. Project 2

Project 2 will become mainly an office building but restaurants, a terrace and shops will also be a part of the building. The project consists of a variety of floor levels, where the highest part will reach 15 floors and the office space will reach 25000 square metres. The project is currently in the latest construction phase and the construction duration is around 3-4 years. Project 2 is operated by the focal construction company in a collaborative form between the building department and the project development department. This project is located within an urban development area where other construction projects are operated in the immediate vicinity of project 2.

The goals and the logistics strategies of the projects were formulated by the construction company in a logistics plan. Project 2 have goals regarding keeping efficient on-site logistics, well-functioning material flows and an organised site. An unloading calendar where deliveries must be registered five days in advance and internal and external site disposition plan is used. In this project, a Logistics Manager was assigned. Further, the construction company provided forklifts on site, available for everyone to use. The project sometimes calls in a third party logistics provider for handling goods. The project also has the possibility to store material, outside the site, in a warehouse.

5. Result

The empirical results consist of brief interviews, in-depth semi structured interviews, and a review of company documents regarding logistics challenges and how they can be mitigated. During the brief interviews, the respondents' claims of different challenges were counted and then calculated as a percentage of the most commonly mentioned. The brief interviews showed that the four most common challenges are: lack of space, constrained conditions for efficient material handling, and construction documents provided late and late changes of construction documents (see Figure 4). The two projects feature some differences, as shown in Figure 5 (see the extended results in Appendix 1), but the challenges mentioned earlier were the four most common challenges for both projects, therefore, the study focused on those challenges.

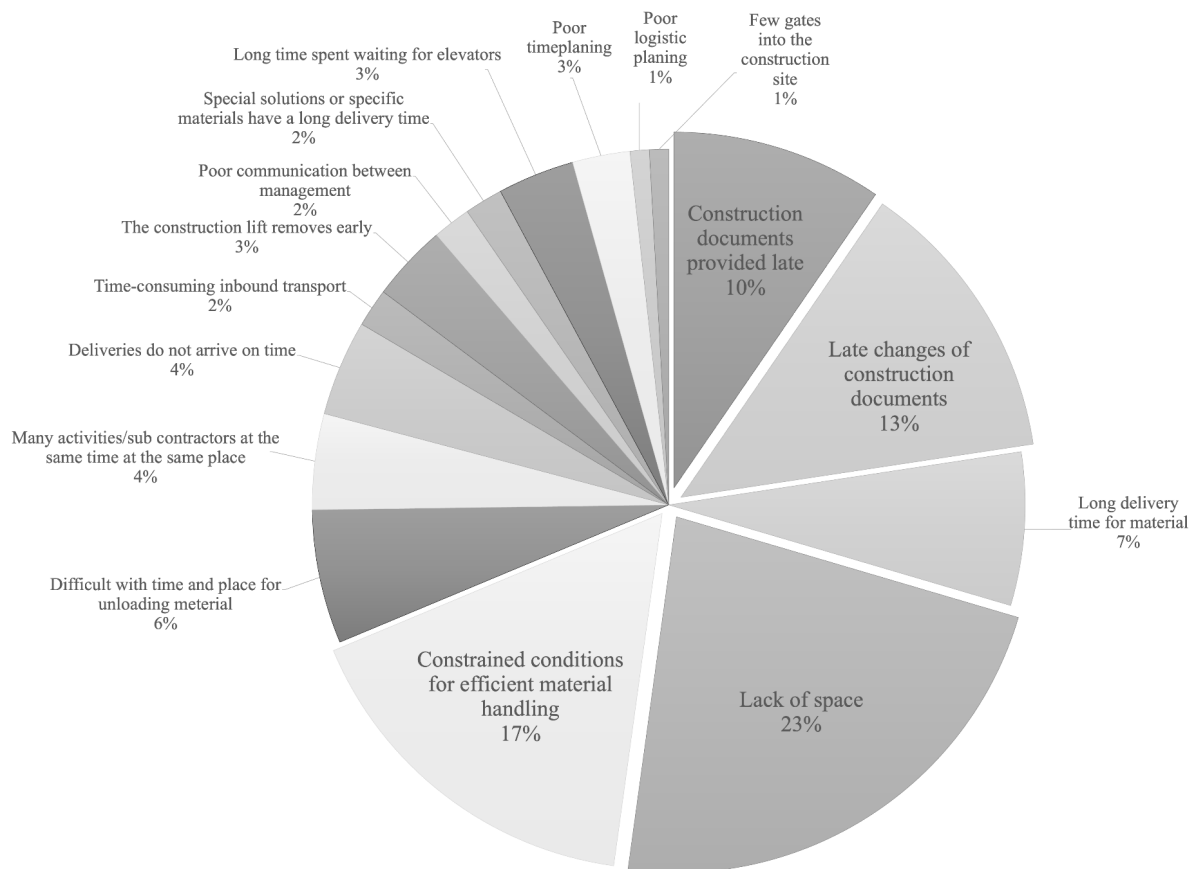


Figure 4: *The total result from the brief interviews.*

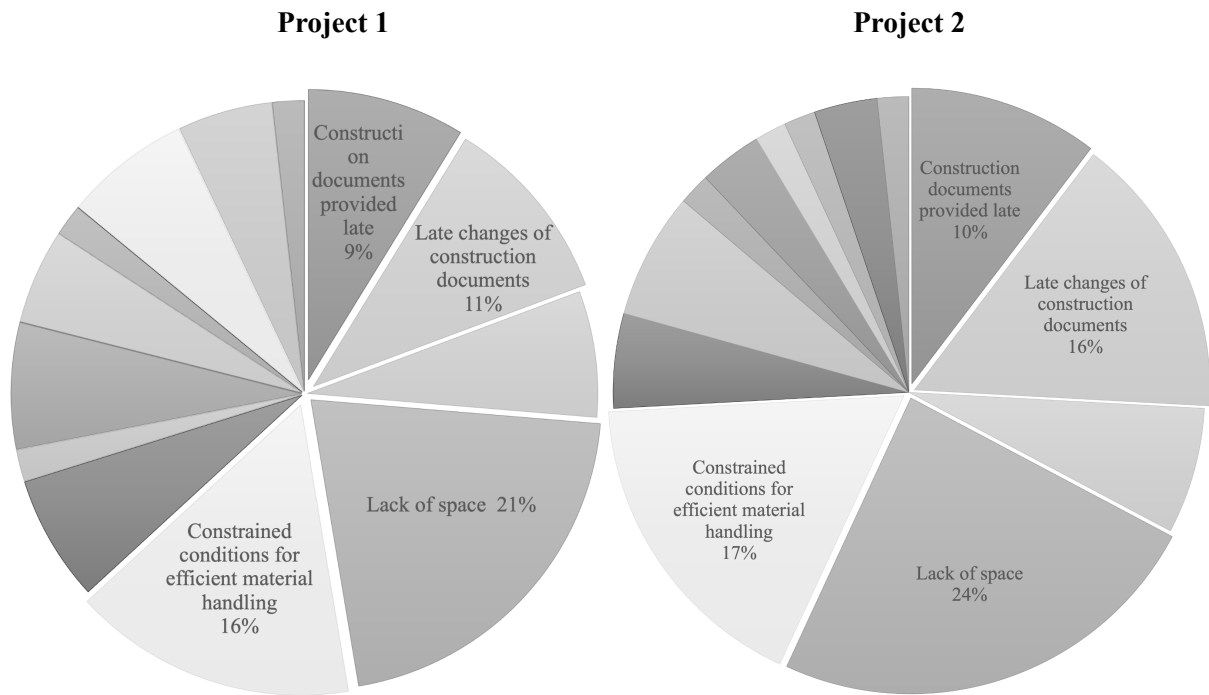


Figure 5: *The result from the brief interviews for the two different projects.*

The following sections present results based on the interviews and a review of company documents, associating causes, effects, and possible mitigation strategies with each challenge. The abbreviation for the interviewees can be found in Table 3.

5.1 The projects' logistics challenges

This section describes how the interviewee has experienced the logistics challenges, the causes of why they occur, and their effects. The causes and effects of the four challenges are summarised in table 5.

Table 5: Summary over the causes and effects identified for the logistics challenges

Challenges	Causes	Description & Effects	General effects
Lack of space	Dense urban areas	Projects in dense urban areas imply a limited area for the construction site leading to limited access to areas for storage and unloading areas for deliveries.	The different challenges contribute to general effects in terms of increased waste of material, time, and money, ineffective ad-hoc problem-solving activities, frustration, and stress.
	Uncertain market	Uncertainty on the market leads to a greater wish to order material in larger quantities and longer time in advance in order to secure material, creating a need for stockpiling of material, which further complicates the situation of limited space.	
	Early removal of the construction hoist	The construction hoist is placed outside the building and can transport larger materials to the different floors. It needs to be removed when installing the facade. When the hoist is removed too soon, it leads to larger materials having to be stored on the floors for a long time and being in the way of installations.	
	Multiplicity and variety of concurrent activities	During the production phase, where many actors work simultaneously in the same areas, the situation of the limited access to space is elevated.	
Constrained conditions for efficient material handling	Limited intermediate storage space	The construction site has no areas for storing material between the delivery and the assembly, which entails additional material movement.	
	Poor communication	The material handling is often complicated due to a lack of communication among the actors in the project since communication regarding deliveries and storage on the floors is key not to disrupt the production phase.	
	Multiplicity and variety of concurrent activities	Many subcontractors are operating on the same floors at the later stage of the construction phase. This issue results in a crowded workspace and frequent movement of material.	
	Timeliness of deliveries	The projects have experienced that booked deliveries tend to show up whenever, and the driver and supplier ignore the booked time. In order to ensure efficient material handling, the JIT delivery principle was applied to the projects, but this has not been successful.	
Construction documents provided late	Commercial building	Commercial buildings are living concepts with different end customers with their unique adaptations. This issue complicates the planning and design process and hinders construction documents from being provided on time.	
	The planning and design process falls behind	The planning process tends to fall behind due to the construction phase usually starting before the design process is finished and not enough resources being invested in the planning phase. Therefore the construction documents are not provided in time, creating problems for the construction process.	
Late changes of construction documents	Commercial building	Late changes to construction documents are particularly common in commercial building projects since commercial buildings are complex products. Commercial leases are usually more expensive than housing leases, giving the client a more significant impact to change.	
	The customer's power	For the construction company, customer satisfaction is very important to enable continuous collaborations. This situation gives the customer much power and creates a culture where the construction company should have a positive and solution-oriented approach to the client, and accept all change requests, even if they are late.	

5.1.1 Lack of space at the projects

Dense urban areas: Several interviewees mentioned that the two projects are located in dense urban areas, which means that the area that the construction site occupies is limited. P2-MC-S3 described that it is impossible to get more area from the Transportation Administration Office since other ongoing construction projects in the project area reduced the possible construction site further, creating more challenges. P2-SC-S1 mentioned that being near a central location leads to more construction sites and increased traffic. Combined with the limited space, a central location makes inbound transport more complicated and requires a longer time than usually planned due to increased uncertainty.

Uncertain market: The subcontractors tended to want to buy everything at once since such a setting was cheaper and easier to control. P2-SC-S2 mentioned that the pandemic had led to material deliveries taking more time and that subcontractors had ordered materials extra early to ensure that they had the material on-site in time. However, the responsibility for checking those subcontractors did not stockpile materials at the site was on the Logistics Manager and related supervisor. P1-MC-SM clarified that the building department had the coordination responsibility at the site for areas and storage spaces.

Early removal of construction hoists: A contributing factor to materials being stored on the floors was that the construction hoist was dismantled early. P1-MC-S8 and P1-MC-S4 described that if the construction hoist was needed to transport material in Project 1, the material needed to be ordered in advance and stored on the assembling floor. Only materials that fit in the elevators in the building could use JIT deliveries. P2-MC-LM described that a tenant was given the right to move in three months earlier than planned, meaning that all installations had to be completed, and the facade needed to be closed three months earlier. Consequently, material that needed to be stockpiled was left on the floors for an extra three months. P2-MC-S2 and P2-MC-S6 said that, for Project 2, they dismantled the construction hoist while the tenant adaptations were not ready, and they had to guess what needed to be stockpiled on the floors.

Multiplicity and variety of concurrent activities: The lack of space implied negative effects on the production performance for the projects. The lack of space became an even bigger issue due to many disciplines working in the same areas simultaneously. P2-SC-S3 described that access to large areas was required when assembling installations, which meant that they needed to ask other personnel to move all the time. The interviewees described how the lack of space resulted in non-value-adding and time-consuming activities, such as moving around material several times a day.

5.1.2 The projects' constrained conditions for efficient material handling

Limited intermediate storage space: Project 1 had no storage space outside the building. Therefore, the received material needed to be directly moved to the assembling area according to P1-MC-S8. P1-MC-S2 confirmed this complication and described how the lack of intermediate storage caused an enormous lack of space on the floors, especially when few existing storage areas had disappeared while running on a full production capacity. According to P1-MC-LM, although Project 2 had some possibility for storage outdoors, the area was only used for crises during material deliveries and had to be emptied at the end of each day, which meant that in practice, no intermediate storage existed as well.

Many of the interviewees described the lack of storage space and moving of material contributed to a stressful environment. The stockpiled materials that blocked the assembling areas caused delays in the pursuit of finding space for that material within an already tight schedule. One of the subcontractors handling heavy materials explained the extra physical strain on the production personnel due to the heavy material moving back and forth. P2-MC-S4 also highlighted safety issues related to the crowdedness, limited space, and need to cross other working areas.

Poor communication: When asked about the communication regarding logistics at both the projects, there were more comments regarding Project 1. P1-SC-S2 particularly expressed discontent with how the communication worked regarding the logistics at Project 1. P1-SC-S2 found that the experience and expertise of many subcontractors working in the industry for a long time were not used. When they made suggestions, they felt more “in the way” rather than helpful. P1-SC-S2 would have wished for a more interactive communication where solutions were developed together to accommodate all parties. The interviewees expressed less concern for the communication at Project 2, although there were some issues there as well. P2-MC-LM described their standard communication process of informing through meetings with responsible supervisors, casual reminders when meeting in the hallway, and mass mail with reading confirmation to everyone in specific critical situations. P2-MC-LM also stressed that the information did not always reach everyone since some supervisors failed to inform their production personnel fully. However, for P2-MC-S4, staying updated with current information is a personal responsibility for everyone. If one missed a meeting, s/he should read the protocol. Furthermore, the Logistics Researcher emphasised the importance of communication and understanding between the construction company and their suppliers. S/He described that sometimes drivers show up with more material than what was ordered for that delivery. They thought they might as well deliver all the material at once, not understanding its effect on the construction site and the limited storage space.

Multiplicity and variety of concurrent activities: The interviewees described the issues of the deliveries, storage space, and the long time spent on moving materials to have become problematic in the later production stages. In the early phases, there were fewer actors on-site and bigger deliveries, whereas later, during the interior work, the number of actors and deliveries increased drastically, causing more crowdedness and disorder. Having numerous different actors working in the same areas on the same floors generated more material and waste and made it more difficult to control the situation. P2-MC-S2 explained that one employee was assigned to spend almost all the day moving material. P1-SC-S3 clarified that their area for storage had been moved three times which had been very time-consuming. This situation placed higher demands on each actor to keep their material and equipment in order, which, according to some interviewees, did not work as desired.

Timeliness of deliveries: Both projects were struggling with the limited space and the fact that this condition forced the deliveries to take place according to Just In Time delivery principles (JIT). The Logistics Expert explained how logistics are “quite simply a question of survival...the site manager realises that if this should work in an inner-city environment, there must be logistics planning and time booked deliveries; it will be a material overload right away otherwise”. P1-MC-SM described that the building department wanted deliveries to be made JIT to the assembly area and that stockpiling materials on-site should be avoided.

Because both projects had limited space, more prerequisites on logistics were needed, especially for delivery planning. When deliveries arrived on-site unannounced, it caused more significant problems

since one single vehicle could be enough to block the entire unloading zone, whereas a bigger area would allow more flexibility. The Logistics Manager (P2-MC-LM) emphasised the importance of following the unloading calendar. Both projects experienced problems when the unloading calendar was not used or not used properly. Quickly unloading and moving the material to free up the unloading zone for the scheduled deliveries required ad-hoc solutions. Even though the deliveries arrived unannounced at the site, the deliveries were almost always accepted. Almost all interviewees pointed out the lack of usage of the unloading calendar from all parties. Many of the supervisors from the building department expressed that some subcontractors did not fully use the unloading calendar. The subcontractors complained about how the calendar functioned and claimed that the driver might show up another time even though a material delivery was booked in the calendar. P1-MC-SM pointed out that it worked better with the larger subcontractors who were around for a longer part of the project since they could then implement their working procedures better. The consequences if their deliveries did not work would be influential. Whereas with smaller subcontractors staying for only a short period, there were fewer incentives to implement standard procedures to the same extent. Several of the interviewees believed this problem to be related to failing communication.

5.1.3 Construction documents provided late during the projects

Commercial building: P1-SC-S3 said that commercial construction projects always have to deal with late changes and that the built products are “living concepts that change all the time”. With many different types of end customers, with different adaptations that sign their leases at different times. This potential delay complicates the planning and design process and can elicit that construction documents are provided late.

The planning and design process falls behind: When production starts before the design is finished and the production catches up, or the design does not have time to process all the changes from clients and consultants, construction documents will be provided late to the production. Another contributing factor to documents provided late is since every floor did not have a tenant at the start of construction, the documents could not be started to be produced until the tenants were confirmed. P1-MC-S8 described how the production has a deadline, and if they do not receive the documents on time, they must build without design documents in order to meet deadlines. P2-MC-S6 described how technical changes could affect both floor formation and installations, and for example, P1-MC-S8 described how they discovered during construction that more accessible toilets were needed, which required rework. P2-MC-S4 explained that when all changes need to be made within the same deadline, the project takes in more people on evenings and weekends, which leads to a higher production pace and catching up with the design. It emerged during the interviews that despite the projects growing because of late approval and late changes of construction documents, the end time did not change. The Logistics Expert said that he knows about the magnitude of this problem and that this is something they are working on for the long term and told a story about a site manager who said, “If you just give me the documents on time, I will be able to plan, but if I do not give me the documents on time it is not so easy to plan”.

5.1.4 Late changes of construction documents at the projects

Commercial building: P1-MC-S4 described that it is mainly in commercial construction projects that the problem of late changes occurs. P1-MC-S2 explained that commercial buildings have more changes because commercial projects have more expensive leases than ordinary housing, leading to a more significant change impact.

The customer's power: The Logistics Expert explained that there are late changes from the client because buildings are complex products, and late changes allow the creation of products that the customer is satisfied with in the end. Many interviewees agree with P2-MC-S5 that it is largely a matter of the customer always having to be satisfied, and P2-MC-S2 believed it has been extra important during the pandemic because it has not been as easy to find tenants. P1-MC-S8 explained it by saying that there are so many different tenants the projects must adapt to, and P1-MC-S4 said that it might also be because the construction company wants to show a positive and solution-oriented side to the client, so they will choose to work with them again. The challenges with late receiving of construction documents lead to difficulties when planning for time and material according to P2-SC-S1. P2-MC-S5 said that late changes had affected almost the entire project, and P2-MC-S3 explained that it is a part of the daily workload. There is a discrepancy between what the client thinks is possible to change and what the production team manages. The client is willing to accept changes received from the tenants while the construction team is doing the actual rework, which generates frustration. Furthermore, the Logistics Expert said, "we want a tuned flow where everyone knows exactly what we are going to do, but we allow a lot of changes, and we are in our everyday life, and we have learned to live with it".

The common theme among the answers regarding the effects of the late changes was how they affected the planning. The late changes created a work environment of uncertainty and hindered the long-time planning. The changes could occur on very short notice; P1-MC-S2 described that they could start with an installation on a Monday, only for it to be changed later the same week, meaning they could not even follow the plan for the material flow for that week. Almost all of the supervisors stressed the pressure it put on them to be agile and adapt their planning to the continuously changing conditions. Many of the interviewees also emphasised the knock-on effect each change implied. P1-MC-S4 explained the impact of simply adding a wall; "It is not just a wall that is added. It is electrical wiring, extra ventilation because there are now two rooms, we had to replace block-walls because all of a sudden it should be a glass wall ... and two doors instead of one ... everything is customised and is ordered that way, so then you have to place a new order ... there will be new orders for the same thing. You have to redo the floor ... On paper, it does not feel like much, but it is."

The late changes also affected the project economy negatively. The need to redo work and demolish completed structures generated much material waste. P1-MC-S2 explained that they handled a lot of customised and project-specific materials, meaning longer delivery times and an inability to return unused material to the supplier. Late changes regarding these types of materials or objects led to waste and extra delays. The late changes implied waste of material and meant that the new material was ordered with short notice, sometimes meaning higher prices. It required ordering express deliveries in many cases, which generated additional costs. The Site Manager (P1-MC-SM) also explained that the people calculating the costs of the changes might not always get the complete picture of what each change would entail. Therefore, it might not be as economically beneficial to accept the change as initially estimated. The Logistics Researcher said that those who approve changes do not see the problems the changes lead to in production. For example, they have to do substantial reworks due to all the changes. The Logistics Expert also described that changes cost much money, not only for the project but for society, and that the production has a considerable overcapacity that can handle what is planned plus the added job.

Even though the changes implied additional work, the end date never changed, meaning a shorter time to finish the project. P2-SC-S1 explained how a shorter time frame meant more personnel and

material in the same area, creating congestion and disorder. Additionally, some interviewees emphasised that the time pressure led to a risk of error and harmed the quality of the finished product. The stressful situation also greatly affected the working environment. The site manager at Project 1 questioned this way of working, confirming people quitting and people being burnt out due to the stress of the situation, and suggested re-thinking pushing the project and people in this manner. Project 2 had also experienced issues with the work environment becoming too much. This point about the late changes and the rework it entailed, creating frustration and stress among the production personnel, was brought up in every single interview. The subcontractors strongly highlighted how it created a very stressful environment and that the schedule was unreasonable. Many supervisors representing the main contractor agreed that this issue strained their relationship with the subcontractors. P2-MC-S2 explained, “it is easy higher up to just thinking about economics, that it is worth it. But, for those of us who are in production, it creates a pretty frustrating atmosphere. The production personnel may get mad at me first, and then I have to explain it, so we have to spend time on that. Eventually, they stop trusting what I say because they do not see it coming from elsewhere. They only see that I have said something and then it was not true.” Several of the main contractor’s supervisors experienced that the stress and distrust from the production personnel created a conflict-provoking situation. Many of the interviewees described the situation as something they had to expect and adjust to, and P2-MC-S6 said, “They say we will improve for the next project, but I do not see it changing”. The Logistics Expert expressed that it is something they are aware of and work on improving. However, it takes time, and people do not change their behaviour right away. It is important for those who decide to understand the consequences further down the line.

5.2 Possible mitigation strategies

This section describes the interviewees’ suggestions for strategies to mitigate the challenges. A description of the mitigation strategies are summarised in Table 6.

Table 6: Summary of the possible mitigation strategies identified for the logistics challenges

Mitigation strategy	Description
Planning and logistics management	Detailed and well-thought-out planning is key to reducing logistics challenges. Additionally, having a Logistics Manager on site focusing on everyday logistics activities will significantly facilitate the logistics work.
Improved structuring of storage areas	Communication between the floors regarding the availability of storage and an internal site disposition plan could help reduce the problems of limited storage areas.
Logistics setups	Many logistics setups could be beneficial and help the projects to achieve better logistics. The setups mentioned in this study are TPL, forklift, smart delivery container, logistics centres, checkpoints, and an unloading calendar.
Stricter deadline for changes	Being more firm with the predetermined deadline would eliminate the late changes and reduce the challenges accompanied by them.
Communication within the projects	It is important to communicate the logistics information early on in the project, make sure the information reaches out to all parties, and follow up and make adjustments when the communication fails.
Information sharing between projects	Learning from other projects and sharing information could contribute to not making the same mistakes. Evaluation after each project should be compiled and gathered in a digital platform, and the information should be shared between the projects.
Central logistics management	The projects could use support from higher up in the organisation through funds and investments in advancing logistics solutions to help develop the logistics work. One example is to introduce pilot projects that try out and evaluate different setups.

5.2.1 Planning and logistics management

Overall, a more precise plan for the execution stage was requested in the interviews. The time plan was claimed to be inaccurate since it was hard to follow. One supervisor (P1-MC-S2) expressed that the plan needs to be based on what should be built rather than on what they assumed they would build from the start. The subcontractors raised concerns regarding how the main contractor communicated and structured the logistics on-site. Further, one subcontractor (P2-SC-S1) claimed that the workflow would be improved if fewer actors did their work simultaneously. The projects had logistics strategies and plans set early in the projects. However, the Logistics Manager (P2-MC-LM) emphasised that a plan cannot be followed in practice since the circumstances are constantly changing. P2-MC-LM also stressed that people on-site prefer to solve problems fast and in an ad-hoc manner. On the other hand, the Logistics Researcher enhanced the importance of putting a lot of effort and resources into the planning stage since a well-executed plan will erase many upcoming logistics challenges on-site. When addressing the symptom of the poor logistics plan with ad-hoc problem solving, extra time and money consumption will appear. In the planning step, it is fundamental to also communicate with the other actors affecting the construction stage, such as suppliers and distributors, according to the Logistics Researcher. For example, issues regarding deliveries not arriving on time should be regulated in the contract, specifying the time of deliveries and consequent penalties if some conditions are not met. Both the projects had requirements for booking deliveries in the unloading calendar, but there was a lack of consequences when deviations occurred. According to the Logistics Researcher, better logistics planning leads to less stress and is a solution for a lower stress level, better work environment, and safety on the construction site.

Many of the interviewees suggested improved actions regarding the Logistics Manager role on-site. For example, the communication between the forklift driver and the Logistics Manager could be improved according to the supervisor P1-MC-S4. The Site Manager (P1-MC-SM) also noticed that the Logistics Manager role needs to be extended to a more operative role that takes care of the material flow and the unloading activities. Today's logistics role tends to focus more on changes within the logistics setup, rather than the daily operational activities.

Many logistics problems are eliminated if the construction documents arrive on time. Preferably, the changes in the design documents should arrive before the construction phase takes place, according to P2-MC-S5. The Logistics Researcher thinks it is because the projects start to build too early and the project does not put enough money and time in the design phase and believes that if they put more money in the design phase, they would save money during the construction phase. The supervisor P2-MC-S3 suggests that a standard building first can be constructed, and after that, the building can be customised to the client's specific technical demands and requests. To account for the legitimacy of the design and that the construction technical aspects are fulfilled, the construction personnel should take part in the design phase according to the Logistics Expert and the Logistics Researcher.

The Logistics Researcher suggested that the lack of space should be viewed as an opportunity to evolve and become better at logistics. Even in projects with much space, they experience problems with moving materials. The prerequisites of having limited space require planning at an earlier stage, which will benefit the project.

5.2.2 Improved structuring of storage areas

Respondents from the two projects expressed suggestions regarding improved management of the floors to enable storage areas. A recurring request from the subcontractors was a provided storage

place for the specific actor, and this was also something the supervisors from the contractor had noticed. Several supervisors from both the subcontractors and the main contractor highlighted the possibility of waiting for the start of interior work on one floor after the structural framing work and using it for storage areas, enabling immediate storage. Interviewee S1-MC-S2 explained that this could be possible if the construction company agreed to postpone renting a one-floor area since there would be no rush to finalise that floor. One of the subcontractors (P2-SC-S1) suggested that every floor could be split into two areas, one where the production takes place, and the other section should be used for material storage. The construction would then be done on one side at a time in order to improve the structure and ease the material handling. The site manager (P1-MC-SM) emphasised that every supervisor from the construction company needs to have responsibility for the areas belonging to the floors under their responsibility. The supervisor P2-MC-S2 described that the storage issue would be improved if a clear plan pointed out where every actor should keep their material and that it was controlled that all production personnel followed this plan.

The interviewee P2-MC-S4 highlighted that the internal site disposition plan was important to manage the material storage areas inside the building, and in Project 2, this plan was established too late. Further, the Logistics Manager (P2-MC-LM) explained that they tend to abandon the internal site disposition plan due to changes and demands for ad-hoc problem-solving. The Logistics Manager (P2-MC-LM) described that material storage and deliveries were needed to be solved ad-hoc “and be approved by me ... it is a lot of work, and it is not a very good solution, but it is hard to do it differently if you do not have a large organisation that works with logistics. Of course, it is better, but it costs more”. Another subcontractor (P1-SC-S3) highlighted improving communications between the floors as a solution to the lack of material storage. The interviewee P1-SC-S3 further explained that improved communication would enable actors with many materials to distribute their materials over several floors, for example, if other actors working on other floors needed fewer storage possibilities and could therefore share.

5.2.3 Logistics setups

TPL: There are many different logistics setups to apply to construction projects. Both projects used external material services providers or TPL, and it was overall an appreciated resource. Many supervisors marked the importance of having the same personnel within the provider company on-site. Project 1 had the same personnel working for the TPL every day, while Project 2 called in the material services when needed, which resulted in different people arriving at the site. Whenever the personnel were unaware of the circumstances on-site, the material service personnel became less self-driven, and the supervisors had to delegate exactly what actions to take. The supervisor P1-MC-S4 stated that the material service relieved part of the supervisors’ responsibility from the logistics. Furthermore, the interviewee P1-MC-S4 described that the material services depended on the material being labelled properly. Otherwise, they had no clue where to move the material. The site manager highlighted that the benefits from the TPL were especially gained when they handled the material after regular working hours since they then did not interrupt other activities or occupied elevators. Moreover, the Site Manager (P1-MC-SM) also highlighted the benefits of the TPLs’ skills in both material handling and cleaning. If no material needed to be handled, they could focus on cleaning up, which also improved the logistics. The TPL at Project 1 also had a fork-driver licence which was beneficial during un-regular working hours.

Forklift: One logistics setup both the projects used and considered useful was that a forklift and driver were provided on-site, available for all actors to use. The role of the forklift driver extended to

receiving the goods, which eased the receiving of deliveries for the supervisors, even though the supervisor who ordered the delivery had the primary responsibility. The Logistics Manager (P2-MC-LM) stated that the forklift solution saved a lot of time and money compared to calling in a forklift service when needed. The difference in cost of leasing a forklift a whole day compared with a few hours was not much. It was also a great benefit to have a forklift on-site all the time since it allowed faster access and not having to plan bookings and spend time waiting for it to arrive. Having a forklift at the construction site meant the opportunity to unload trucks and move materials in the projects.

Smart delivery container: The interviewees from both projects considered the smart delivery container solution useful for smaller packaging deliveries. However, the specific solution was used only in Project 1, while Project 2 had another solution with similar features. According to the Logistics Manager (P2-MC-LM), they chose not to have a smart container due to the lack of space. However, they had daily deliveries arriving simultaneously from a company that provided smaller goods. This agreed delivery of smaller goods did not need a special delivery routine and could be picked up later from a specific area. The Site Manager at Project 1 (P1-MC-SM) claimed that the smart delivery container made sure all the small material was held in the same place and erased many extra deliveries that would disturb the already crowded site. P1-MC-SM also added that the smart delivery container at their site has resulted in fewer deliveries that would interrupt the work at the site.

Construction logistics centre and checkpoint: In the two projects, physical logistics setups such as logistics centres and checkpoints were not utilised. Even so, both the projects evaluated the alternatives of using a checkpoint but found it to be expensive. They had already applied methods for well-established and well-functioning deliveries, and P2-MC-LM did not think that a checkpoint would work better or be more profitable. According to the site manager in Project 1 (P1-MC-SM), the possibility of having a logistics centre (CLC) was investigated but was rejected due to its costs and extra personnel working in the CLC, and since the project only had one crane for unloading, the material flow was not expected to be in the size that required a CLC. According to The Logistics Expert, the construction company had started to embrace some consolidation solutions developed by some of their distributors, and the alternative to initiating in-house logistics setups is therefore not prioritised. The construction company thus sees that there is an increased market for terminalisation solutions, but refers to already existing solutions and does not plan to develop its own. It is up to each project if they see a need for a CLC, and in such cases, they can choose from solutions from distributors or local actors, according to the Logistics Expert. The Logistics Researcher described that when TPLs entered the market, they started by optimising logistics inside the gates, then quickly became good and expanded on things outside the gates, such as checkpoints and CLC. These services were developed simultaneously as the construction industry was forced to become better at logistics not to lose time and money. The Logistics Researcher thought that this was a service that construction companies should buy, not all companies can be the best at everything, and it would be smarter for contractors not to start competing as logistics companies as well. The Logistics Researcher sees that the projects should consider logistics setups as a toolbox. The solution will then be to choose proper logistics tools in the logistics plan that support each project's specific needs.

Unloading calendar: Another logistics setup used by both projects was the unloading calendar. The general opinion about the unloading calendar was that it is an excellent tool to use, as long as it was appropriately used. According to P2-SC-S2, such a calendar should be a must in projects with these conditions. The Logistics Expert explained that all projects must use the unloading calendar according to their logistics checklist. However, there was a common view among the interviewees that the

calendar could be developed further and used to a larger extent. The booking system did not always work as intended according to P1-SC-S1. S/He wished to be able to book the hoist and storage area in the calendar as well. P2-MC-LM also emphasised the usefulness of booking an area for storing the unloaded material in the calendar to better structure the temporary storage. P1-MC-SM mentioned that not all the information needed was included when a time slot in the calendar was booked. Some actors even delivered to the site without booking a time slot. P1-MC-S4 described that the problem with actors not using the calendar primarily was because actors ignore the booking procedure even if they know it is required. Although there is some friction in the calendar's operational use, it was still seen as a solution to deliveries not colliding or the same unloading tool being double booked. P2-MC-S6 mentioned that if there was good communication and the calendar was used in advance, it usually worked to unload two deliveries simultaneously, and the calendar was a helpful solution for managing the delivery flow.

Even though the building department and subcontractors correctly used the calendar, the interviews often raised an issue regarding how the delivery companies respected the time slots. Several interviewees explained how some drivers would show up with their deliveries outside the booked time slot, even though the booking was made in the calendar, and agreed with the supplier. P2-MC-LM expressed that receiving unannounced deliveries did them a disservice as it sent the wrong signals and said that they “try to keep areas around the building as free as possible to be able to handle emergencies when there are unannounced trucks because they always appear. It happens every day.”. P2-MC-LM and P1-MC-S8 emphasised that unannounced deliveries should be denied to not allow interruptions in the structure. Several interviewees stated that a zero-tolerance policy against accepting and unloading deliveries that had not arrived within their time slot would reduce the amount of unneeded material on-site and force deliveries to arrive on time and all actors to use the calendar. On the other hand, P2-MC-LM stated it was more important to receive the material in practice to keep the production running, which took priority over following the right delivery procedure. P2-MC-S3 agreed and raised that they had to accept all deliveries, even if they were not booked, to make sure they at least had the material on-site and not risk arriving late. Meanwhile, P1-MC-SM expressed that “it is the smaller contractors that just order, getting them to follow the procedure completely is quite difficult and I think you have to have a lot of authority in your own organisation in terms of using the unloading calendar ... And vehicles not arriving on time should be sent away from the site... if they have to leave the workplace three times, they will learn that it is not acceptable to show up, and perhaps that is the only way”. Even if there were some negative side effects to sending deliveries back again, it was seen as a solution to nurture deliveries during a project to arrive on time. The Logistics Researcher agreed and informed about other projects and organisations that have put more pressure on the drivers' arrival time and the positive outcome.

5.2.4 Stricter deadline for changes

One recurring suggestion mentioned to reduce the effects of late changes was to set a nonflexible date as a deadline for the latest possible changes. The deadline solution entails that it is possible to make changes until a pre-set date. Then, the changes will be too comprehensive to execute, and the construction company will not approve any new requests. However, P2-MC-S6 raised an issue regarding the risk of disappointing the client if a non-tolerance deadline was set. Many supervisors marked that the deadline decision needed to be determined higher up in the organisation since today, the production personnel on-site perceive the situation as they should be flexible towards changes. Further, P1-MC-SM stressed that the top segment of the main organisation might not be aware of the consequences of making changes after a certain time and the pressure it results in for the personnel

working on-site. However, the Logistics Expert explained that they are developing a restructuring of the operating system to make the deadline for changes clearer. Forwards, it will be clearer for the clients when the deadline is set; today, the organisation has been too generous with accepting changes after the deadline. According to the Logistics Expert, the organisation's behaviour and leadership need to change in order to transform today's working procedures of accepting late changes into stricter frameworks. Overall, several interviewees highlighted that the communication with the client needs to become better if acceptance towards rejection of changes after the deadline should be a reality. Instead of just having a "we will sort it out" mindset toward the client, it is beneficial to communicate the difficulties of the change and its effect on the quality, working environment, and stress, as described by P1-SC-S3 and P2-MC-S6. Hence, the Logistics Expert described that the client dialogue is extra important today since the end-customers lack knowledge of construction and have no clue about what their suggested changes entail and the enormous resources that will go to waste due to the changes. Furthermore, the Logistics expert described that changes cost money but believed there are huge savings if the construction company becomes better at making demands on the customer.

5.2.5 Communication within the projects

Respondents from both the projects agreed on issues regarding communication on-site. Several interviewees noted that it is hard to make sure the information is communicated to every person working on-site. There are many actors, and every supervisor of the different subcontractors is responsible for sharing information with their personnel. A suggestion that could improve the communication was to make sure all supervisors were attending meetings according to P1-MC-SM and that a procedure of communicating the information to the production personnel every supervisor is responsible for was established. On the other hand, it is still challenging to make sure information is perceived and not only communicated. Therefore, the Logistics Researcher believes the logistics decisions must be communicated already in the early phases of the project. The subcontractor's supervisors explained their frustration with regularly missing logistics-related information in the interviews. The Logistics Researcher highlighted the importance of following up on situations when a lack of information was present to learn from these mistakes. For the Logistics Researcher, logistics changes on-site are also of great importance to communicate to the delivery drivers. The interviewees often pointed out that the drivers often lacked information about the site, which should be communicated from the supplier that receives the goods, but that was seldom the case. However, the Logistics Manager (P2-MC-LM) understood the communication as okay and thought other strategies would make it more complicated to make it work in reality.

According to the Logistics Researcher, in dense urban construction projects, communication with neighbouring projects should also be addressed to support the logistics. In the interviews, it was stated that Project 2 had regular cooperation meetings with the next-door construction sites, and the Logistics Manager (P2-MC-LM) explained that it worked well and that it was an important aspect in order for the logistics to proceed smoothly.

5.2.6 Information sharing

The interviewees pointed out benefits of sharing information between projects and not only within the single project. The Logistics Expert described how the production development unit works with a network for logistics. At present, the network consists of an open network with much one-way communication from the production development unit. The idea is to develop a closed IT-based network as well with more two-way communication. The closed network will consist of a designated

logistics specialist in each department and will enable more information transfer and learn more about what works and what needs to be developed in the organisation's operational work. The site manager (P1-MC-SM) described that a dedicated person to logistics at the site enabled more information sharing between projects, but if the logistics were a shared responsibility, there was less information sharing. Information sharing happens mostly between the large and central projects where logistics plays an extra important role, and the smaller projects share less information. On the other hand, P1-MC-SM described some information sharing between projects in the role of Site Manager, especially if a project used a similar solution as another project (e.g., the same framing work system or subcontractor). This information sharing occurred through meetings, site visits, and team meetings with suppliers. The Logistics Manager (P2-MC-LM) agreed that the construction company is relatively poor at information sharing between projects. A system collects data on accidents shared between projects, but there is not as much information about logistics. Furthermore, the Logistics Manager (P2-MC-LM) described that even if there is no information sharing through a central system, employees usually exchange information. This exchange happens by contacting colleagues who have done something similar before (e.g., other similar projects can be contacted when the logistics plan is developed).

The Logistics Researcher described how information sharing or information integration helps avoid repeating the same mistakes in new projects and suggested that digitalization makes uploading information accessible by everyone possible. Repeated mistakes cost the industry billions every year and are "a holy grail in the construction industry. Whoever solves this issue has untied the whole knot in the industry". Due to digitalization, compiling information from the project is possible. Nevertheless, many employees move on to the next project fast, and the information gets locked to individuals due to the project-based industry. The Logistics Researcher compared it to being a sports team playing a match together. In every new project, there is a new team. The people always have a match in this industry, and to win, they need to meet the time schedules and budgets. However, the Logistics Researcher explained, "we do not have time to train together, we do not even have time to talk to each other about what we did in the previous project ... we barely have time to tie our shoes. It is a match again". The Logistics Researcher emphasised that this is not very easy to solve, but it is possible. It is about following upon, for instance, how the delivery calendar and inbound transport work. The project manager should not proceed to the next project before completing the logistics evaluation. In the information compilation at the end of every project, the Logistics Researcher thinks that an assessment of logistics performance should be a part, even if it is difficult to get it down on paper as a clear cost. However, if the logistics are not written down, it is difficult to know the logistics cost or whether it was better or worse than other projects. If the logistics performance is evaluated at the end of the projects, it makes the logistics easier to measure and easier to share experiences as well, according to the Logistics Researcher.

5.2.7 Central logistics management

During the interviews, a dilemma that emerged was who should be the driving force of the use and development of the logistics resources. Should it be a single project, or should it come centrally from the building company? The Logistics Researcher pointed out that the projects have significant autonomy in the construction industry and want to make their own decisions and pursue their specific project principles. Managers can not step on them and push down centrally decided logistics solutions. However, when discussing potential logistics solutions, the Logistics Manager (P2-MC-LM) at Project 2 expressed that many logistics solutions would require a restructuring of how they work and implementation that would require help from the building company. At Project 2, they chose not to

use some logistics tools as they felt the restructure would be too comprehensive for that single project to introduce.

Since the management of the projects already has the responsibility for time, economy, and work environment, the Logistics Researcher suggested that the risk should be carried out centrally when trying out new logistics solutions. Otherwise, it might lead to the development being slowed down or halted. The Logistics Expert working centrally in the building department explained that their ambition is to have a person in each department dedicated to and responsible for the logistics development who could coach the projects in logistics matters. The problem was that the projects were terrified of overhead costs, which made it very difficult to implement such supporting functions. They only see the costs it brings, but the Logistics Expert argued that it would save money for the project in the end. However, the Logistics Expert understood how the managers at the project level saw it, and therefore the implementation of this function would happen gradually to not “shock the projects”. The Logistics Researcher emphasised the importance of not forcing solutions on the projects but encouraging them and said there is a lack of incentives. One approach to encourage innovation suggested by the Logistics Researcher was to have some pilot projects where several extensive logistics solutions are implemented to evaluate what works and what does not, and in those projects, those costs would not be covered by the project but instead be financed centrally.

6. Discussion

In this chapter, the research questions are answered by comparing the empirical result to previous research presented in the literature review.

RQ1 - What are the challenges, and their causes and effects, to achieving high performing on-site construction logistics?

The construction industry's struggle to achieve high performance relies heavily on efficient construction logistics, but there are challenges to achieving successful logistics (Vrijhoef & Koskela 2000; Brusselaers et al., 2020; Thunberg & Persson, 2014). The four most frequently mentioned challenges for on-site construction logistics in this study were: lack of space, constrained conditions for efficient material handling, construction documents provided late, and late changes of construction documents.

Lack of space arises from congested sites due to project locations in dense urban areas hindering storage and delivery possibilities (Nolz, 2021; Misron et al., 2018). Findings clarified that uncertain markets forced the projects to stockpile at the site, and the multiplicity and variety of concurrent activities also contributed to limited space. Constrained conditions for efficient material handling appear from stockpiling in the building, along with many disciplines working at the same place at the same time and deliveries not arriving on time. The lack of structured planning and communication about material handling procedures created unstructured material storage, hindering the production pace since analogue material handling methods are time-consuming, leading to additional costs and time delays (Kasim et al., 2019; Tetik et al., 2021). Findings confirmed that late construction documents are an output from production starting before the planning and design phase is finished and due to limited resources assigned to this phase (Sullivan, 2011; Hanna et al., 2002). Commercial projects have several end customers with different needs (Ying et al., 2018), entailing challenges in providing construction documents in time and avoiding late changes. Changes in construction documents impact planning, time, and cost and are among the most common reasons for project delays (Khalifa & Mahamid, 2019; Al-Momani, 2000; Al-Emad & Nagapan, 2015; Assaf & Al-Hejji, 2006). These four challenges are interconnected. They complicate on-site construction logistics and thereby hinder production from enhancing efficiency and productivity (Vrijhoef & Koskela, 2000). In addition, the challenges also contribute to increased waste, time-consuming and non-value-creating activities, unnecessary costs, and ad-hoc problem-solving activities (Sundquist et al., 2018; Challa & Das, 2019). The adversarial atmosphere between actors creates frustration when construction documents are provided late or changed (Khalifa & Mahamid, 2019) and due to poor communication about material handling and storage. Findings also show that the time-consuming nature of these challenges increases the stress of meeting the deadline.

RQ2 - How can the challenges be mitigated by possible solutions?

Planning is vital for successful construction logistics (Sundqvist et al., 2018). Findings show there is a lot to gain by being proactive rather than reactive. Dedicating resources in the form of time and money earlier in the project will help deal with the core problem rather than just treating the symptoms. The situation described in the interviews showed ad-hoc and reactive measures, leading to stressful situations and costly activities. The literature supported that more extensive planning would help reduce the ad-hoc measures and reduce the waste of resources (Sullivan et al., 2011). For planning, the importance of the role of the Logistics Manager should not be overlooked. Increased

productivity, reduced costs, and collaboration management were highlighted in the literature as benefits of incorporating a Logistics Manager (Sullivan et al., 2011). Findings show that many problems could be allayed by evolving the role of the Logistics Manager. Investing more time and resources in the planning and design phase is also highly likely to pay off since, at that stage, the impact of changes is immensely more minor than in the later stages of production (Platen, 2009). The benefits of mitigating the issues regarding late changes and late construction documents, which could be achieved through better planning and design, should be seen as enough incentive. Since there might be resistance on a project level to invest further resources without the possibility of showing reduced costs, the incentives might need to come from the central part of the company, such as pilot projects or straight funding of logistics setups.

Findings also proved that efficient communication is essential for successful construction logistics within projects and organisations. The benefits of communication within construction projects are confirmed by Emmitt and Gorse (2009) as they state that temporary arrangements require communication channels due to the lack of relationships between the members. Information sharing is often limited to informal chit-chatting within already established relationships (Almeida & Soares, 2014), which is also reflected in the findings. The literature and empirical results confirmed the lack of an established system to generate knowledge sharing in construction companies (Argote et al., 2000; Love et al., 2005). To ensure information sharing within the organisation, top managers should take the lead and set a strategic framework regarding how it should be done (Leal et al., 2017). Therefore, the statement from the top-management regarding plans to start up an IT-based network forum and integrate more logistics specialists through the organisation should be viewed as a legit stage towards establishing knowledge sharing. Previous literature also confirmed that it is a useful strategy to use IT-based platforms to collect information to make it possible to save and share with others (Wikforss & Löfgren, 2007; Chen & Kamara, 2008; Almeida & Soares, 2014). Sundquist et al. (2018) also confirmed that communication between the actors involved in the projects plays an important role. For example, effective communication between actors could limit rework (Sørensen, 2014). Findings suggest that more informative communication with customers concerning the deadlines for changes could potentially reduce rework and consequent logistics challenges. Thunberg & Persson (2014) emphasised communicating information regarding how the delivery should be done with the suppliers. In line with this observation, findings suggest zero-tolerance, penalty-oriented policies against untimely deliveries (whether they are early or late).

Construction logistics challenges can be mitigated by adopting logistics setups in construction projects (Janné and Rudberg, 2022; El Moussaoui et al., 2021; Rudberg & Gholami, 2019). The literature and findings highlighted performance benefits when adopting solutions such as TPL and Smart Delivery Containers. As derived from the empirical results, the unloading calendar was also found to be an effective tool when used properly. However, since every construction site has its specific conditions (Janné, 2018), a detailed setup of logistics tools for every construction project is not recommended.

6.1 Suggested framework

The study's result has been illustrated in figure 6 into a suggested framework, summarising the most important theoretical and empirical findings. The suggested framework shows the strong connections between on-site construction logistics and project performance. The suggested framework illustrated how the different causes contribute to different challenges and then how these challenges negatively affect the relationship between on-site construction logistics and project performance. Finally, the suggested framework shows how the negative effects of the challenges can be reduced (e.g. positively

impacted) by identifying possible mitigation strategies. The purpose of the illustration is to highlight the different relationships between causes, challenges, effects, and mitigation strategies and how they can influence the connection between on-site construction logistics and project performance both positively and negatively.

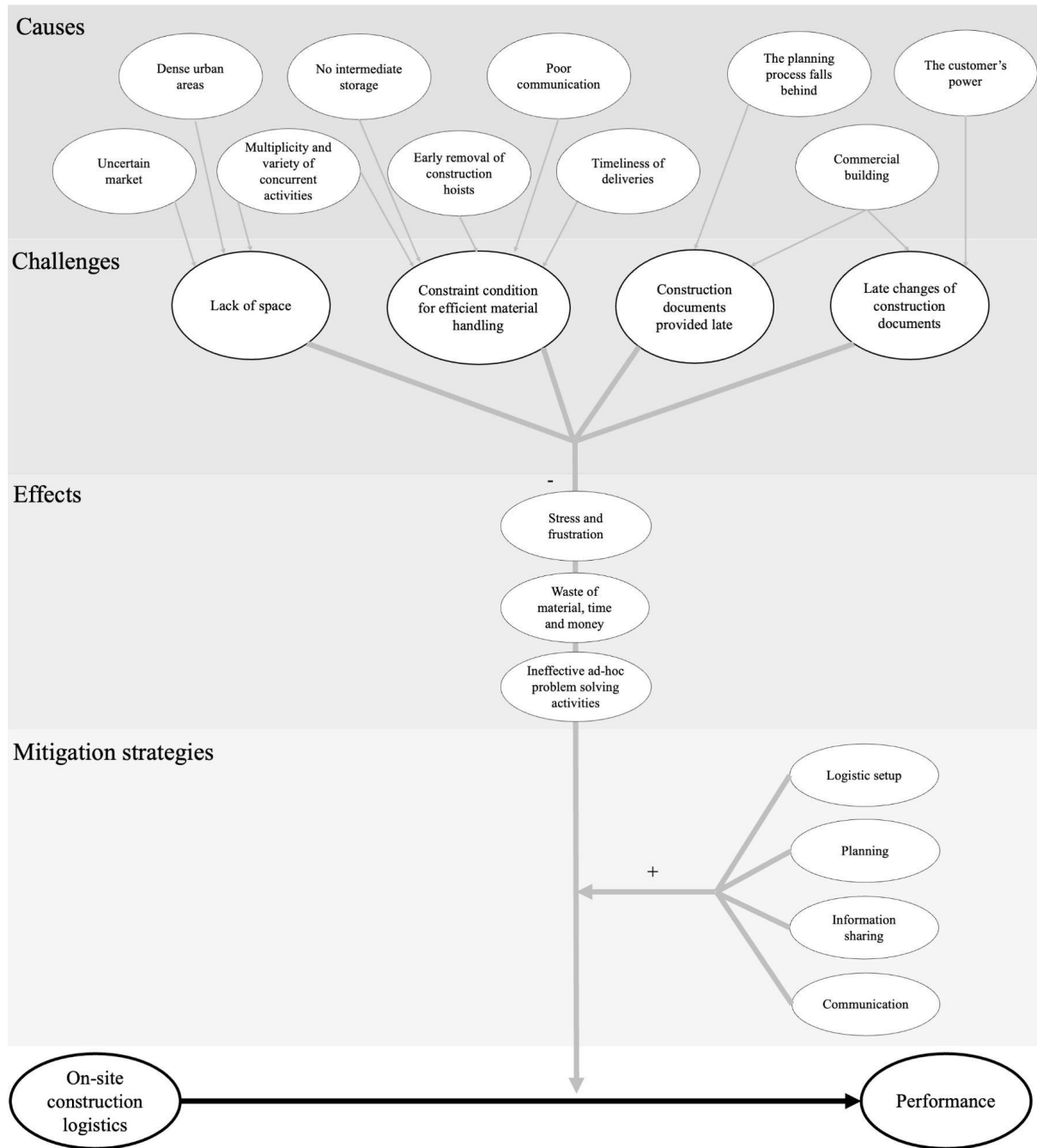


Figure 6: Illustration of the suggested framework.

6.2 Theoretical implications

This study contributed with theoretical implications for the field of construction logistics research. Starting construction with the design not being completed beforehand might be seen as an effective use of time where activities such as designing and production can occur concurrently. The findings


however show that this way of working negatively affects project performance. Concurrent design and production lead to the design falling behind and production catching up, which in turn leads to inefficiency in the form of application of ad-hoc measures. The same phenomena can be found regarding the multiplicity and variety of concurrent activities in relation to the challenge of lack of space. There the concurrency of activities negatively impacts efficiency by hindering availability and creating disorder. These two examples imply the opposite of the general view that concurrency of activities generate efficiency. Concurrency of activities can of course still positively impact efficiency, however these examples show there is a need to understand when to apply it.

6.3 Practical implications

The findings entail several practical implications for construction companies. First, this study provides an overview of four logistics challenges, including their causes, effects, and suggestions for how they can be mitigated. This information highlights what issues to be aware of and plan for when working with construction projects. These challenges could be relevant for large construction projects in dense urban areas, particularly commercial buildings. Second, this study highlights the needs and incentives for investing in logistics planning and management. Findings show hesitation in this regard, and the presented arguments for investing in logistics could help push in the right direction. Finally, the findings in this study also stresses the importance of information sharing and this would be an important take away for people working in the construction industry to consider. In order to evolve and improve the logistics work, logging information about it is an important step. Without logging the information it is impossible to measure and learn from previous mistakes. Table 7 presents a practical guide for how to mitigate the challenges based on the findings in this study.

Table 7: Practical guide for mitigating the challenges.

Information sharing between projects



Challenges	Project start	Planning and design phase	Construction phase	Finished project
Lack of space	Start by looking at evaluations about logistics work from previous projects and see what lessons can be learned.	Use the conditions at the construction site as a framework to develop the site disposition plan. Choose the appropriate logistics set-up for the specific project, set a plan for the material storage and plan for activities in the same area to occur sequentially.	Adjust the plan as the conditions at site changes and communicate the changes. Be strict with the material storage at site, do not allow stockpiling. The responsible supervisor and Logistics Manager needs to continuously control and check the material at site.	Evaluate lessons learned regarding the logistics at the project and compile in a digital database.
Constrained conditions for efficient material handling		Set a plan for deliveries and material handling procedures and include it in the contract. Construct a plan to ensure that all actors are aware of the procedures.	Assign a Logistics Manager handling the everyday logistics work on-site. Consistently communicate the material handling procedures and be stricter with declining untimely deliveries.	
Construction documents provided late		Invest sufficient resources (i.e time and money) to assure a more accurate plan and design delivered on time. Make sure the planning and design is sufficiently completed before the construction phase starts.	If changes still occur in the construction phase, the right resources at site (such as Logistics Manager, logistics setups and functioning communication) can mitigate the symptoms of late construction documents, but not the challenge itself.	
Late changes of construction documents		Communicate with the client about the importance of the deadline for non-functional changes and set a deadline for the latest changes that is reasonable for both parties.	Stick to the deadline for the latest changes, allow no flexibility after a certain date.	

6.4 Sustainability

This study has contributed to knowledge regarding how challenges in construction logistics negatively affect sustainability and how mitigation of these challenges reduces the ecological, economic, and social impact. The ecological sustainability is affected by waste of resources when having insufficient construction logistics methods (Agapiou et al., 1998). This study highlighted material waste issues due to insufficient material storage on the crowded floors and the many changes leading to the demolition of complete structures. The study also provided suggestions for how to improve material handling and the frequent changes and thereby reduce the negative ecological impact from waste. Waste is not only negatively impacting the ecological aspect but the economical aspect as well (Agapiou et al., 1998). The economical sustainability is also impacted by the inefficient logistics procedure; for example, ad-hoc working procedures increasing the costs (Sundquist et al., 2018). The empirical result showed how common it is with rework and waste from changes and lack of planning. Proactive activities and logistics planning is the key to not waste resources in the construction phase (Sullivan et al., 2011). The risk of social issues related to safety problems increases in a crowded work area (Tetik et al., 2021). A crowded and unstructured working site increases risks both physically in the form of unsafe working activities and mentally in the form of stress and frustration. The findings proved that the logistics challenges resulted in stress and pressure among the personnel.

7. Conclusion

This study aims to increase understanding of the poor performance of on-site construction logistics by identifying logistics challenges and investigating their causes, effects, and possible mitigation strategies. Four main challenges that hinder high-performing logistics were identified: lack of space, constrained conditions for efficient material handling, late construction documents, and late changes of construction documents. Those challenges are found to be potentially mitigated by allocating additional resources to the planning phase, improving the communication within the projects, adopting a strategy for integrated information sharing within the construction company, and using appropriate logistics setups for the specific project.

This master thesis has contributed with implications for theory and practise. The theoretical implications describe that the general view found in this study regarding the phenomena of concurrency in operational and strategic activities contributes to low project performance in relation to construction logistics. Additionally, this study provides practical implications for the construction industry regarding awareness of issues and benefits of planning for construction logistics and sharing information, especially in large projects in dense urban areas. However, there are some limitations that may have impacted the implications. The study's exploratory nature and the adopted in-depth orientation limited the number of cases that could be selected. Therefore, future research is encouraged to depart from the suggested framework considering a larger sample size to refine and complement the identified constructs. A broader spectrum of different projects will generate insights and perspectives that broaden the understanding and increase the findings' generalisability. A tendency among the interviewees to have biased opinions and answers can also be a limitation. The majority of the interviews were held with employees within the studied construction company. Therefore, they could potentially be withholding sensitive information to avoid damaging the company's public image. In an attempt to avoid this, all the respondents were kept anonymous toward the company, but still the possibility of an absent result exists. Therefore there should be further studies to confirm the results.

A range of empirical findings in this study require future research in order to be confirmed. The findings show the importance of using the right logistics setups for the specific project. The study shows that there are a lot of different logistics setups available, but there is a lack of guidelines for when each setup is suitable. Accordingly, future studies that investigate how and when the possible logistics setups can be implemented in organisations and projects are required. Furthermore, the findings show that the decision for the logistics setup should take place at project level but there is still a need for guidance from a central level. Projects have a low profit which has shown to limit the will to invest in logistics measures, meanwhile the central level wants the company's logistics work to evolve. This calls for studies covering how to distribute the costs of logistics efforts between the project and organisation levels to encourage the logistics efforts to advance. One interesting observation concerning the role of information sharing is that it is currently very limited and usually occurs in informal communication channels. There is a lack of structure for how the data about logistics should be collected and shared in the organisation. One required strand is focusing on how the data can be collected at the end of a project and shared. Another path is concerning how these changes can be implemented in the organisation. Finally, future research should investigate how to implement a structured IT-based system to evaluate logistics after each project to enable information sharing.

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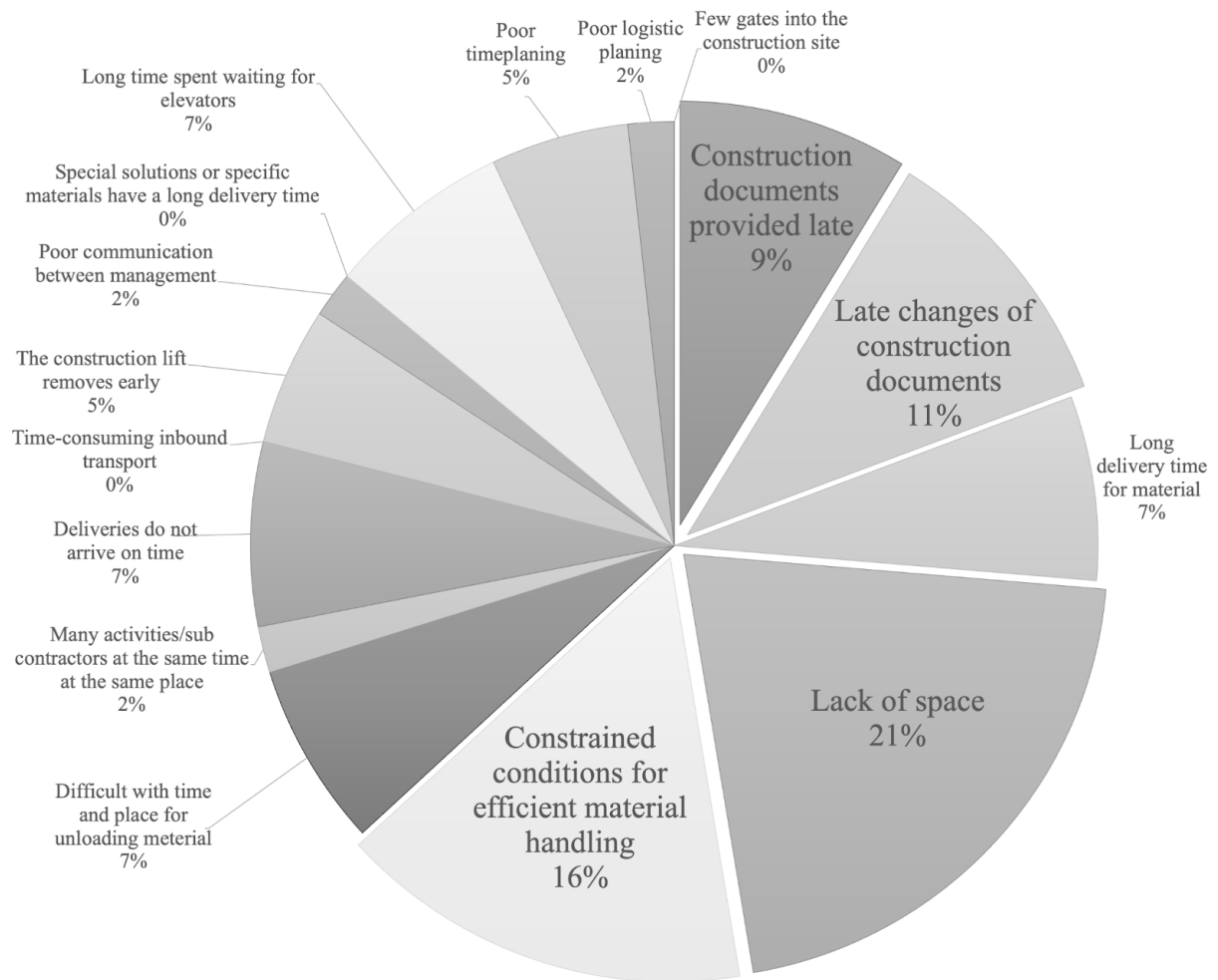
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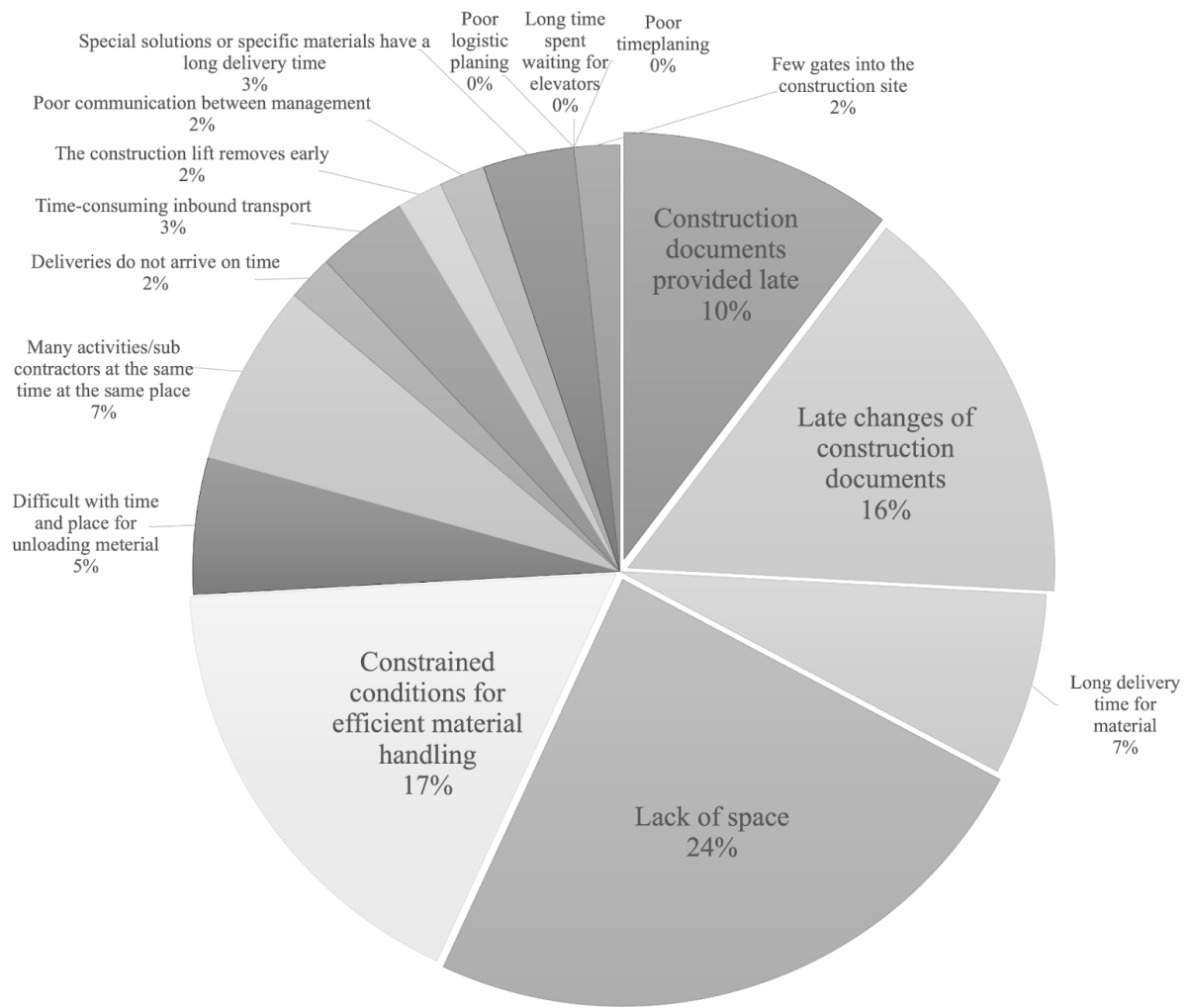
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Appendix 1, Result from brief interviews

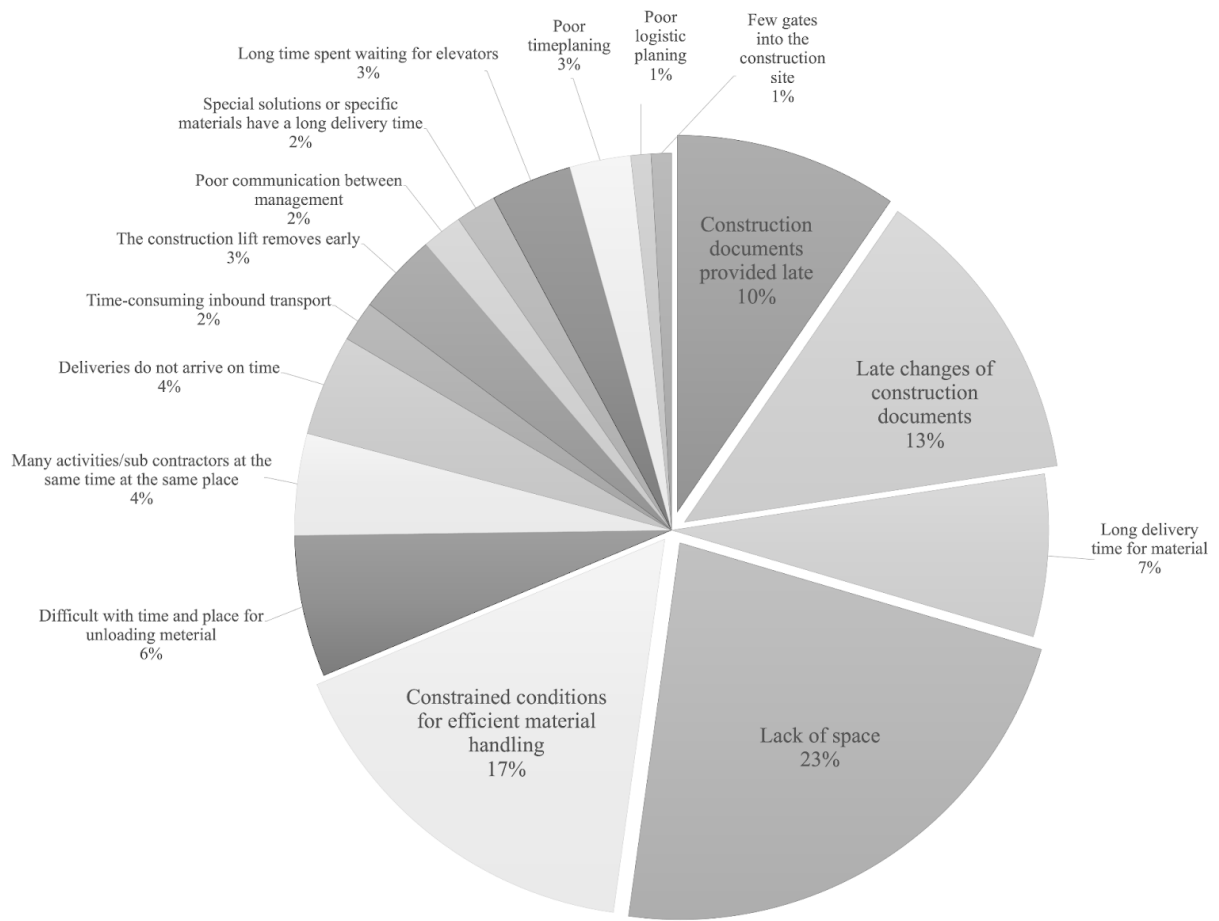
Project 1



Project 2



Total



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