Reusing Construction Materials through the use of a Logistics Terminal

A case study of redesigning logistical flows in the collaboration between a main contractor and a rental company

Master's Thesis in the Master's Programme Design and Construction Project Management

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CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden 2022
www.chalmers.se

MASTER’S THESIS ACEX30

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Gothenburg, Sweden, 2021

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ABSTRACT
The construction industry is resource-intensive and with the increased number of construction projects, the amount of construction waste is also increasing. Reusing construction materials to a larger extent has been identified as one important aspect in the transition towards a more sustainable construction industry. However, this challenges the established logistics setups between the supply chain and the construction site, including the roles of different actors. Potentially, increased reuse of construction material could also generate more construction transports, thus contribution in a negative way to increased emissions and congestion. Various projects may also need different logistics setups.

Reusing construction materials through logistical solutions could potentially be a solution to decreasing the amount of construction waste that has such a detrimental effect on the environment. Reusing filling materials within construction has been given increased attention and is widely researched. However, this has not extended to materials used in the construction of buildings. The study aims to investigate the possibility of improving the reuse of construction materials by using a logistics terminal. The study covers the case of a planned logistics terminal in the Gothenburg region and develops a flow model, taking into account the material-, information-, and economic flows that relate to the terminal and the potential changes from using the logistics terminal. The case involves a construction company and a rental company, that aims to run the terminal as part of its logistics services. The data is gathered by semi-structured interviews with logisticians, logistics managers, site manager, purchasing manager etc.

The study shows that the current flow model without a logistics terminal has poor on-and off-site logistics coordination, communication and a loss of feedback that hamper potential reuse improvements. Conclusively, the biggest challenge for implementing a logistics solution for an increased reuse of construction materials are factors related to information flows among the various actors in the supply chain, and across projects. The uncertainties of economic aspects of reuse serves as a big obstacle to breaching, that causes a resistance to invest. However, the study concludes that the potential environmental and economic gains when investing in reusing construction materials are immense. Thus, solving challenges of material handling, information infrastructure and economic factors enable the benefits of reusing construction materials. Concentrating efforts on enabling efficient construction logistics would appear imperative for solving the indicated challenges.

Keywords: *Construction Logistics, Construction Consolidation Centre (CCC), Logistics Terminal, Reuse*, Construction Material

Återanvändning av konstruktionsmaterial genom användning av en logistikterminal
En fallstudie för omdesign av logistiska flöden i samarbetet mellan en huvudentreprenör och ett uthyrningsföretag
Examensarbete inom mastersprogrammet Organisering och Ledning i Bygg- och Fastighetssektorn

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SAMMANFATTNING
Byggbranschen är resurskrävande och med det ökade antalet byggprojekt ökar också mängden byggavfall. Att i större utsträckning återanvända byggmaterial har identifierats som en viktig aspekt i omställningen till en mer hållbar byggbransch. Detta utmanar dock de etablerade logistikuppläggen mellan försörjningskedjan och byggarbetsplatsen, inklusive olika aktörers roller. Potentiellt kan ökad återanvändning av byggmaterial också generera fler byggtransporter och därmed bidra på ett negativt sätt till ökade utsläpp och trängsel. Olika projekt kan också behöva olika logistikupplägg.

Att återanvända byggmaterial genom logistiska lösningar kan potentiellt vara en lösning för att minska mängden byggavfall som har en så skadlig effekt på miljön. Återanvändning av fyllnadsmaterial inom byggnation har fått ökad uppmärksamhet och är mycket forskat. Detta har dock inte omfattat material som används vid uppförande av byggnader. Studien syftar till att undersöka möjligheten att förbättra återanvändningen av byggmaterial genom att använda en logistikterminal. Studien omfattar fallet med en planerad logistikterminal i Göteborgsregionen och utvecklar en flödesmodell som tar hänsyn till de material-, informations- och ekonomiska flöden som relaterar till terminalen och de potentiella förändringarna från att använda logistikterminalen. Fallet handlar om ett byggföretag och ett uthyrningsföretag som har som mål att driva terminalen som en del av sina logistiktjänster. Uppgifterna samlas in genom semistrukturerade intervjuer med bl.a logistiker, logistikchefer, platschef, inköpschef mm.

Studien visar att den nuvarande flödesmodellen utan logistikterminal har dålig logistikkoordination, kommunikation och en förlust av återkoppling som hindrar potentiella återanvändningsförbättringar. Sammanfattningsvis är den största utmaningen för att implementera en logistiklösning för ökad återanvändning av byggmaterial faktorer relaterade till informationsflöden mellan de olika aktörerna i försörjningskedjan, och över projekt. Osäkerheten i ekonomiska aspekter av återanvändning fungerar som ett stort hinder för intrång, vilket orsakar investeringsmotstånd. Studien drar dock slutsatsen att de potentiella miljömässiga och ekonomiska vinsterna när man investerar i återanvändning av byggmaterial är enorma. Att lösa utmaningar med materialhantering, informationsinfrastruktur och ekonomiska faktorer möjliggör således fördelarna med att återanvända byggmaterial. Att koncentrera ansträngningarna på att möjliggöra effektiv bygglogistik verkar absolut nödvändigt för att lösa de angivna utmaningarna.

Nyckelord: Bygglogistik, Bygglogistikcenter (BLC), Logistikterminal, Återbruk, Konstruktionsmaterial

Acknowledgments

This master thesis is the culmination of everything we have learned during the DCPM master's program and additionally the years we have spent arriving to this point. We would like to convey our deepest appreciation to our supervisor, Viktoria Sundquist, who has provided us with invaluable insight and guidance during the duration of our work. In addition, we would like to extend our appreciation to the supervisors from the main contractor company and rental company with whom we have collaborated, as well as to all the respondents who volunteered their time to participate in this research.

Finally, we would like to reach out with our gratitude to the group that opposed our report as well as all our friends and family members who supported us and cheered us on throughout the most challenging phases of writing.

Gothenburg, May 2022

Farzad Daraee & Oskar Granat

Abbreviations

CC – Consolidation Centre

CCC – Construction Consolidation Centre

CE – Circular Economy

CDC – Construction Distribution Centre

CLC – Construction Logistics Centre

JIT – Just-in-time

SC – Supply Chain

SCM – Supply Chain Management

SRS – Stockholm Royal Seaport

Glossary

Co-loading	Samlastning
Construction Consolidation Centre	Bygglogistikcenter
Milk run	Slingbil
Site Manager	Platschef
Stockholm Royal Seaport	Norra Djurgårdstaden
Supervisor	Arbetsledare, Handledare
Main contractor/Construction company	Huvudentreprenör/Byggföretag

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1. Introduction

The construction industry faces severe problems with construction materials that end up as waste, instead of potentially being reused as a contribution to a more sustainable construction industry. A circular economy model and the adoption of a reuse strategy for construction materials have therefore emerged as a more effective waste management approach. Such as strategy impose a need to reconsider construction logistics solutions, logistics coordination and logistics management to support the transition towards increased reuse of construction materials. The issues related to inefficient waste management and logistics will be presented further in section 1.1, followed by section 1.2 presenting the aim of the thesis, section 1.3 presenting the research questions for the study, section 1.4 explaining the limitations of the study and finally, section 1.5 explaining the structure of the thesis.

1.1 The Problem of materials waste and importance of improved construction logistics

The construction industry accounted for 37 per cent of global emissions in 2020 (GlobalABC, 2021), and approximately a third of all the waste generated in the EU (European Commission, 2022). Hence, the construction industry accounts for a prominent amount of the global greenhouse emissions and is responsible for an excessive amount of the world's generated waste (Lima et al., 2021). The industry inevitably provokes destructive environmental issues such as high energy consumption, resource depletion and emissions (Ahmad et al., 2021). In the Swedish construction industry, the total amount of greenhouse gas emissions generated by the construction industry in 2019 corresponded to 21 per cent of total emissions in Sweden (Boverket, 2021). At the same time, the industry was responsible for 35% of all the waste that was generated (SCB, 2018).

Due to the construction industry's adverse effects on the environment, the EU is increasingly focusing on environmental measures, with a number of announced directives and strategies gaining traction, e.g., Agenda 2030, Green Deal and climate declarations. By the year of 2045, it has been agreed upon by Swedish authorities that greenhouse gas emissions will be zero, which also accordingly pertains to the construction industry’s total emissions. Additionally, the Swedish authorities emphasise the demand for circularity, incorporating reuse strategies for counteracting climate impact and resource depletion (European Commission 2020). The construction industry has been recognised as a resource-intensive industry, also being the largest global user of resources and raw materials (Guerra et al., 2021). Out of the 35 per cent of waste that was generated in the Swedish construction industry in 2018, only 52 per cent was recycled. Instead, a substantial percentage of the construction sector continues to operate on the linear paradigm of take-make-dispose, where most of the waste ends up in landfills (Benachio et al., 2020).

Due to issues of waste production in construction, the implementation of circular economy (CE) has been studied and considered within the built environment (Guerra et al., 2021). The construction industry wastes approximately 15% of the total materials extracted, which necessitates effective waste management methods (Ellen McArthur Foundation, 2022). The prevailing strategy for the majority of construction industries, associated with circularity, is currently maintained as a recycling strategy, which is not as effective as adopting a reuse strategy. Recycling processes implies the outcome of inferior material quality and at the same time necessitates energy and raw material resources (Chileshe et al., 2018). The circular economy model is based on the concept of preserving materials and resources in a circular flow while maintaining the maximum possible value independent of supplementary resources added (Guerra et al., 2021).

At the same time, there is rapid urbanisation in Sweden with a high amount of construction projects taking place in city-centre, urban areas, which necessitates more transportation of construction-related materials and resources within urban settings (Janné & Fredriksson, 2021). Considering the resource-intensive industry that the construction industry is, with factors such as an increasing number of construction projects in urban environments and a large amount of waste generated from construction projects, a lot of materials are transported to and from the construction sites, requiring an extensive number of transports. Economically and environmentally viable construction need to be considered, as well as copying with the limited space and resources that are available in urban areas (Nolz, 2021). As construction involves unique and temporary projects (Ying & Tookey, 2017), the distinctiveness of temporary construction sites situated in various locations necessitates the use of distinct logistical configurations that are adapted to the project at hand. The flows of materials and resources to and from the site take place on an irregular basis (Balm et al., 2018). Thus, construction projects demand transport to and from the construction site, and when projects are taking place in dense urban areas, problems such as congestion and increased emissions will increase (Lindholm & Browne, 2015).

The increased need for materials and resources for construction in urban areas increases the importance of construction logistics and the use of various construction logistics solutions as to improve construction logistics management and tackle challenges of emission and congestion, (Janne & Fredriksson, 2021). Implementing a reuse strategy for construction materials as a more effective waste management approach further highlights the need to address logistics management. Such as strategy impose a need to reconsider construction logistics solutions, logistics coordination and logistics management to support the transition towards increased reuse of construction materials. One solution for enabling a more efficient construction logistics setup that has been advocated in several studies is the use of a construction consolidation centre (CCC), Janne & Fredriksson (2021), Muerza & Guerlain (2021), which functions as logistics terminal.

In line with the contemporary challenges described above, the thesis covers a case in which a large Swedish contractor in collaboration with their supplier, a rental company, will look into the establishment of a logistics terminal in the Gothenburg region. The terminal aims to provide building supplies for local construction projects run by the main contractor. Apart from facilitating consolidation of multiple material supplies, the terminal could provide efficient packing and labelling, JIT-delivery, kitting, weather protection and theft security. Additionally, the future objective is to investigate the possibility of reusing materials in subsequent projects, potentially facilitated by the logistics terminal, which may have financial and environmental advantages.

1.2 Aim of the thesis

The aim of the thesis is to design a flow model that takes into consideration the information-, materials-, and economic flows associated with developing a logistics terminal solution for the reuse of construction materials. The flow model for reuse of construction materials by making use of a logistics terminal will be compared to the present flow model.

1.3 Research questions

The following research questions have been identified to fulfil the aim of the thesis:

RQ1: What characterises today's logistical flows, taking into account the materials flows of surplus construction materials at construction sites, as well as economic- and information flows in the supply chain?

RQ2: What are the current challenges and obstacles of reusing construction materials in relation to construction logistics?

RQ3: What are the benefits and challenges for the main contractor and the rental company when adopting a reuse-solution through a logistics terminal?

1.4 Limitations

The main objective of the thesis is to investigating the establishment of a logistics terminal and, subsequently, the possibility of construction materials being reused through the terminal operations. The reuse process addresses the surplus of traditional construction materials during the production phase. The study has deliberately chosen not to have the intention of identifying suitable construction materials that may be reused. Thus, the study has chosen to have a focus only on the flows of materials regarding reuse and not the type of materials themselves, despite the awareness that various materials may have significant features that requires certain adaptations in regard to the reuse of them. Furthermore, the study will take on the perspective of a main contractor company and a rental company, identifying their respective benefits and challenges of adopting a reuse solution through a logistics terminal. Thus, the study is limited to a single case situated in the proximity of the Gothenburg region in Sweden.

1.5 The structure of the thesis

Figure 1 below illustrates the structure of the thesis, including the interplay among the theoretical framework, empirical inquiry, research questions, analysis & discussion and finally, the conclusion. All the research questions have both theoretical and empirical groundings, with the third research question being case-oriented. The research questions having both theoretical and empirical groundings formed the basis for the analysis and discussion and finally the conclusion of the thesis.

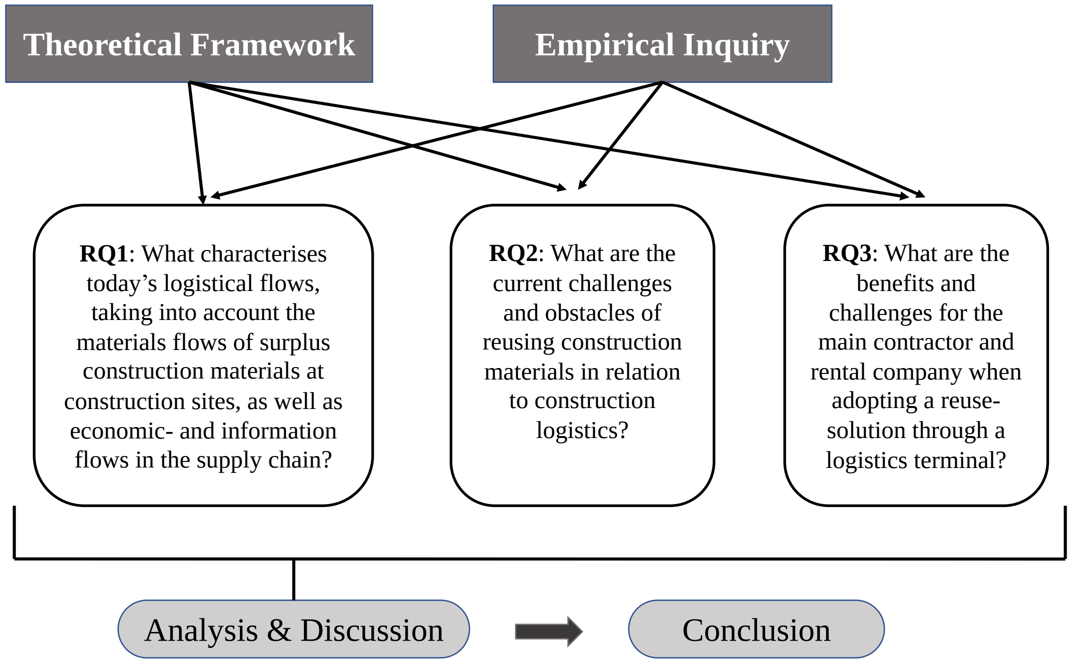

Figure 1: Illustrating the structure of the thesis.

2. Theoretical framework

The theoretical framework is structured into seven main sections with additional sub-sections. The first section discusses the construction supply chain including the importance of construction logistics. Secondly, logistical configurations are presented including the potentials of a construction consolidation centre (CCC). The term referring to construction consolidation centre is a form of a logistics terminal with similar functions, which is investigated in the following thesis. The concept of a CCC is further discussed and explained in section 2.3. Hence, the term logistics terminal will be used when referring to the case. Thirdly, purchasing within the construction industry is investigated as it is an important function within the main contractor organisation. Finally, the environmental aspect of the construction industry is covered including circular economy and reuse in connection to construction materials.

2.1 Supply chain management in construction

The concept of supply chain (SC) in the context of construction is critical as it constitutes all the interconnected series of activities in the process of extracting raw material until the delivery of finished product to the final costumer (Ofori, 2000). The concept of SC in construction implies extending beyond the involvement of client, contractor and supplier to all actors that, through value adding activities, are more or less affecting the final product. Delineating the SC structure, it includes a network of interrelated actors rather than a business-to-business relationship. Thus, it has been advocated that the integration of the supply chain management (SCM) may bring prosperity to the project effectiveness and efficiency while simultaneously increase the competitiveness and success for the SC members but also the end customer. Integrating the SCM entails that all involved members are working towards common objectives in creating a synergistic effect, which in the end implies bringing value to the end customer. The traditional relationship between businesses conveys a win-lose outcome which is rooted in an inadequate communication and information exchange between businesses, uncertainty, dishonesty etc. (Ofori, 2000).

One of the challenges of construction supply chain management is the features of the construction industry as a project-based industry which distinguishes it from other industries. The industry being project-based implies the uniqueness of having a temporary organisation (Guerlain et al., 2019). According to Ofori (2000), the industry is fragmented in the sense of all involved actors having their separate objectives, thus leading to inadequate coordination of construction related activities. At the same time, Ying et al. (2021) highlight the fragmented structure of the construction industry as an underlying factor for many of the existing logistical issues, not to mention, the lack of trust and commitment as well as arm-length relationship between actors. Frödell et al. (2013) highlight the risk that follows for each actor due to the increased uncertainty that comes with the disjoint structure of the involved actors. Moreover, the project-based industry entails a contextual setting with geographical distinction and a specific product that continuously must be adjusted based on the requirements of the client. In other words, the construction supply chain is, to a certain extent, also a project-based setting, with a constellation of actors coming together and forming a supply chain for a specific project, as a temporary setting.

Vrijhoef & Koskela (2000) depict the concept of logistics management as a part of CSCM providing the following definition: "Logistics is that part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point-of-origin to the point-of-consumption in order to meet customers' requirements." (Vrijhoef & Koskela, 2000 p.67). Based on the abovementioned quotation, construction logistics and CSCM is not disjoint but integrated with each other. Therefore, construction logistics is an important part when managing the supply chain process.

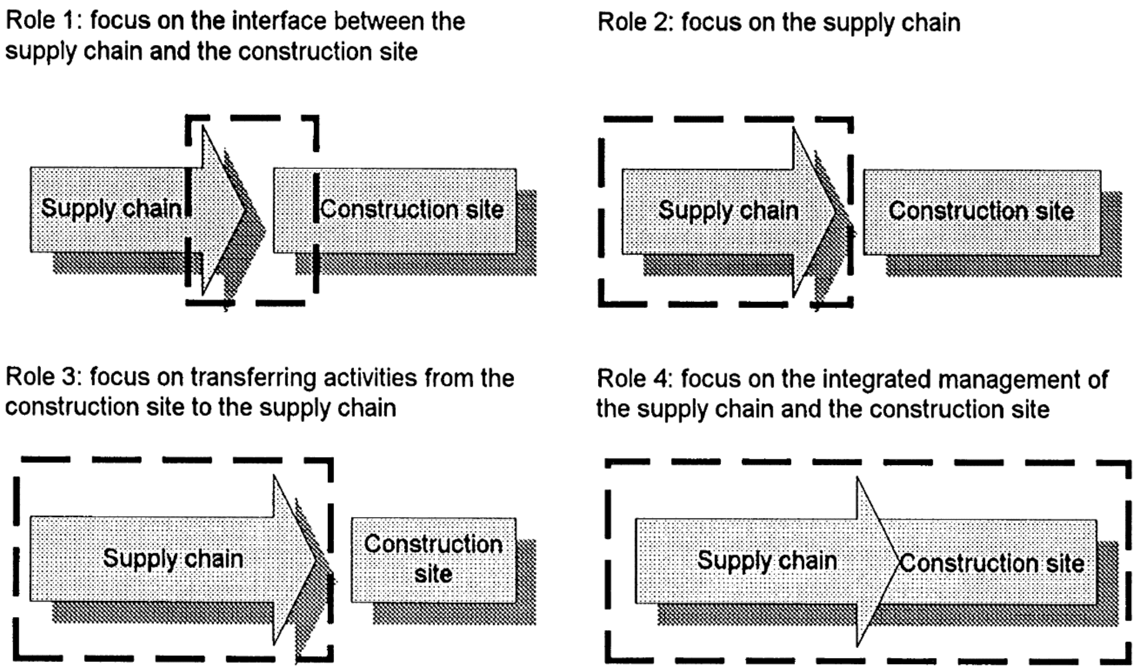

Figure 2: The four roles of CSCM (Source: Vrijhoef and Koskela, 2000).

Vrijhoef & Koskela (2000) identify four different roles of supply chain management in construction. The different roles imply a shifting focus between the site, the supply chain and the interface between the site and supply chain. The first role focuses on how the logistical activities of the supply chain may subsequently affect the on-site activities by reducing the time and cost parameters. The focus being on the interface entails avoiding disruption of work on site activities which may be considered by the main contractor. The seconds role focuses on the supply chain were the main objective is to decrease the logistical costs, e.g., material inventory, in the supply chain process. This focus may be adopted by the suppliers being in the position of affecting this process. The third role focuses on transferring activities to the earlier stages in the supply chain from the construction site. Similar to the second role, the main objective is to decrease the time and cost parameters, being adopted by either the suppliers or contractors. The fourth role adopts an integrated focus by the management in the activities on site and the supply chain. The management functions, such as suppliers, customers, and contractors, may embrace this focus in an integrated way (Vrijhoef & Koskela, 2000).

2.2 Construction Logistics

There is a constant need for different set of logistical configurations in the construction industry due to the nature of projects being managed within a temporary supply chain of actors. The construction as output is produced at the construction site, hence, necessitates the supply and discard of materials and resources to and from the site (Janné & Fredriksson, 2019). According to Janné & Fredriksson (2021), logistics within construction projects are generally overlooked and performed reactively.

There are a variety of definitions depicting the implicit conception of construction logistics. Ghanem et al. (2018) described it as the management of material and resource delivery-processes to a construction site. Usman and Ibrahim (2015) define construction logistics as a part of the supply chain that coordinates the movement of materials and associated information from their place of origin to their point of consumption or installation.

Ghanem et al. (2018) distinguishes construction logistics in on- and off-site logistics. The off-site logistics is described as part of the supply chain management including the inter-related activities of material and information flows amongst a network of actors with the objective of supplying the construction site. On the contrary, the on-site logistics encompasses planning and coordinating the movement of material flow at the construction site efficiently with storage, material handling, space allocation etc. being frequent activities.

2.2.1 Construction Logistics in relation to the Construction Site

Efficient logistics off-site facilitates the core objective of production on-site (Ghanem et al., 2018). According to Usman & Ibrahim (2015), the complication with construction logistics is in its complexity and dynamic nature with deliveries to the site occurring on an irregular basis. As the construction site and the surrounding environment changes and progresses between different phases of a project, the logistics must consistently be adapted and configured accordingly. Additionally, the type of construction materials and components which enters the site during different stages of the project constantly varies. Thus, consisting of time-consuming activities of planning, managing and coordinating logistics activities (Usman & Ibrahim, 2015).

According to Dubois et al. (2019), deliveries that arrive on schedule, at the correct location and without damage are predicted to be fewer than 40%. Lindén & Josephson (2013) emphasize the uniqueness and inconsistency of construction projects as adding further complexity to the coordination of logistics. The uniqueness of construction projects implies a constantly new set of supply chain actors operating interdependently together. One common issue in the context of construction logistics is the general need of temporary storage of materials on-site. However, the storage capacity is often inadequate on-site causing damage due to movement by workers and equipment but also bad weather conditions. Additionally, Lindén & Josephson (2013) raise the poor material procurement which often occurs on an *ad hoc* basis, causing interruptions in schedule and production. However, when excessive number of resources are at the site, this interferes with the production due to lack of workspace capacity while inadequate number of resources implies delays in production. Hence, right resources must be available at the right time to maintain efficiency (Lindén & Josephson, 2013). According to Agapiou et al. (1998), there are various factors that should be considered in parallel to material purchases, considering the characteristics of the material. These include how the materials will be delivered, how likely they are to get damaged, how they will be packed, how they will be stored on site, etc. Furthermore, Agapiou et al. (1998) highlights the issue when procuring material in bulk which can result in waste in inventory, handling and transport. Additionally, Sezer & Fredriksson (2021), emphasise the crucialness of coordinating and the deliveries of materials with the production activities on-site by considering the pattern of material flow during the different phases of a project. Thus, identifying the bulk transports of material in the early phases e.g., soil, rock, concrete etc, and smaller deliveries towards the later phases e.g., deliveries on pallets and in packages etc.

Lindholm & Browne (2015) investigate the urban freight transport related to construction, highlighting the challenges related to "external logistics". The vehicles used by haulers for freight transport, to and from construction sites are causing multiple issues, not to mention, issues of road safety, congestion, noise, air quality and pollution. These issues are particularly relevant in urban settings considering the growing trends of urbanization and densification in cities. Construction activities often disturbs or blocks the accessibility on roads and streets in the immediate area of the construction site making room for inbound and outbound construction transports. Further, Sezer & Fredriksson (2021) highlight concerns about turnaround times for vehicles entering and exiting the site. The turnaround time is the entire amount of time between the vehicle's arrival at the location for unloading or loading and its departure. The increased turnaround time, which implies, e.g., congestion and increased emissions, is further caused by the lack of coordination and planning between deliveries and on-site operations.

In a construction project, transport of construction materials to and from the site constitutes a large part of the logistics flow, whereupon Dubois et al. (2019), assert may include up to 100 000 deliveries during 1-1,5-year period. Also, Sezer & Fredriksson (2021) highlight that daily project deliveries might range from one to two deliveries. As a result, transportation as part of the construction project's logistical activities accounts for a significant portion of the overall project cost. Thus, effective logistical planning of transportation deliveries has the potential to reduce overall project costs by up to 20 percent. Simultaneously, Ying et al. (2018) state that transportation costs account for around 39 to 58 percent of the overall logistics costs.

In a previous study, the logistics cost was estimated to constitute 60% of the total purchasing cost of a specific material category and between 25-30 for two others. According to Sezer & Fredriksson (2021), construction workers spend around 15% of their time transporting supplies, in which they were unloaded to where they would be assembled. This accounts for around 43% of the overall logistical cost.

According to Dubois et al. (2019), the understanding and incentive of implementing effective planning of logistics and transportation has increased because of its potential economic benefits in construction. The fact that the cost of logistics activities is strongly tied to the cost of materials makes it hard to measure the effectiveness of logistics and separate the logistics costs (Dubois et al., 2019). However, Sezer and Fredriksson (2021) emphasise environmental issues over economic issues related to construction material deliveries. Sezer and Fredriksson (2021), assert that inefficient transportation of construction materials is a consequence of inadequate management of deliveries to the site.

2.2.3 Organising logistics and transport activities

Incoherent coordination of supply chains results in ineffective logistics management. Currently, the management of logistics and transports differs between e.g., contractors and subcontractors having their own supply chains. Dubois et al. (2019) assert that joint coordination of logistics management between actors has the potential to enhance the logistics flows and the communication between different actors. In the article by Dubois et al. (2019), three different configurations of logistics activities and transport in construction projects were identified: the *de-centralised coordinated configuration*, the *on-site coordinated configuration* and the *supply network coordinated configuration*. The three configurations cover the whole process, from the activities involved in supply logistics to the deliveries on-site, including the logistics on-site. While the supply logistics includes all activities connected to supply of material e.g., storage packaging and transport, the on-site logistics includes material handling.

The de-centralised coordinated configuration (see figure 2), being the most common, implies disjoint coordination of on-and off-site logistics activities between contractors and subcontractors. This configuration entail material handling being a significant part of construction workers daily activities apart from production activities. The configuration generally entails two different scenarios. Due to subcontractors’ contractual agreements with suppliers, often including free transport, deliveries are ordered every so often, resulting in many trucks arriving with a low fill rate. In the second scenario, the subcontractors have contractual agreements that include bulk discounts, implying fewer trucks with full loads entering the site. This generally results in lack of storage area and deliveries of material arriving before the time of installation, disturbing production activities due to material handling on-site (Dubois et al., 2019).

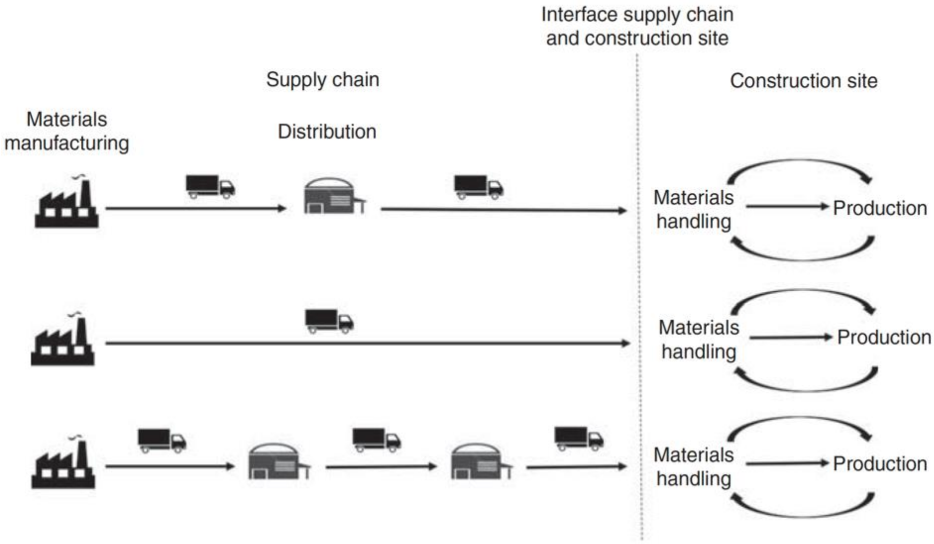

Figure 3: The de-centralised coordinated configuration (Source: Dubois et al., 2019).

The on-site coordinated configuration, which is generally implemented in complicated projects and projects with a lack of storage capacity (see Figure 3), entails that the logistics activities on-site and at the interface between the supply logistics are managed jointly. However, supply chain logistics often lacks this level of coordination. Consequently, the delivery of transportation to the site is synchronised, allowing for just-in-time (JIT) deliveries and effective on-site logistics management. Common is the involvement of a logistics coordinator who manages the logistics activities on-site, such as transport routes, elevators, cranes, etc. Typically, this coordinated configuration requires planning and analysis of material and resource flows in advance. Less materials handling by construction workers implies a stronger focus on production activities. Supply of materials is often ordered with just-in-time delivery, after which the material is delivered to the assembly area to reduce the risk of material damage or loss. This integrated arrangement necessitates more rigorous supply logistics activities, which further may streamline the on-site logistics. Thus, delivery of goods and value adding activities must be adjusted in the supply logistics so that they may be transported directly to the assembly area. In addition, this interface between supply logistics and on-site logistics may need information systems for scheduling the deliveries (Dubois et al., 2019).

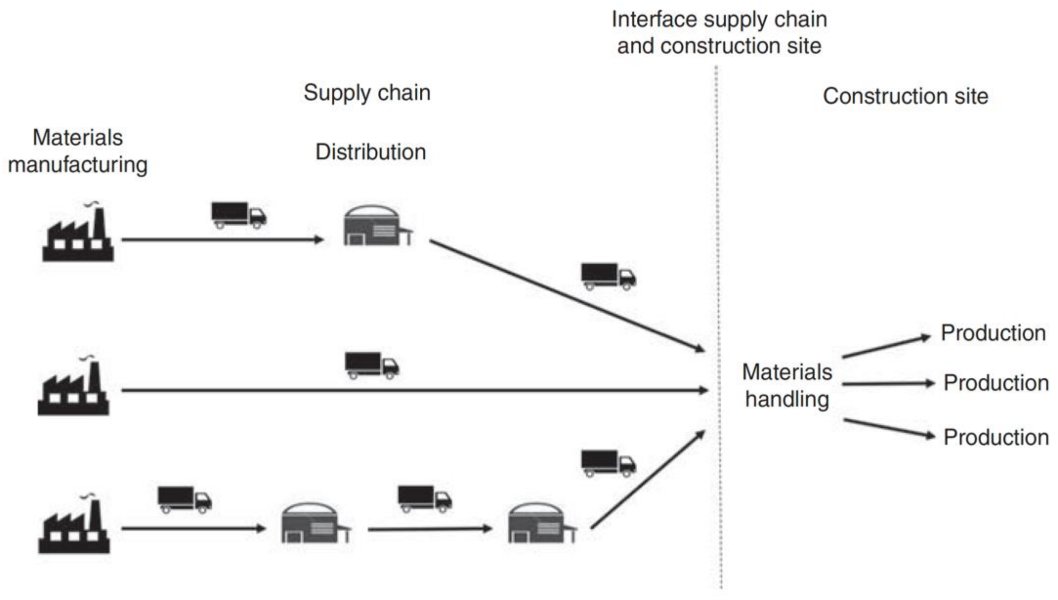

Figure 4: The on-site coordinated configuration (Source: Dubois et al., 2019).

In contrast to the aforementioned coordinated configurations, the supply network coordinated configuration (see Figure 4), extends beyond the joint coordination on-site and includes the supply logistics as well. Utilizing a nearby consolidation centre for storage of construction materials in proximity to the construction site is common. All deliveries are transferred to the consolidation centre, whereupon they are transported to the designated areas of assembly on-site. Prevalent is the appointment of a logistics specialist. Not only does the logistics specialist possess physical resources, such as a consolidation facility, equipment, and tools, but also a high level of experience in planning, analysing and coordinating logistics activities. Thus, the logistics specialist is responsible for coordinating logistics activities both on- and off-site, as well as at the interface. Additionally, the logistics specialist is responsible for coordinating the logistics activities at the consolidation facility, enabling, e.g., immediate storage and co-loading of deliveries, resulting in less transports to the site. Most of the material handling is performed at the construction facility, which enables for value added activities on-site. Despite the prominent advantages of implementing the on-site coordinated configuration, this in turn sets more requirements for more engagement between the relevant actors across the supply chain and the site (Dubois et al., 2019).

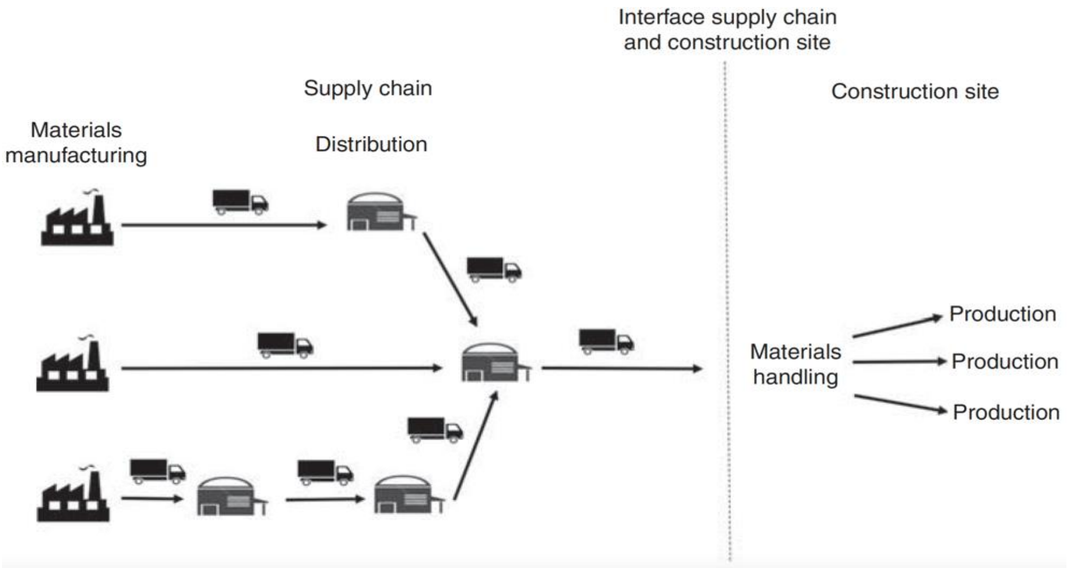

Figure 5: The supply network coordinated configuration (Source: Dubois et al., 2019).

2.3 Construction Consolidation Centre (CCC)

A Construction Consolidation Centre (CCC) is described as a logistics facility which allows for construction materials to be delivered to, subsequently be consolidated, classified, and then finally be delivered to the designated construction site (Muerza & Guerlain, 2021). Guerlain et al. (2019) use the same definition of a CCC while also adding sorting among the list of services that a CCC can provide. Sulivan et al. (2011) say that "operation of a CCC involves receipt, temporary storage and distribution of construction materials and equipment" (Sulivan et al., 2011 p.180). Based on these three examples, we can tell that a CC involves receiving and storing construction materials to be distributed to construction sites. That seems to be the basic function, while a CCC can also contribute with additional value-creating activities (Guerlain et al., 2019) such as sorting, consolidation and classification. Another phrase of the consolidation of materials that takes place at a CCC is used by Nolz (2021) who describes materials as being bundled from different suppliers before being transported to one or several construction sites. This is illustrated in Figure 5, which shows the fundamental function of a CCC when different materials from different suppliers are delivered to the CCC before being consolidated and transported together to the construction site, where the materials are placed in the right place.

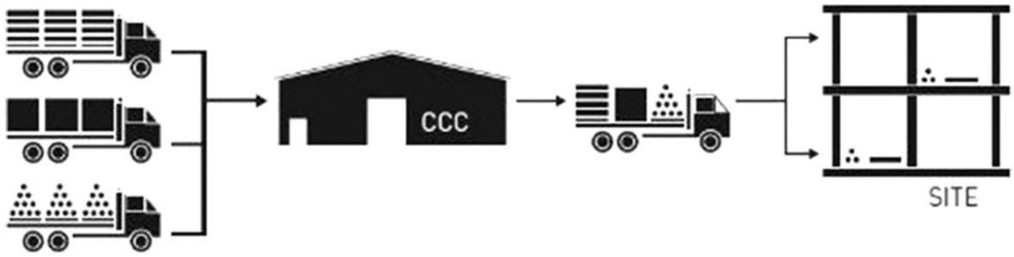

Figure 6: Fundamental function of CCC (Source: Nolz, 2021).

2.3.2 Different labelling of CCC

However, since Sulivan et al. (2011) use the term "CC", meaning Consolidation Centre, it brings up the question of whether the different authors are discussing the same concept. Moussaoui et al., (2021) discuss kitting services within Construction Logistics Centres (CLC), where the CLC is described as "a facility that is usually used for receipt, temporary storage, and redistribution of materials according to the construction site orders that are received" (Moussaoui et al., 2021 pp.108). This shows that the CLC has the same function and is defined in the same way as a CCC. Further, Moussaoui et al. (2021) state that several labels exist for this concept apart from CLC and additionally refer to Construction Consolidation Centre (CCC) and Construction Distribution Centre (CDC) to represent the same concept. From Sulivan et al. (2011) it is also clear that a CCC is the same as a Consolidation Centre within the construction industry context, but it shows that the concept of Consolidation Centres exists in various industries outside of the construction industry. Due to the above considerations, it is necessary to refer to the model that includes a site for receiving and dispersing building materials in conjunction with value-adding activities.

2.3.3 The potential practices of CCC

According to Sullivan et al. (2011), construction projects located in city centres often suffer from a lack of storage space on site. This is reinforced by Gueralin et al. (2019), who point to the lack of space on site as being challenging when it comes to the logistics of material handling. Moussaoui et al. (2021) suggest that delivering materials to site according to the just-in-time (JIT) principle for instant installation, would take away the need for the material to be stored on site. JIT is a principle that was first applied in Japanese manufacturing, and it is based on "having the right items of the right quality and quantity in the right place and at the right time" (Pheng & Hui, 1999, pp.658). One of the factors that led to this principle being developed is the lack of space that Japanese firms suffered from, and rather than using the limited space for storage, delivering materials directly to the factory floor allowed for utilising the limited space more efficiently.

The problem of lack of space is evident in the construction industry as well, and as Moussaoui et al., (2021) suggest, delivering according to JIT in construction allows for more efficient use of the limited space on a construction site. This is something that a CCC would enable by matching the supply and demand of the construction site better than traditional delivery methods. Moussaoui et al. (2021) explain this principle further by describing how this works in practise. This is done by having suppliers deliver to the CCC, where materials are stored short-term before being bundled and delivered at the right time and right place at the construction site.

The advantage of this practise is identified in several studies, e.g., Sulivan et al. (2011), who states the additional advantage that utilising a CCC can reduce construction-related traffic in the vicinity of the construction site. This advantage is also argued by Montwi et al. (2021), who state in their paper that using a CCC is expected to reduce the number of lorries in cities. This is done by consolidating different shipments of goods coming from outside the city centre, in a CCC located close to the city centre. Further, distributed from the CCC, optimising last mile distribution by loading vehicles fully and using well-suited transportation for the final leg of the journey (Nordtømme et al., 2015). This would have additional advantages such as reducing pollution in the air, avoiding traffic congestion and decreasing the risk of accidents related to traffic due to fewer and more optimal transport options (Montwi et al., 2021).

Adding a CCC into the logistics setup also allows for value-adding activities to be established to provide the customer with services that otherwise would have taken more resources (Janne, Fredriksson 2021). According to Janne & Fredriksson (2021), logistic activities that are usually undertaken on the construction site can be moved to a CCC and offered as additional services to improve the logistical coordination within a project. Value adding activities can include kitting, consolidation, storage, marking materials for tracking and inventory management.

2.3.4 The CCC of Stockholm Royal Seaport

An example of a project utilising a CCC, and which serves as an example of the core services and value-adding activities that can be offered, is the Stockholm Royal Seaport (SRS). SRS is a development project in Stockholm that contains many construction projects within a large geographical area. "SRS is one of the biggest and longest-running development projects in Sweden that uses a CLC. This makes it a great place to look at how CLCs are used" (Janne & Fredriksson, 2021, p.53).

In the case of the SRS CCC, several additional value-adding services were offered to the different projects within the SRS development area. Kitting was offered and it allows for materials to be bundled for specific areas of the construction site or sections of buildings to make it easier to organise the assembling and installation of the construction. On-site waste management was also offered to allow the CCC to operate and dispose of construction waste during construction as well as provide waste containers.

External long-time storage was offered for bigger construction elements at an external site since the operation of the CCC was only intended for smaller construction elements. However, this was not used and only the storage at the CCC was used. A part of the service that was provided by the CCC was logistics coordination. The SRS CCC offered manpower in the form of a designated logistics coordinator who could help with the planning and managing of the logistical issues as well as conducting analysis of the material flows. Several projects designated the logistical coordination as a part of the site managers responsibility. The rest of the projects were assigned logistical coordination within the projects with their own logistical coordination setup. However, none of the projects used the logistical coordination services that the SRS CCC had to offer.

In the case of SRS, not many of the value-adding services were utilized. However, the mandatory core services were utilised to a much higher extent. Among the core services was short-term storage, which included storage of materials at the CCC for free for a short while, and for a longer time, a fee was charged based on the square metre the materials occupied and the duration of the storage. Transport consolidation was also mandatory and deliveries that were not big enough to get their own transport had to be consolidated with other materials at the CCC until a vehicle was full for them to be delivered, which added to the delivery time. Return transport gave the opportunity to return materials to the supplier or whomever was chosen as part of the CCCs' milk run to the construction sites. These materials could be taken to the CCC for short-term storage or to another site for long term storage. Because very few of the projects within the SRS used value-adding activities, the CCC was primarily used as a buffer for materials to be delivered to the construction site as needed. This was emphasised as a positive by several of the project managers. In the SRS project, storage of materials was not allowed on-site, which might have contributed to the positive outlook for some of the project managers since they did not have a choice. With the requirement of not allowing storage on site, the CCC had to implement solutions to cope with inventory management and to be able to trace materials, which some project managers saw as helpful when it came to on-site material handling. Handling materials took less time and was deemed less dangerous on site due to being able to properly get the right materials delivered to the right place because of the tracking and tracing of materials, according to some project managers.

2.4 Purchasing in relation to construction supply chain management

The most important factors for choosing a supplier of construction materials are quality, delivery dependability and price (Benton & McHenry, 2010). However, to which extent these factors are valued varies between different companies. In order to choose which supplier should be selected to deliver the different types of materials for a construction project, various potential suppliers need to be selected and evaluated. According to Benton & McHenry (2010), the first selection of potential suppliers is usually based on previous experience and performance. After the first pool of suppliers are selected tenders are sent out and after a process of negotiation one or more supplier is selected (Benton & McHenry, 2010).

Quality of the materials is one of the most important factors that suppliers are chosen on. Often the previous experience with the supplier speaks for if they are able to deliver the quality that is required, and it is assumed that the supplier can continue to deliver the quality in the same way as in earlier projects (Benton & McHenry, 2010). Depending on the type of materials that are to be purchased, more or less of an inspection is done on the materials. For less sensitive and time consuming to produce elements, a visual inspection will be done while more crucial and complex construction elements will undergo a more thorough inspection. Quality is hardly ever a problem in the construction industry since if a supplier delivers subpar quality, then it will greatly reduce the likelihood of receiving future work since often the first selection of suppliers are done with regards to previous experience. Additionally, the company procuring suppliers send specifications to the supplier with which they must comply which further reduces the risk of receiving materials with poor quality (Benton & McHenry, 2010).

The next important factor when it comes to choosing a supplier of construction materials is delivery dependability. Due to the nature of construction projects and the intricate planning that goes into every project, delivering according to deadlines is a crucial part of supplier evaluation. Missed deliveries can lead to the project not meeting its completion date which can incur costs to both the contractor and the client. This means that a supplier that can deliver faster and more dependable will have a significant leverage in a procurement process and Brenton & McHenry (2010, p.55) express that “delivery considerations are the most important criteria used in selecting suppliers for the construction industry”. The final of the major factors when considering suppliers is price. While important and often the most crucial it does not always outweigh all the other factors. There is a balance to be found between price and the other factors and the procuring company must weigh for example faster deliveries with the increased costs that will come with it. This is where the procuring company and the supplier enter the negotiation phase and often prices are not set in stone but there is space for negotiation on either side (Benton & McHenry, 2010).

Except for the three biggest factors mentioned above, other factors might come in to play as well, such as customer service or the locality of the supplier to the construction project, although not in the same extent as price, quality and delivery dependability. With regards to if the construction company should procure one or more suppliers to deliver materials, often bulk materials, there is arguments to be made for both views. The end goal is to create a situation where the construction company receives the best value for the materials purchased. Value in this context is not only monetary value but several factors such as quality, risk, cost of material, total cost and delivery all contribute to the total value that the construction company receives. To achieve the highest value a company may use multiple sourcing or single sourcing (Benton & McHenry, 2010).

Multiple sourcing is when a company uses multiple sources for their materials in order to have the suppliers compete against each other for the majority of the business. The advantage is that it can create a situation where the suppliers compete and push their prices as low as possible which gives the construction company increased value. The construction company will also secure their supply of materials since if something happens to one of the suppliers that makes them unable to deliver, the construction company can use the other supplier to make sure that they always will receive their supply of materials. This contributes to the security of the deliveries which also adds value for the construction company. Multiple sourcing may also allow the construction company to keep an eye on the market in order to keep up with new developments, changing practises and other information that is valuable to them (Benton & McHenry, 2010).

Single sourcing is when a company uses only one supplier for the supply of materials. The most apparent advantage with single sourcing is that since all the materials come from the same supplier, bulk prices and other deals can be reached since the volumes of materials are guaranteed for the supplier which leads to lower costs per unit for the construction company. This adds value to the construction company in the form of reducing the cost of material. With the guarantee of the contract, the supplier might also be more willing to change their organisational structure to more easily accommodate the requirements of the construction company which adds a layer of security for the construction company. The communication and cooperation could also be strengthened due to the closer and more focused collaboration with only one supplier and fewer actors involved than in multiple sourcing (Benton & McHenry, 2010).

The majority of the profit for a construction company comes from the surplus of money from construction projects, therefore controlling the costs of the construction projects is an important aspect to consider since the costs will cut into the profit of the construction projects. According to Wang & Wang (2010), 60-70% of the total cost of a construction projects comes from building materials which means that if a company can manage construction materials in a good way, then there are costs to be saved and cut which will directly impact how big the profit will be in the projects. Wang & Wang (2010) also points out that applying logistics to construction projects in order to manage materials costs in the most efficient way is an important part in keeping costs low and profits high. Other factors for managing materials are purchasing and managing inventory (Wang & Wang, 2010).

Because of the large costs associated with construction materials, "improving the accuracy of materials estimate, reducing material consumption, eliminating waste, reducing inventory backlog" (Wang & Wang, 2010, p.199) are important factors that needs to be emphasised in order to save costs and create a more economically viable situation in construction projects. Costs related to materials also include costs associated to procurement, transportation and storage. According to Wang & Wang (2010), only materials that lives up to the proper standards of right price, right quality and arriving on time at the construction site can give the project the best conditions to be profitable. This in turn puts additional importance on purchasing who is responsible for procurement of the materials and services that the suppliers provide (Wang & Wang, 2010).

The cost for procuring materials is not only the direct cost of the materials but also associated costs such as transportation costs and packaging. To achieve lower costs when purchasing materials, the purchasing department can not only look at the direct materials costs and purchase at the lowest price. Thus, also consider the associated costs to achieve the lowest total cost which will lead to increased profits (Wang & Wang, 2010).

Wang & Wang (2010) points out that despite the need for materials during a construction project being continuous, the delivery of materials is made in intervals. Thus, it is advantageous to keep a stock of materials and management of that inventory in order to avoid disruptions in the work at the construction site.

Purchasing is an integral part of many companies which can contribute to the profitability of specific projects and in the extension the company itself. Within the construction context, purchasing can happen in almost any phase of a project. Purchasing within a construction company plays a crucial role in materials management and within a construction project. Majority of the costs are associated with materials which makes purchasing an important aspect with opportunity to contribute to the profit of the project. Purchasing often includes many of the activities that are associated with buying, such as deciding what the needs are, selecting who should supply the materials and negotiating a price with choosing the supplier being one of the most important functions within a construction context. The supplier chosen must be able to deliver the specified good in a satisfactory way according to the agreed specifications. Figure 7 below shows the main functions of purchasing which extends beyond the function of only selecting the supplier (Samarasinghe et al., 2012).

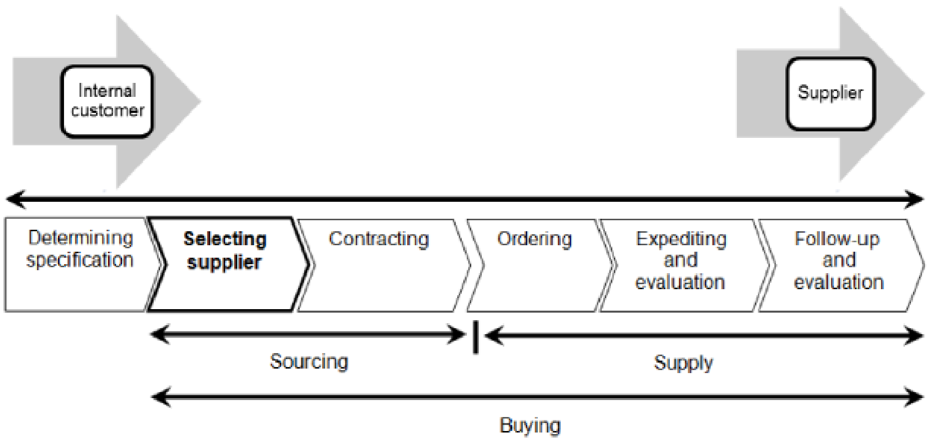

Figure 7: Functions of the purchasing function (Source: Samarasinghe et al., 2012).

Samarasinghe et al., (2012) argue that construction companies should not only select their suppliers based on price but instead on their value-adding possibilities and that the relationship with the supplier has significant impact on the construction company's ability to be competitive in the construction industry.

2.5 Environmental sustainability in the construction industry

Currently, the average atmospheric temperature is increasing continuously because of human activity, contributing to global warming and climate change (Ahmed Ali et al., 2020). Arora et al. (2020), emphasize todays conventional strategy for material use as a driving factor for the increase of the global emissions. Hence necessitating reduced amount of material consumption, and in particular, sustainable resource consumption for mitigating the ongoing climate change.

Construction being a resource intensive industry, there are also a considerable amount of energy use in conjunction to activities such as material gathering and material production, transportation, waste disposal, production etc., (Fořt & Černý, 2020). The amount of waste that are generated globally by the construction industry amounts to approximately 40% (Eberhardt et al., 2022). The construction industry accounted for more than 37% of global emissions in 2020 (GlobalABC, 2021), while generating approximately 45-65% of all waste ending up in landfills (Lima et al., 2021). The construction industry's prolonged use of non-renewable resources is immensely inefficient and will inevitably implicate natural resource depletion (Eberhardt et al., 2022).

Currently, there are several drivers, such as government regulations and national legislation, pushing the construction industry toward a focus on sustainability (Pero et al., 2017). According to Ahmed Ali et al. (2020), authorities advocate the reduction of carbon emission and energy efficiency by introducing standards, policies, guidelines, codes etc. Pero et al. (2017) imply that construction companies may gain benefits by implementing actions towards reducing their environmental impact, such as attaining a "green image", gaining competitive advantages and reputation etc.

The conventional waste management method of deliberately disposing waste material in landfills has for long been the most convenient and cost-effective solution in the construction industry. However, because of this destructive practice, people have become more aware of the consequences of dumping unwanted material without further consideration. Resource depletion, global warming, increased pollution, etc., are just a few of those detrimental effects that have become noticeable as the outcome of discarding waste in landfills. Simultaneously, people have become more knowledgeable and aware of the environment at the same time, which has made the industry more compelled to adopt environmentally responsible actions (Teo & Loosemore, 2001).

According to Opoku et al. 2019, there are several identified impediments having counteracting effects for construction companies in adopting sustainable practices. Commonly, adopting sustainable construction practices are often associated with higher investment costs in comparison to conventional construction practices. This argument is acknowledged by Pero et al. (2017), who affirm that sustainable practices, while lucrative from an environmental view are often unprofitable from an economic point of view. Additionally, the high investment costs can be a consequence of taking the risk of unforeseen costs which makes this a further barrier (Opoku et al., 2019). Generally, it is the request of the client that is the decisive factor in whether sustainable construction practices are utilized, however the uncertainty that comes with high risk may have a negative effect in the decision making. These risks are generally related to implementing unfamiliar techniques, lack of knowledge and information, lack of previous experiences in the industry etc., (Opoku et al., 2019). Simultaneously, Pero et al. (2017) highlight the knowledge of implementing sustainable practices as being limited to the single organisation, meaning not covering the whole supply chain and all involved actors. This is because, in general, sustainability in construction is the outcome of collaborative efforts by all stakeholders. At the same time, Isaksson & Linderoth, (2018) emphasizes the direct costs of considering environmental practices as the determining factor, while disregarding many of the expenses that, over time, might result in profitable outcomes.

2.6 Environmental sustainability in the Swedish construction industry

During year 2019, the total amount of carbon emissions generated by the Swedish construction industry constituted approximately 21,1 per cent (Boverket, 2021). Due to the adverse effect of construction industry, the Swedish government has conveyed several environmental directives to drive the construction sector in the process towards sustainable development (Sverigesmiljömål, 2020). Agenda 2030 is one of the directives that aspires for a "good built environment" (Regeringskansliet, 2022). "Good built environment" refers to Sweden's growing urbanization, which raises demand for housing and transportation in urban areas, posing issues such as increased transportation demands, increased material, resource and energy consumption etc., (Sverigesmiljömål, 2021). Additionally, EU has launched the Green Deal which is a strategic effort to transform EU to become climate neutral. The Green Deal advocates the circular economy model as paramount prior to the conventional linear model in achieving the objectives of climate neutrality, applying to, amongst others, the construction industry (European commission, 2020), which cohere with the Green Deal directives (Boverket, 2021). Further, the recent debate of climate declarations in Swedish new building will gain legal effect by 2022, implying reducing but also reporting the buildings total impact on the climate (Boverket, 2021; Regeringskansliet, 2022).

2.7 Circular Economy

Many practitioners, organisations, academics, and government officials have advocated the paradigm shift of transitioning from a linear economy (LE) model to a circular economy (CE) as a viable strategy for mitigating the detrimental activities of the construction sector (CI). The conventional LE model, which includes the actions of take-make-dispose, has been an inefficient way of consuming materials, resulting in material scarcity and increased emissions into the environment (Hossain et al., 2020).

CE adoption has significant potential for addressing environmental challenges, even though less than 10% of the world economy have recognizes it (Fořt & Černý, 2020). According to Guerra et al. (2021), while only 40% of construction and demolition waste are reused, recycled or used for energy recovery, the potentials are significant. According to Norouzi et al. (2021), modern waste management is currently putting humans at risk by pushing the planet's limits in an unsustainable direction. Additionally, the price of materials is increasing unceasingly, which puts more demands on efficient waste management. While LE equals a limited lifespan of materials where materials are predominantly disposed at the end-of-life-stage, the CE model entails the endeavour of a closed-loop system in which materials are utilised to their maximum value (Çimen, 2021).

One of the most disputable issues concerning CE is the disagreement over its interpretation, which has been rendered differently in its definition (Anastasiades et al., 2020). According to Eberhardt et al. (2022) CE is currently taking different courses based on the focusing area. However, regardless of how CE is depicted, there is a common understanding on its increased efficiency for material management and elimination of unnecessary resources (Anastasiades et al., 2020). On a closer note, the CE model involve a restorative and regenerative system in a closed material loop, by the approaching methods of reduce-reuse-recycle (Eberhardt et al., 2022).

Hossein et al. (2020) assert that by implementing CE solutions and sourcing waste material in the various stages of a construction project, this implicates utilizing resources to its maximum conceivable value. Consequently, the amount of waste material generated, and the total cost of a construction project are reduced, resulting in environmental and economic benefits. Furthermore, the supply chain must be adapted to take advantage of every possibility to recover resources, whether via recycling or direct reuse, for a successful CE implementation. (Hossain et al., 2020).

According to Eberhardt et al. (2022), the EU has been planning and enacting legislation for future actions to increase reuse and recycling strategies in the construction industry. In addition to the authorities' planning and proposals for increasing efficient and sustainable waste management, implementing reuse and recycling strategies as part of CE has been recognised by different organisations. According to Hossain et al. (2020), establishing a successful CE solution necessitates transparency among involved actors, which entails strong communication and close collaboration. Three measures were discovered in previous research to promote CE adoption in Scandinavian countries. This includes establishing guidelines for improving material quality assurance via increased information sharing and material traceability. Secondly, establishing standards for material reuse and recycled materials. Finally, develop waste management strategies for sorting reuse and recycling (Hossain et al., 2020).

2.7.1 Reuse of construction materials

Increasing reuse in the construction and real estate industry offers the benefit of mitigating several environmental challenges. This includes, for example, climate change, the amount of waste, and resource consumption (Wennesjö et al., 2021). However, a reuse market is required for reuse to be implemented on a bigger scale in the industry. There is an incentive to move waste management up the waste ladder to the level of reuse. However, this also necessitates a change in the current procedures and practises used by construction workers. In order for the construction industry to adopt resus solutions, incentives must be extended across the whole supply chain. Moreover, this necessitates significant planning in the earliest phases of projects. Furthermore, the processes associated with reuse have an effect on the environment. The degree of climatic effect is case-specific and may be modified by factors such as the need for heated storage and transportation. The reuse market in the Gothenburg area of Sweden is confined to a smaller number of actors (Wennesjö et al., 2021).

Depending on the role in the supply chain, players engage in a variety of value-added activities associated with the reuse effort. Important is that the reuse activities should not surpass the point where they constitute an expense for the actor. Although economic value provides an incentive to migrate away from the conventional linear waste management approach, reuse is primarily valued for its environmental benefits. This indicates that each actor in the supply chain has unique business model challenges when implementing a reuse strategy. The present drawbacks of reuse include the time-consuming effort and difficulty of locating reused materials, hence making the purchase a difficult process. Thus, a marketplace that displays reusable products is a critical aspect of the purchase process. Today a circular flow for construction materials within the construction sector is non-existent, thus making it difficult in flows that revolved newly produced buildings (Wennesjö et al., 2021).

3. Methodology

In the following chapter, the methodology of the thesis is described. Initially, the research design and the research process are described followed by the research approach, collection of data and evaluation of data. Lastly, the ethical and sustainable aspects in regard to the thesis are discussed.

3.1 Research design and the research process

This research comprises of a theoretical framework that is based on literature, which includes scientific articles, scientific journals and reports. The inquiry of literature references was conducted through search engines such as Google Scholar, Chalmers Library, Scopus, ResearchGate. The output of desired data was acquired by the input of keywords such as *Construction and Reuse, Construction Logistics and Reuse, Construction Logistic*s, *Construction Logistics and Urbanisation, Sustainability in Construction* etc. The literature review provided the foundation for comprehending the issues related to construction logistics, including the conception of Construction Consolidation Centres (CLC). Also, apprehending the issues of Circular Economy (CE) in construction settings and the conceptions of reuse and recycling. Further, the literature review was utilized to from the theoretical framework in the study. Before initiating the literature review process, introduction meetings were held with designated supervisor from the educational institution and subsequently the assigned supervisor from the collaborating company, as to discuss the framing of the study and important research fields. . During the introduction meetings there was exchange of thoughts whereupon a distinct case was proposed by the collaborating company. The case study proposal provided a frame of scope for the research, considering the timeframe and area of interest but also contributing to formulating the initial research questions and the aim of the study.

Once niching down to the research area in focus, acquiring and reviewing relevant sources of data and consulting with supervisors, relevant interview questions were formulated. The interview process was divided in two rounds. The first round of interviews aimed to comprehend the current situation, while the second mainly aimed to understand the future concepts related to the case in focus. However, the interview chapter was divided in three parts which is explained further in chapter 4. By consulting with supervisors, relevant key persons were chosen as potential interview interviewees, enabling for valuable data acquisition. Interview requests was mainly sent out by email, whereupon some potential interview interviewees were proposed during the interviews. All interviews were conducted through semi-structured interviewing.

According to Bryman & Bell (2015), the semi-structured interviews are less structured and are more flexible to be adjusted to the interviewee's response. According to Patel & Davidson (2015), the respondents is given more space to express themselves freely and the interview may more likely resemble a conversation. Furthermore, the interviewer, who has already specified subjects to be discussed during the interview, may ask them in a different sequence. Thus, implementing semi-structured interviews suited our study well as it involved an area of focus which was mostly based on new conceptions where all type of speculations and ideas where of value.

The interviews conducted in this study was semi -structured meaning leaving a considerable degree of space for the interviewee to express themselves freely. The interviews had also a considerable degree of standardisation which, according to Patel & Davidson, implies how organized the questions where in relation to each other. This enabled comparing the responses in relation to each other but also identifying topics that were mentioned repeatedly by the respondents.

3.2 Research Approach

This research takes an ontological constructivism stance, meaning that social phenomena originate in the social world, which emerges via social interactions and is always evolving (Bryman & Bell, 2015). According to constructivism's ontology, there is no absolute reality but just a distinct version of it (Bryman & Bell, 2015). This implies that the responses that we have received from the interviewees does not necessarily reflect the truth of matters. The interpretation is based on the interviewees' interactions with other actors that has shaped conception of reality. The interviewees' response is not the objective truth either but what they state as facts are interpretations of their social interactions that have shaped them.

The study follows an abductive reasoning, which allows for an iterative process between theoretical and empirical findings. Thus, allowing for continuous revision and development as the process for data inquiry and empirical findings unfolded simultaneously and complemented each other. An abductive reasoning enables for understanding phenomena's which may have limited theoretical grounding by continuously interacting with the social world as empirical source. Abductive reasoning enables an iterative interaction between the social world or phenomena and the theoretical findings (Bryman & Bell, 2015). As it prevails ambiguities around the research area in focus with weak theoretical grounding, abductive reasoning was best suited for this study. Thus, it enabled a work process of alternating between theoretical and empirical findings which complimented each other.

The research area under focus is still in its infancy, with weak theoretical grounding. While some interview questions had a foundation in literature, others were based on future projections and assumptions, thus eliciting responses that were factual supported or based on prior experience, while others were more of a speculative nature. The empirical inquiry, providing new perspectives on the research area, further provoked the inquiry of new topics in the theoretical framework, hence was continuously developed during an iterative process.

Qualitative research encompasses the data gathering strategy that has a more interpretative nature which implies interpreting and perceiving words which distinct from quantitative research having a more quantifying characteristic. The objective of qualitative research is to gather rich, deep data that is often unstructured in a natural setting and through close interaction with people in order to get a contextual understanding (Bryman & Bell, 2015). Thus, the study was conducted through a qualitative data gathering method in order to get an in-depth understanding of the new phenomenon and interpret the different interviewees' experiences and perceptions.

A case study implies conducting research based on a specific case, i.e., a delimited group, organisation, etc., (Patel & Davidson, 2015). Case studies is primarily applicable in studies wanting to investigate change or processes for a distinct case from a holistic point of view. Thus, this type of study which was assigned to the authors where suitable as this involves a change between current and future flow models.

3.3 Collection of data

The interviewees which that were chosen to be included in the contemporary study was initially identified in conjunction to consulting with designated supervisor at the collaborating company. Further, interviewees were identified by a snowball sampling strategy. The snowball sampling technique, according to Bryman & Bell (2015), entails identifying the network of contacts, initiating from a small group of relevant interviewees to further, through these people, establish contact with more interviewees. The studied case is unfamiliar to the industry, geographically delimited and with a limited number of actors being involved. Thus, the initial approach of finding suitable interviewees was limited. Furthermore, additional interviewees were identified during the initial interviews but also recommended by the supervisor. Interesting was to perceive and interpret actors who was both familiar to the concept but also those who were unfamiliar. This, in order to avoid bias and to obtain external reflections and thoughts on the matter. The prepared interview-questions were customed to each interviewee, meaning, the questions were costumed to the working company of the interviewee but also to the professional role and background.

The first group of interviews aimed to comprehend the current situation. During this stage, interviews were held with a unit manager for recycling and reuse, a purchasing manager and a site manager, see Table 1. During this stage, the current situation, involving challenges and opportunities, could be perceived from perspective of different actors. This group of interviewees had no previous experience of working with a CCC nor had they any connection to the case. The unit manager for recycling and reuse provided knowledge in how materials may be reused today. The purchasing manager illuminated the purchasing-and quantification process from the perspective of the purchasing department. The site manager described the current situation on construction site in the context of logistical challenges and waste management. The second group of interviews were conducted with actors who had experience of working similar to the case i.e., having experience from working with a CCC, but not having any connection to the case, see Table 1. This group of interviewees includes logistics managers and logisticians who highlighted the challenge and potential of logistics and the implementation of a CCC. The third group of interviewees included interviewees that had previous experience of working with a CCC but also having connection to the case, see Table 1. One of those interviewees having the role of logistics manager was responsible for the upcoming terminal, thus provided valuable information about the challenges and possibilities. This groups of interviewees facilitated in understanding the current flow model but also how the future flow model potentially may look like. The interviewees responses covered all the parts in the flow models i.e., the construction site, purchasing department, CCC, reuse and recycling company except from the supplier which similar to the unit manager for recycling and reuse where outside the organisations.

All interviews were semi-structured and conducted, either remotely or at site, see Table 1. The interviews were held in Swedish and was further audio recorded with the interviewees consent. All recorded interviews were initially transcribed before being analysed. Similarities were found in the interviewee's answers for which was categorized in topics, making it easier for the reader to follow in the report.

Table 1: List of interviewees with information about how interviews were conducted.

Interview	Role	Company	Duration	Date	Interview type
1.	Logistics development manager Master thesis Supervisor & Examinator	From the main contractor company Chalmers University of Technology	~40 minutes	2022-11-25	Zoom
2.	Logistics development manager Business Development Manager (& Head of Logistics)	From the main contractor company From the rental company.	~1 hour	2022-02-01	Microsoft Teams
3.	Unit manager for recycling and reuse	Municipality owned recycling-centre	~1 hour	2022-03-09	On-site
4.	Purchasing manager	From the main contractor company	~1 hour	2022-03-16	On-site
5.	Business Development Manager (& Head of Logistics)	From the rental company	~55 minutes	2022-04-04	Microsoft Teams
6.	Site Manager	From the main contractor company	~30 minutes	2022-04-06	Microsoft Teams

7.	Logistics Manager	From the main contractor company	~50 minutes	2022-04-08	Microsoft Teams
8.	Logistics Manager for the terminal	From the rental company	~50 minutes	2022-04-11	Microsoft Teams
9.	Logistician A	From the main contractor company	~50 minutes	2022-04-12	Microsoft Teams
10.	Logistician B	From the rental company	~45 minutes	2022-04-21	Microsoft Teams

3.3.1 Evaluation of data

The empirical data that was gathered during the interviews where thematically analysed according to the following themes: *Status of logistics today, Status of recycling and reuse in construction today. Potential of a logistics terminal, Possible future solutions, Purchasing as a potential factor*. This, according to Byrman & Bell (2015) entails identifying themes that emerge when analysing the empirical data. The status of logistics, recycling and reuse in construction today, initially enabled us to identify and understand the current challenges and obstacles that exist in connection with how logistics is managed as well as to what extend recycling and reuse are implemented. The potential of a logistics terminal and possible future solution enabled us to interpret and understand how the terminal may contribute to efficiency and allow for effective waste management in a futuristic scenario. Purchasing was identified as a crucial and affecting factor that controlled how the logistics was executed both in the supply chain and on site. The data was coded i.e., colour coding and mapping parts of the data that was out of the scope of the study. Once the data was divided in topics, it enabled to outline the flow models on whiteboards which was further drawn using Microsoft PowerPoint.

The conception of trustworthiness in research has been debated and what is noticeable is the existence of different assumptions about its applicability in different research approaches. Many authors deny the applicability of validity and reliability in qualitative research which is more relevant in quantitative research (Bryman & Bell, 2015). Thus, Lincoln & Guba (1985) developed the concept of trustworthiness as a substituting assessment approach for qualitative research. This approach includes the four criteria's *credibility*, *transferability*, *dependability* and *confirmability* which according to Bryman & Bell (2015), has an equivalent in quantitative research i.e., validity, reliability and objectivity.

The criterion for *credibility* entails that all individual that been subject of research shall be given the right of confirming what has been interpreted. The criterion for *transferability* is based on the assumption that the subject of research or the phenomenon studied may be contextual oriented meaning not generalizable to other context which causes issues in its transferability. The criteria for *dependability* include the archiving of all types of data collected during the various phases of the research process. Lastly, the *conformability* criteria imply ensuring that the data collection took place without any influence of personal values on the respondent's own response, which may have resulted in a deviation from the actual reality (Bryman & Bell, 2015).

During the empirical study, all interviewees' responses were audio recorded and transcribed before being analysed and further included in the results of empirical inquiries. Further, the respondents were given the opportunity of reviewing the results to confirm its accuracy. However, it not avoidably to overcome a full objective rendering of the interviewees' responses which creates issues in the obtaining full credibility. When it comes to the criteria for transferability, this becomes challenging in the contemporary study as it involves a specific case. However, many of the findings from the interviews includes activities and processes that are common in all construction projects. However, this study does not intend to be generalised but mainly contributes to knowledge dissemination within the construction industry. The dependability criteria were attained by, as aforementioned, audio recording and transcribing all interviewees' responses which were further presented in the result chapter. Additionally, interviews and descriptions pertaining to date, duration, company, role, and interview setting were documented. All interviews were conducted in a semi-structured manner which provided space for the respondent to express themselves freely. addition, the questions were posed without providing examples, and follow-up questions were posed after the responder provided a complete response which ensures the criteria for conformability.

Even if the study's trustworthiness has been considered, the research still contains limitations. The research was conducted under a limited period of time, also, identifying suitable interviewees for the study was also a restriction of the study. Thus, resulting in a limited number of interviews, which implies not considering the responses of all significant actors to obtain a more complete picture of reality. Additionally, the case was limited to a single case in a defined geographical area, thus, counteracts the generalizability. Moreover, all interviewees were interviewed once, meaning that perceptions, interpretations, and beliefs may have been affected by mood, project, focus, attitude etc., limiting the research.

The workload in this paper has been divided equally between the authors contributing equally to data collection, reflection and writing.

3.4 Ethical and sustainable aspects

The aim of this research is to develop a flow model that relates to reuse of construction material through construction logistics. This is closely related to sustainability considering that the construction industry generates a large amount of waste each year (Eberhardt et al., 2022) and reusing materials could decrease the amount of waste generated (Hossein et al. 2020). Reuse of construction materials is in line with the circular economy paradigm which have significant potential to face environmental challenges (Fořt & Černý, 2020). Reusing materials is also becoming increasingly necessary to comply with rules and regulations set forth by the EU (Eberhardt et al., 2022).

Regarding the ethical aspects of research, Bryman & Bell (2015) refers to four main areas of consideration to which ethical issues are usually connected. These are: *whether there is harm to participants*, *whether there is a lack of informed consent*, *whether there is an invasion of privacy* and *whether deception is involved*. The four areas will be explained briefly followed by an explanation of the considerations taken to these areas. Harm to participants relates to the physical and emotional harm that might come to the participants as a result of their participation. It is suggested to anonymize the participants to avoid the participants being identified and being traced to their answers in the research. This is complied with in this study and there are no reasonable way specific respondents can be traced to specific answers. Lack of informed consent concerns if the people interviewed have been given enough information about the research and what the purpose of the research is, to make an informed decision about if they want to participate or not. The participants were informed what kind of research was conducted and the topic of the research, giving them a reasonable amount of information to decide about participation. Invasion of privacy regards the gathering of information in form of questions and observations that reveal information that is sensitive to the participant. It is impossible to know if a certain topic is sensitive to one person since it can vary from person to person. However, the respondents were asked questions that related to their professions to avoid personal sensitive information. The respondents also had the option to not answer a question if they did not want to. Deception is when a researcher does not disclose what their research is about or disguise it as something that it is not. This can be due to the researcher wanting authentic answers from the respondents and not wanting their answers to be influenced by the purpose of the research. In this thesis, the respondents were informed about the topic and purpose of the research to establish trust and to be transparent.

4. Empirical inquiry

The empirical inquiry will initially include a case description which explains the conditions and circumstances of the logistics terminal. Furthermore, a brief presentation of each interviewee will be included prior to the results of each interviewee's responses.

4.1 Main contractor, rental company, and the logistics terminal

The main contractor company in collaboration with the rental company will establish a logistical terminal in the Gothenburg region. The main purpose of the terminal is to work as an intermediate storage of construction material, serving several projects simultaneously. The second purpose which is being developed, is the possibility of reusing excess construction materials to be utilized in other projects under the same ownership. The logistical terminal will have similar features as what is commonly referred to as a CCC: enabling consolidation of several material categories, just in time (JIT) deliveries, kitting, joint loading, labelling etc. The terminal will contribute to decreasing the total amount inward and outward transports to and from the construction site. All purchased construction material will arrive to the terminal, by which it is consolidated and co-loaded before being delivered in last mile-transport to the construction sites. Thus, avoiding traffic congestion in urban dense areas but also minimizing the total, otherwise necessary, transport to the site.

According to the *business developer*, the main contractor company and the rental company have had a long business relationship where the rental company acts as a service provider. The rental company, in collaboration with two other large actors provides everything that concerns the construction but not the construction itself. These services are divided into different business areas and includes e.g., rental of equipment and tools, establishing construction site facilities, temporary electricity at the construction site, dehydration of the construction, traffic shutdown, etc. The recent business area that is developing and will be provided as a full-service package is a holistic logistical solution. This implies the possibility of appointing a logistics expert with a range of different logistics solutions. These solutions include e.g., delivery planning systems, feasibility studies, logistics plans and analysis of different flows. Thus, incorporating flows in the supply chain but also at the construction site e.g., dimensioning the lifts and planning drop-of zones, checkpoints etc.

The logistics terminal will be implemented with the logistics services provided enabling coordinating logistics activities in the supply chain, which further facilitates the coordination of logistics activities on-site. The rental company being able to provide holistic logistics services using a logistics has established the idea of being able to reuse construction materials so that they can be utilised in other projects within the main contractor company. The logistics will mainly work for short-term storage and intend to serve several projects simultaneously, maintaining a fast phase in the movement of materials entering and exiting the logistics terminal. Furthermore, according to the *business developer* and the *logistics manager for the terminal*, the logistics activities in the supply chain including the logistics terminal and logistics activities on-site will be coordinated through a digital system which will incorporate the delivery planning system and display reused materials that are available at the logistics terminal. Thus, all materials entering the logistics terminal will be labelled and registered in the digital system. The *business developer* highlights that the logistics terminal enabling reuse will not necessarily generate a high source of income but rather make the rental company more competitive. Further, the *logistic manager for the terminal* implies that the logistics terminal will enable the rental company to be the sole provider for all services not related to the construction itself. Additionally, the main contractor company will mainly have the benefit of avoiding acquiring the service of waste management from recycling centres but also potentially reducing the overall consumption of material purchases.

4.2 Purchasing manager

The purchasing manager addresses the difference between purchasing agreements, feedback to the purchasing department, environmental requirements and finally the current status of reuse. The purchasing manager works as regional purchasing manager, warranty manager and production support manager at the main contractor company. The purchasing manager has no prior experience of working with CCC solutions and is not involved in the development of a logistics terminal solution with the rental company.

Purchasing in framework agreements and project agreements

The procurement of construction materials occurs through two different channels; construction materials are purchased through framework agreements or through project agreements. The framework agreements encompass conventional construction materials (e.g., gypsum boards, steel doors, steel rules, etc.), generally used in all projects, accounting for approximately 80% of the total material purchase. Materials that are frequently utilised in construction projects are generally covered by framework agreements. The central purchase department manages the framework agreements and chooses the target suppliers. The procurement of construction materials through project agreements is chosen for specific material purchases and projects. Quantification of required materials is done in accordance with the construction documents. Additionally, a spill percentage is added to the quantity to account for material damage, material loss, etc. Given the fact that there are no fixed reference values related to each material quantity, this is often based on prior experience. Another approach is to send the construction papers to the material supplier, who will quantify and supply the material. The added spill percentage on quantified material generally covers the bulk materials, e.g., gypsum, rules, etc., to ensure they are not causing delays in the production process.

The framework for minimising packaging, waste and material returns is generally clear in framework agreements. However, while the possibility of material returns is rarely utilized, it is included in the terms of the contract. If the supplier quantifies the material acquired, the accountability is generally moved to the supplier. This, however, does not necessarily result in the material being returned; rather, it often ends up in landfill and is economically compensated. This is because the processing and transportation expenses associated with returns of lesser quantities of materials are seldom profitable in the long run. However, in project agreements, the possibility of material returns to suppliers is non-existing and requirements relating to packaging and trash are typically incorporated as regular terms of purchase.

Framework agreements apply the negotiated price across several projects, generally resulting in a lower market price and establishing a long-term partnership. Further, framework agreements result in an annual sales discount, meaning the lower the price, the more purchased, which however, constitutes a fractional amount. The price of purchased materials in project agreements is fixed at negotiated prices. The agreed upon pricing might be altered in accordance with both parties' contributing resources and work allocation, giving a more accurate price breakdown. While pricing is a determining factor, it is also critical to ensure obtaining the correct supply of goods that are quality assured.

Each project has at least one purchaser who is responsible for the acquisition of supplies, particularly bulk goods. Specifying how material deliveries should be conducted is a critical parameter that generally occurs on a basic level, by which the supplier is often held accountable for the transport to the site. At this level, the material delivery is agreed to be transported by the supplier to the site whereby the purchaser is accounted for the unloading or where the supplier is accounted for both transport and unloading. Sporadically, in conjunction with the appointment of a third-party logistics provider, a logistical appendix is sent to the suppliers outlining the planning, coordination, and management of the logistics, also making sure that deliveries are initially made to the terminal. Incorporating a terminal, this fluctuates the unloading area, pushing the need for active communication to the terminal, reporting upcoming material deliveries. Additionally, contractors are tasked with the responsibility of making all material deliveries to the terminal before being delivered to the site, increasing the complexity of the logistics process. When no intermediate storage of material is being utilized, meaning all material deliveries are made directly to the site, the unloading and material handling are generally managed by white-collar workers, craftsmen, etc. Today, there is no demand for incorporating a third-party logistics solution. The size and complexity of a project play a big role in whether an external logistics manager should be hired.

Feedback and Requirements

At the construction site, there is constant interaction between the site manager and the purchaser, who, along with the supervisors, forms a team. Further, the purchaser is responsible for the purchasing process, which involves continuously following up inputs from the site manager and supervisors. Currently, there is no structured way of conveying experienced feedback to the purchasing department on the quantity of material and resources purchased, covering every individual purchase in a project. This includes surplus material that is subsequently not being utilized. Valuable feedback experience could consist of possible mistakes in the early purchasing order due to, e.g., insufficient information exchange. However, there are waste statistics which show the amount of waste material disposed at every project, distributing material into different categories, e.g., wood, packaging, plastic, gypsum, etc. Furthermore, the invoice is based on the weight of the waste and the transportation costs. Thus, the weight of the waste disposed is an important parameter which is followed up continuously during the projects. Currently, however, there is a lack of annual reporting following-up on the weight of material disposed of. However, there is currently no follow-up yearly report on the weight of materials discarded. In addition, the uniform composition of materials contributes to increased complexity in the distinction of different material categories. Consequently, the quantity of waste material disposed corresponds to total weighted material, which can further be translated into a corresponding volume or square metre of that material. This, however, may result in miscalculations, i.e., weighting rainwater and gypsum together because they have been standing without rain protection. Hence, this results in uncertainty parameters in the annual waste statistics report.

There is one person in production support who works with the environmental coordination and has the responsibility to continuously follow up on the waste material disposal statistics. Additionally, there is an annual procedure which aggregates environmental data upward in the organisation. Since there are various goals for the quantity of material that should be permitted to be thrown away, there is a constant endeavour to reduce the kilogrammes of waste in the projects. As there are not yet any formal requirements linked to the amount of material that is allowed to be thrown away, the economic factor such as costs linked to the delivery and collection of the container is the primary impetus for reducing waste. Currently, discarding excess material is the fastest and cheapest method. However, views toward the environment are evolving, with an emphasis on environmental stewardship. Working with material recycling is becoming more prevalent, and what's notable is the ability to recycle while at the same time discarding materials easily. The objectives for minimising discarded waste are interrelated to the internal requirements of decreasing overall carbon dioxide emissions. Additionally, increasing environmental awareness in the company is crucial as the demands from the client side are continuously growing. Hence, being at the forefront of environmental work may induce competitive advantages.

Reusing materials

Purchasing new materials is always easier since reused materials are seldom available in the required quantity. Additionally, ordering secondary material requires much more effort and labour, which is why purchasing new and discarding the old has proven to be more cost-effective. On rare occasions, the client may require the use of reused construction materials in the project. Previously, there has been a greater debate about proper recycling, taking the "waste ladder model" into consideration, even though it has never been a mandatory requirement. Additionally, agreements have been concluded with reuse companies to leave material not used in the projects. However, there has never been a demand for retrieving secondary materials.

Prior to the incentives of reusing construction materials, it is the main contractor's responsibility to deliver without any faults in the final inspection and follow the inspector's instructions. Thus, utilising reused materials in projects has the risk of materials being in bad condition, failing quality assurance and resulting in increased expenses. Had there not been such stringent standard criteria, such as allowing a door to pass inspection despite a little scratch, there would have been far less waste in the bins. Purchasing reused material does not necessarily imply that the purchasing department purchases fewer new materials, nor does it necessarily affect purchasing costs, given the small volume involved. Reusing material is a significant benefit, as it implies disposing of less material. However, there is no guarantee that it will be more economically beneficial than acquiring new material. The ideal scenario is that it is not more expensive than the current waste management method, i.e., a "zero-sum game". However, this would still imply an environmental benefit. Additionally, if it is not administratively demanding, there is a significant benefit to implementing a reuse strategy that entails meeting established environmental targets. Recently, it has been much stricter to dispose of less material, thus, a reuse solution would be advantageous in this regard.

From the purchasing department's perspective, establishing a terminal for reuse of construction materials would not directly affect the purchasing department. This would affect the person in charge on-site making material call-offs. The purchasing department is responsible for the large volume purchases while the supervisor, appointed from the purchasing department team, makes call-offs on smaller quantities of material required. Purchases of materials will therefore begin by checking the reuse account before making new purchases. However, coordination of delivery to the site is critical. From the purchasing department side, it is important to get a good overview of the types and quantities of reused material available. Also, it is important to know the exact condition of that material to ensure that it does not raise concerns during the final inspection. Additionally, the materials must be standardised to some extent to be reusable and useful in subsequent projects. Finally, the process must be smooth and able to be synchronised with new material purchases from the time the reused material is ordered until it arrives at the construction site. Today, the primary obstacle impeding material return flow is the lack of storage space on the construction site. There is no structured process for material return flows to be reused. In a few cases, agreements with reuse firms have resulted in the material being collected and reused. This is a flow, but it's not very organised and is very project-specific, even if it's used in the project.

4.3 Unit manager of recycling and reuse

The unit manager of recycling and reuse explains the function of the reuse station, the business area and the current status of reuse and the challenges that follows. The unit manager of recycling and reuse is an external actor that has no connection with the main contractor or rental company. Hence, the unit manager has no prior experience of working with CCC solutions and is not involved in the development of a logistics terminal solution with the rental company. However, the unit manager of the reuse and recycling centre have contractual agreement with the construction company, enabling transfer of surplus construction material in smaller volumes.

At the reuse station owned by the Gothenburg municipality, people can come and leave their things for both recycling and reuse. There is an increased focus on reuse in society as a whole and it keeps on increasing, which the reuse stations have seen based on their turnover. It has increased steadily over the years since the reuse station was founded, and it is because they are selling more things for reuse every year. There is also an increased interest in reuse, and the reuse station receives a lot of visitors who want to learn how to implement a similar reuse station where they come from.

The reuse station has contracts with certain construction companies, and at the end of the construction project, the company calls the reuse station and lets them know what kind of materials that they have left over and how much. The reuse station then decides, based on the quality, quantity and demand of the material, if they will come and collect it and then sell it at the reuse station. The materials are often bought by private individuals and smaller construction companies since the quantities and quality suit them. The materials that the reuse station receives they get for free, and then they make a profit by selling the materials. The profit covers the expenses of keeping the reuse station running. The cost of transportation of the materials from the construction site to the reuse station is also something that the reuse station covers themselves using the profit from their sales. Construction companies will be more eager in the future to give away construction materials for reuse to appear more environmentally friendly, as they currently do not use as many reused materials. A reason for this could be that there is an issue with not having any guarantees for reused materials as opposed to buying from a supplier, as well as not having the exact correct measurements for the reused materials. If a company can reuse some of the more expensive materials, then there is some money to be made since reused materials are not as expensive as new ones. However, there might not be any economic incentives to reuse materials since the construction company can make a profit when procuring materials due to supplier discounts

A challenge for the reuse station and their operations to grow today is the limited storage space for materials. Some materials are turned down from ending up at the reuse station because there is not enough room and there needs to be an interest in the materials that they accept. If there was a bigger space available and that included heating, then more materials and a wider selection of materials would be able to be stored at the reuse station. Materials at the reuse station are often stored for a varied duration. Some materials are stored for several years, but the reuse station tries to have fewer of those items in store. When it comes to construction materials, the materials that are easiest to sell are things that can easily be replaced, such as doors that are made to standard measurements. The problem with reusing gypsum boards is that they are sensitive to weather and are easily damaged, which is why the reuse station rarely receives them. If the construction company could establish a reuse solution on their own, then the municipality owned reuse station might receive fewer goods to sell, but their objective is not to make as much money as possible but to enable more recycling and reuse. If materials could be reused and recycled closer to the source, then that would be better and would be in line with the objectives of the reuse station.

4.4 Site manager

The site manager addresses the way purchasing and transportation of construction material is conducted, how waste is taken care of, what advantages and disadvantages that exist when implementing a CCC and lastly to what extent reuse and recycling is implemented today. The site manager works at the construction company but has no prior experience of working with CCC solutions and is not involved in the development of a logistics terminal solution with the rental company.

Purchasing and transportation

Orders for materials are placed before construction begins by the purchasing department, and additional materials and smaller purchases during construction are made by the site manager, while sub-contractors order materials from their own suppliers. These deliveries come to the construction site without coordination, and on a singular day, there might be many smaller deliveries for both the main contractor and the sub-contractors. There is no information feedback from the construction project to the purchasing department about the amount of materials purchased at the beginning of the project, if there was an abundance of materials or not enough materials purchased.

Depending on how much space is available on site, trucks from suppliers were either full or not. If there was plenty of space, then full trucks were ordered since they come at a lower price than trucks that are not full. However, if there was limited space on site, then there was no option but to order trucks that were as full as the space on site allowed. The trucks leaving the construction site do not take back any materials, so they would come to the site full and leave empty.

Waste

Most materials that are left over and not used during a construction project are gypsum boards and wood-based sheet material, and that is probably because those are crucial materials without which production comes to a stop. Therefore, additional amounts are ordered on top of the amount that was calculated and the usual margins that are taken into account for damage to the material. One factor that determines how much is left over at the end of the project is the person who has calculated how much material is required for the project. An experienced person has a better understanding of how much materials, such as gypsum boards, are consumed, and then there will not be as much left over as if an inexperienced person had done the calculations. In the case of materials being unused at the end of the project, if the packaging is intact, then the supplier can buy the materials back and the construction company will be economically compensated according to the agreement with the supplier. However, opened packages of materials are thrown away. Materials that are thrown away are registered according to the type of waste and reported to a group that goes through those numbers and evaluates if the number of dumpsters was enough so that materials could be sorted or if there were any discrepancies in the amount of materials that were thrown away. The main contractor is responsible for waste management on site, which includes providing dumpsters for sub-contractors as well, according to contracts with them. This means that all costs associated with waste management, including having the dumpsters emptied, fall on the main contractor. Some construction projects have high demands when it comes to recycling and reuse of materials, machinery, and equipment that were set by the client because they wanted the building to have a certain environmental certification.

CCC and reuse & recycling

On construction sites where there is limited space, there might be a small gain in using a consolidation centre, but if there is enough space, then there is no advantage. Using a consolidation centre is an expensive solution that is hard to justify for the client, which means that the costs associated with it would be taken from the main contractor's profit. Depending on the location of the consolidation centre, there might not be any environmental gain as well if the trucks have to drive long distances between the consolidation centre and the construction site.
Reuse of construction materials is not used, and it is because of the lack of infrastructure supporting reuse of construction materials in the geographical vicinity. Therefore, most materials are thrown away in dumpsters at the end of the construction project. If materials were to be reused, then wooden joists would be possible to reuse, along with parts of kitchens that were not the right kind for one project could be used in other construction projects. Because gypsum boards are very sensitive to the weather, they are not viable for reuse. The problem with storing reused materials is that it is hard to keep track of what is in store, which would require someone to work there and look after the materials if such a solution were to be possible. If that is not done, then the materials will be thrown away after all since no one knows what or where they are. To use the reused materials in another construction project, fast information must flow from the construction site to storage and back again to make sure that the materials needed for that project are there when they're needed at the construction site, too.

Today, there is no information feedback from the construction site to the next project regarding how many materials were ordered and how much was thrown away. There is a positive trend today when it comes to recycling. Previously, all materials were thrown in the same dumpster on the construction site, but these days the sorting is much more precise and there has been an increased focus on the environment. Even though there is more focus on recycling than reuse today, there is a shift towards reuse. There is quite a lot of resistance towards environmentally friendly work, such as recycling, today since it adds additional work on the construction site, and it is easier to not recycle. Additionally, if sorting is done correctly on the construction site, then there are very small costs with recycling so that is one incentive to recycle which otherwise would have made recycling even more difficult to implement.

4.5 Logistician A

Logistician A addresses the status of logistics today, the status of recycling and reuse in construction today, the potential of a logistics terminal and possible future solutions. Logistician A works at the construction company, have prior experience of working with CCC solutions but is not involved in the development of a logistics terminal solution with the rental company.

Status of logistics today

A big challenge regarding construction logistics today is that it is still new to a lot of people and many people do not think of logistics when planning construction projects. Little consideration is taken to planning and materials are delivered to the construction site little by little. Planning for construction logistics is seen as an expensive alternative to doing things as they have always been done and the traditional ways works just fine but it is hard to see the advantages if the new ways are not tried. To introduce a change towards more focus on logistics it is important to have a site manager or similar positions that are interested in construction logistics. Often there is not a designated logistics role on smaller construction sites, and that responsibility falls on a site manager or a foreman. It then depends on their knowledge or interest if construction logistics are taken into consideration. Larger construction projects more often have a designated logistics supervisor and sometimes there is a demand from the client to have such a position. There is a growing trend with more focus being put on construction logistics as an enabler for economic and environmental advantages in construction projects. This is a trend that is expected to continue as environmental issues becomes more important and the advantages with construction logistics within this area becomes more prominent.

Using Third Party Logistics with a consolidation centre some distance from the construction site, and materials being delivered in the evening, are examples of logistical solutions that has been used. A delivery planner where all the deliveries from the suppliers and the consolidation centre is registered and planned, is a popular tool to use. This give a good overview of what deliveries are coming to the construction site and what materials they are carrying. Often when trucks come to the construction site, they will deliver materials but not take anything with them so they will return to the supplier empty. It would be a gain to have the planning available so that trucks return materials and equipment instead of having an empty truck coming to the site for only the returns.

To have a well working coordination of logistics, it is important to have a good dialog with all the parties involved. Sub-contractors are important since they are many of them on a construction site so to have a good dialog between them and the supervisors as well as the site manager is important to create a functioning logistical solution.

Status of recycling and reuse in construction today

The right amount of materials is often ordered to construction sites today and there are not much extra materials left in the end of a construction project. In situations where time pressure becomes too much, then there might be cases of ordering too many materials that becomes standing idle and ruined by weather and then it is often gypsum boards, wooden joists and other bulk materials, that are thrown away. Ending up in this situation is often the cause of poor planning or other reasons for being behind schedule. Materials are thrown away in dumpsters that are provided by a waste disposal company that also comes and collects them. Most materials are thrown away today but there is a growing interest in exploring opportunities to reuse construction materials. There are also certain demands from both the construction industry in general and within the company that focuses more on recycling and performing better from an environmental perspective.

Potential of a Logistics terminal

The biggest gain from using a logistical terminal or consolidation centre is that it gives the ability to control deliveries in another way. Suppliers that are far from the construction site are often more unreliable and harder to plan for. A consolidation centre can be used as a buffer where materials can be stored and the deliveries from the consolidation centre to the construction site are easier to plan for since it is a shorter route. This helps the planning on site and allows for more space on the construction site since materials does not have to be stored on sites with limited space. This allows the construction workers to focus more on what they are there to do instead of waiting for deliveries. The time saved for the construction workers results in money saved in the end of the project.

What is challenging about a consolidation centre is that it is hard to keep track of what materials are delivered and which project they are supposed to go to. This is due to two factors, markings and the knowledge of the staff. Suppliers use their own markings for keeping track of their materials but when it is delivered to the consolidation centre and is about to be consolidated with other materials from different suppliers then all materials have different markings. This can be hard to keep track of which makes it more difficult for the staff working at the consolidation centre to know to which project materials are supposed to go to. In combination with the staff, who might not be familiar with construction materials and equipment, getting the right items to the right construction site and also keeping stock, might provide a challenge.

A consolidation centre has several benefits such as reducing the number of transports, with one transport to the construction site from the consolidation centre equalling five transports to the consolidation centre. Having a truck coming to the construction site requires a lot of work with having the right personnel and equipment available so reducing the number of transports to the construction site is beneficial. Having the transports coming to the consolidation centre were equipment and personnel is always available makes a big difference for people working on the construction site. Also, it is important to have a good dialog with the purchasing department since they set the parameters from the start of the construction project in order to create a good logistics setup.

Possible future solutions

If there was a way to effectively register and keep track of both what kind and how much materials were left over after a project, then it would be possible to reuse that material and share it with other construction sites. Often the problem is that no one knows what materials are left over, how much and at which construction site it is on, so if a system existed that could keep track of that then it would allow for reuse of construction materials. A platform where people can go on and look for old materials before purchasing new ones, would be really appreciated. This platform would preferably include clear instructions and pictures to make sure the materials are in the right condition. Simplicity of ordering reused materials is also really important, otherwise it will not be used. If it were as simple as using a phone to click and select what you needed such as within e-commerce, then it would be more utilized. However, this is dependent on what volumes of materials are available for reuse. If only a small part of one sort of material is taken from reuse, then it might create an unnecessary transport of only that small part while the majority is taken from the supplier. There is an environmental gain in reusing that small part of materials, but which might incur a negative environmental impact with an almost empty transport for only the small part of materials. If a milk run would be utilized than that truck could pick-up left-over materials from several projects which would be very beneficial. If a route could be constructed for the milk run so that it fits several projects and also the delivery company, then there is potential to save several transports returning materials.

There are few obstacles for reusing construction materials today. If standard materials, that all projects use, are reused and provided that they are in a good condition and is taken care of properly, then it should be no problem to reuse. There might be some resistance from people who only see the costs of reusing materials and that it is cheaper to order new materials, but it is a shame that costs are the only thing that should matter.

4.6 Logistician B

Logistician B addresses the status of logistics today, the status of recycling and reuse in construction today, the potential of a logistics terminal, purchasing as a potential factor and possible future solutions. Logistician B works at the rental company, have prior experience of working with CCC solutions but is not involved in the development of a logistics terminal solution with the construction company.

Status of logistics today

Logistician B have experience from working as a logistics manager in the construction consolidation centre (CCC) established in conjunction to Stockholm Royal Seaport, supplying several construction companies and construction projects with the “Urban Escape” - galleria in Stockholm, being one of the largest projects.

All transports with supply of materials arriving half empty were to go through the CCC for intermediate storage. Construction companies had storage access at the CCC in return for a warehouse rent, calculated in square meter price. Additionally, the CCC provided a delivery planning system with integrated digital system, enabling checking the reuse account for inventory balance and ordering milk run etc. However, the material inventory of surplus material was not used much by the construction companies. When surplus of materials is transported back to the CCC, there is need for a delivery note on the pallets, describing the type and quantity of that material but also potential changes performed on that particular material e.g., reduction of length. The personnel working at the CCC, often not having a background in construction, must consolidate and label all material received for further entered in the digital system, becoming searchable for others. There is a question if the labelling should already be conducted by the construction workers at the site, before being transported to the CCC. The personnel at the CCC may have difficulties in separating certain similar materials that been processed differently. This kind of activities increases the material handling time making the work process more complicated. The lack of set requirements makes these activities, often, not being carried out. Additionally, there is a need for site managers and supervisors to enforce work requirements for their workers. Otherwise, there is a risk of the CCC working as a “slop-bucket”, becoming a dumping place for all sorts of unneeded material which also implies unnecessary transportations. The material being consolidated and labelled at site implies an extra exhausting activity by the construction workers which may not occur without enforced requirements.

Status of recycling and reuse in construction today

Today, there are reuse-companies that collect materials for free and resell them. However, they collect a limited quantity of material categories. By mainly accepting intact pallets of materials, the reuse-companies takes away construction workers function of reusing all materials for sustainable purposes.

Requirements that were set during the “Urban Escape” project, was the registration of a reuse-account for checking inventory balance but also initiating by checking the balance once making material purchases. However, there were no set requirements for returning materials to the CCC. Additionally, as large quantities of materials were purchased to the construction sites, there was a three days’ time limit, meaning, materials not being used during that timeframe were to be sent back to the CCC. The biggest obstacles for managing the CCC was the lack of knowledge amongst the construction workers at site, insufficient information allocation to the construction workers and discordance in how material labelling should be conducted. Simultaneously, there are legal restrictions that do not allow sales of reused material to private individuals.

Potential of a Logistics terminal

The CCC, which works as an internal storage and serving several projects, will be an economic and environmental advantage due to less material purchases. In smaller projects like e.g., small/private houses, the terminal can provide larger amount of the material needed. The use of milk run which drives past several construction sites before arriving to the terminal, collects and leaves material, waste and equipment’s, contributing to almost half the many, otherwise, needed transports.

Purchasing as a potential factor

The contemporary purchasing is mainly adapted to a purchasing perspective with a lack of consideration to a construction logistics perspective. The purchasing department uses lump sums for calculating the quantity of materials needed. Many of the lump sums may be linked to ordering materials with included discounts and free delivery once order full transports in larger quantities at once. This creates logistical difficulties at the construction sites inducing waste material once being stored for longer periods of time with risk of damage.

The objective of establishing a CCC is to not need one in the first place and having no need of reusing materials. The objective is to do right from the beginning, starting at the purchasing department, using delivery planning and where materials are purchased according to the right quantities. This in turn implies reduced congestion at site and material handling which minimizes material damage. Additionally, the need of intermediate storage and joint loading disappears, meaning no CCC is needed.

Possible future solutions

Material that are chosen to be returned and stored at the CCC should be selected with consideration of avoiding unnecessary waste material. This information should be provided to the construction workers at site, for them knowing, what materials that are considered waste to be disposed, also what are recyclable and reusable. For this to be realized, except for the common sense amongst workers, a regulatory framework should be established for supporting these sorts of activities. However, there should not be a greater limitation to the receiving of different material categories, most like the contemporary reuse-companies. This, because it will damage the way of working and the mindset amongst construction workers not taking full responsibility for the environment. Additionally, the material and equipment must be inventoried at the CCC, avoiding material remaining for longer periods of time dragging storage costs. Establishing a terminal for warehousing purposes, serving various projects, implies, identifying the key persons who must be involved and that correct and adequate information is allocated to those people.

As logistics at construction projects are a determining factor which controls the parameters of how successful the outcome is, every project should have a knowledgeable logistics manager taking on this role. There is a need of a coordinating function which interconnects all parties who needs to be involved. The CCC implying new ways of working, requires a control document which outlines all the rules and requirements that should be considered. This being new to the industry and to the construction workers, will take time to be fully accepted by all actors.

Finally, the implementation of a CCC and the changes to the way of working should not be too complicated. Also, numbers should be presented over the different costs for e.g., transports, returns, storing, material handling etc. By seeing opportunities for saving costs, this will create economic incitements for implementing the CCC and adopt reuse strategies. There should be a digital system which facilitates the utilization of the CCC services and the reuse functions. The digital system should be convenient to use and support systems should be provided. As the construction workers task is to build, the support must come from management, making the new way of working convenient and smooth for the workers. Thus, there should be people who carries the smart roles, who developed and propels these questions forward within the companies.

4.7 Logistics manager

The logistics manager addresses the status of logistics today, the status of recycling and reuse in construction today, the potential of a logistics terminal, purchasing as a potential factor and possible future solutions. The logistics manager works at the construction company, have prior experience of working with CCC solutions but is not involved in the development of a logistics terminal solution with the construction company.

Status of logistics today

When it comes to the logistics, the construction industry goes a lot on old routines, not realizing the true potential of logistics as a great tool in the production. This often depends on the uncertainty of implementing something outside the traditional way of working. Despite being very skilled at construction, the logistics lag behind in the production. In the construction industry, the execution of every project entail reinventing the wheel.

Currently, many site managers do not see the holistic picture of a project which involves of several actors who are equally important for accomplishing the project. The project being a joint effort of several actors, all parties are equally critical for the project. The experience of implementing a logistics terminal have been with the lack of contractual agreement involving all actor's obligation to use it. The terminal has often been implemented in conjunction of utilizing a TPL service. Thus, there is a lack of requirements for all party's obligation of involvement in utilizing a logistics terminal. Generally, site managers have difficulty in seeing the financial benefits of using a terminal, which generally depends on mainly seeing the direct cost rather than the total cost linked to material flows. Previously, land area was rented from the municipality enabling storage of excess construction material. However, the construction material was never utilized due to inadequate material handling control, resulting in e.g., having rusted reinforcement material left over. There needs to be a way to make the material visible on the market, otherwise it becomes an additional cost. Today, donating reused material is more of a charity as it is not possible to sell it, which is still a better option than to dispose it.

Status of recycling and reuse in construction today

Excess material in the end of a project implies failing in purchasing. However, there will always be a small amount of material left over e.g., sheet materials. Today, materials that are left over, both during and at end of a project will, without hesitation, directly end up in the waste containers. This, since preserved left over material at the construction site equals additional costs and are usually not utilized throughout the whole project. If it is still to be utilized after a time, it has become too old or damaged anyway, ending up in the waste container. There should be a solution for recovering these materials. Today a lot of material is discarded ending up in the containers at the construction sites. From today's waste statistics it is noticeable that the sorting of material for recycling have been much more improved. One reason it that the management of waste as service is paid for and becomes much more expensive if not sorted correctly.

The requirements for waste management, which is included in all contracts has increased in the recent years. The biggest challenges of reusing construction material today are the organisation at the construction site. The economic benefits are most important and there needs to be certainty of how large volumes the excess material constitutes. Despite being easy to discard material in the containers, considering the money, energy and labour that is put in to produce the material, there should be alternative solutions for handling the excess material.

Potential of a Logistics terminal

The logistics for construction projects is the fundament for a successful construction. What goes into the project, e.g., material should have equal logistical preparation and activities as what comes out from the project. Crucial is the interest and engagement of the site manager, which otherwise lead to no change in how to manage the logistics. Every unique project is like a small company of its own, meaning, it is hard to push regulations and requirements to control the project from up the organisation.

Purchasing as a potential factor

The purchasing department has earlier worked according to the lowest price principal prior to the total cost principal. The total cost principal takes consideration to e.g., how deliveries of material are packed and how the material is organised with each other on pallets. This affects how the delivery to the site is made and the amount of material handling needed. Generally, construction materials like e.g., windows are all packed in one load which is most convenient for the suppliers. However, preferable would be to have materials being kitted after the specific location of assembly e.g., building, floor, room etc. This implies separating the material once at the site inducing large material handling costs. The material handling at site is often ineffective and implies making calls, finding the right owner of the material, arrange the right equipment e.g., pallet puller, forklifts etc. to move the material. Thus, the logistics is critical to avoid these unnecessary activities.

Possible future solutions

Left over material during the production or once the project is finalized often depends on miscalculations in the quantity or potential changes during the production. The terminal can be a solution, creating the opportunity of returning or selling back material to suppliers. This, since many of the agreements with suppliers today includes the option of returning and selling back material. The possibility of having a place for storing excess material and recovering materials is a valuable resource that are non-existent today. However, there should be clearly stated, who owns the material and what type of contract it comprises. Reusing excess construction material is morally right but also economically justifiable as it can be a further source of income.

4.8 Business Development Manager & Logistics development manager

This section includes the interview with the business development manager and logistics development manager in section 4.8.1 and the logistics manager for the terminal 4.8.2. The business development manager and the logistics manager for the terminal works at the rental company while the logistics development manager works at the construction company. All interviewees have prior experience of working with CCC solutions and is involved in the development of a logistics terminal solution. The interviewees address the current challenges and obstacles of logistics as well as reuse and recycling today but also the potential of a logistics terminal enabling reuse of construction material.

There has been a bigger focus on potential actions to decrease the environmental impact from the main contractor’s construction projects. One area that is now being explored, via conversation with the main contractor and their other subsidiaries, is how to implement a service for reuse of construction materials in combination with other logistical services and solutions.

Reusing filler material such as dirt and concrete is not unusual today and something that companies are quite good at but the same is not the case when it comes to classic construction materials and components such as windows, doors and joists. When evaluating a solution with reuse of construction materials, it is important to make a distinction of whether every material is of interest for reuse or only some materials, since there are so many kinds of materials. For the business of reusing materials as a service. one also must consider what the client needs and wants from a reuse service. Should it include all materials or only some?

Site managers or similar positions often have a storage site where they can keep materials from previous construction projects which might be good to have in the future. However, there is a financial cost of having a storage site and often the material stored there never come to use in other projects since one site manager only has connection with a few projects and often they cannot use the material. This makes the costs associated with the storage site unnecessary. If a consolidation centre was used, then it could supply a larger area with the possibility to reach more projects to both collect material from and supply with.

A trend that is growing within the construction industry is an increased focus on what the main contractor does with materials after the project is done. This is an area where more clients are putting pressure on contractors with environmental certifications that the client wants to live up to, putting demands on responsible waste management. This will most likely become a factor in procuring processes in the future. If a system for dealing with material waste and reusing and recycling materials in an effective way, is already in place, then there is a bigger chance to win procurements in the future.

The construction industry in general is not good at saving data and statistics to be able to learn from previous projects. The profit margins are often the only ones looked at and if the project reached the desired margins. Then the books are closed, and the next project is focused on.

Seldom are reflections made if things could be more efficient or done in a better way. Factors such as delays or material purchasing are not evaluated, factors that could lead to higher profit margins. This sort of data and statistics could be used to show possibly that some materials are purchased in too large of quantities and that there is a potential to save both materials and money. This may result in a change in behaviour throughout the construction industry when it comes to how purchasing departments in construction works.

To reuse construction materials must be sustainable from an economic point of view. There are essentially two cases from which points of views, economical sustainability must be achieved. One is the service provider, who must bear the costs for storage, inventory management, transportation and other associated costs. They must then charge the main contractor in this case an appropriate amount which covers their costs and adds a profit margin. This cost may not be too high for the other business case, which is the main contractor. The main contractor must see the value and make a profit by having the construction materials reused in the next project which must cover the costs of the extra service that is provided, instead of throwing the materials away. There must be a model that is economically sustainable from both points of view in order for the reuse solution to stay in practice, otherwise it might not be sustained, and reuse of construction materials might not be a viable solution. However, from the main contractor's perspective there might not be a requirement to make a profit with this solution. If the reuse solution can have an impact on procurement and allow the main contractor to take on more projects because they have this solution implemented, then it might be enough to break even economically. The environmental gains are allowed to cost a bit for the main contractor if it is made up for in other ways, such as giving an advantage in future procurements.

Today there is a digital system for booking transportation and planning deliveries and this system also contains a reuse function as well. This function would need to be connected to the main contractors purchasing department to enable them to check the reuse balance before ordering new materials. However, it is hard to know how valuable it would be for the purchasing department to order reused materials since there is not data on exactly how much materials are left over from projects or what kinds of materials that would be available.

4.8.1 Business Development Manager & Logistics development Manager

The terminal can reduce what is usually called the "last mile" of transport, being the last bit into the project, by up to 80% through group loading. Additionally, the group loading enables full trucks with material transport so that there are no half-empty trucks arriving at the site. The kitting-solution will also enable material deliveries to be placed at the right assembling point once the construction workers start their work shift. The intended terminal will also need some form of heating, weather protection and staffing in order to enable the intended services. One problem from the purchasing department side is the purchasing of many materials in bulk at once to get the price down. This can create problems with the storage capacity at the construction site while also causing damage due to e.g., movement but also rain and wind. The terminal solution will solve these issues by relieving the stress at the construction site. Additionally, the terminal making it possible to control all transport to the site will enable the use of a milk run, circulating between several projects picking up recycling bins. The milk run can either drive directly to the recycling centre or temporarily store the waste in the terminal area, whereupon the recycling managers come and pick it up. Thus, they do not have to drive into, e.g., an urban environment.

The implementation of reuse in construction is currently a complicated issue. There are, for example, legal problems if materials change owners. The conditions are uncertain regarding the general volume of excess material today, in particular reusable material. Smaller volumes of construction materials, which make up roughly 10-20% of the total, may be of little interest for use in other projects. The projects must then also be reasonably geographically close, which otherwise will not be environmentally beneficial, i.e., transporting smaller volumes of material over long distances. Then there are the economic issues, where the terminal will constitute a cost for e.g., inventory, transport, immediate storage, etc. As it has always been cheaper to dispose of the material in the projects, the price of reuse must not be too high, despite being more environmentally beneficial. One possible business model for the service is that the rental company takes over the material without any cost, providing the service of stockholding the material whereby the profit becomes what the reusable material is sold for. The main contractor will then make savings by not having to pay for the removal and transport of waste material to the recycling centre. However, in order to be profitable, the business model may need to be expanded to the private market.

To make a good business model, there needs to be clarity on the kind of material that is generally left-over during projects. There are two ways that material reuse would be relevant through a logistical terminal. One is that it is financially attractive for other projects to buy the reused material. The second is that the construction company sets requirements to always check the "second-hand market" prior to material purchase. However, this will require some kind of internal website for displaying the reused material. A further issue related to the logistics terminal is its location. The terminal must be fairly central as most large construction projects are adjacent to big cities like Gothenburg, Stockholm and Malmö. However, this also means that land prices are quite expensive, which puts a limit on how many square metres the terminal can be. This also means that there is a risk that the terminal will be full, necessitating a fast turnover rate for the materials.

There is constantly an incentive to minimize the cost. The rental company is dependent on the price model and will have to compete with the cost of the construction company having recycling centres managing the waste material instead. However, before the legislation requires it, which it will inevitably do, sooner or later, other economic incentives for circular production are needed. There has not been any closer consideration for outlining efficient waste management during the production phase. The main contractor wants, at the end of the project, “close the books”, and go on with the next project. The logistics terminal will imply a closer dialogue with the customer, while working more active and proactive from both sides. The digital system enables checking the balance for material available at the terminal. However, the terminal service provider must provide high customer service by actively point out and inform upon the need for material at the construction site. Also, reporting upon any remaining material at the terminal which will otherwise imply a cost due to storage. Other ongoing projects may need the material which been stored at the terminal. Thus, the terminal service provider must coordinate material supply for several projects at the same time.

The terminal must use a delivery planning system, enabling booking of transports. Using the delivery planning system implies that the transports must arrive at the planned times, enabling JIT deliveries. Also, there is a need for a checkpoint for checking the booked deliveries, making clear what the load contains, the volume and who the recipient is. Also, in extensive projects, there should be delivery planners employed in the project, who handle the entire dialogue and who in turn handle the collaboration with contractors. The delivery planner will control and follow up the different construction phases and make orders of material needed. It is assumed that all environmental alternatives and production methods will require more planning than traditional production methods but also improved coordination and closer communication with different parties.

There needs to be a connection to the purchasing department, meaning all purchasing initiates by checking the reuse balance before new material purchases. Further, the purchasing department may need assess the geographical location to see if it is environmentally and economically profitable to retrieve material from the terminal. Furthermore, the reused materials and the new purchase of materials needs to be consolidated at the terminal before arriving to the site. However, preferable would be to have just-in-time deliveries for larger materials being sent directly to the construction site.
The top priority for reuse of construction materials in the production will be dependent on the purchasing department. This may lead to the ultimate goal of not needing a logistics terminal for reuse in the first place. Today the purchasing department works with flat rates, adding 10-15 in waste percentage. By putting more effort into the planning of logistics and storage of material, these margins will decrease.

Currently, thinking in reuse paths is limited which generally occurs once the client requires it. However, the challenge lies in spending time in performing proper logistics planning which further will enable time savings during the execution of the project. Consequently, the issue of reuse will then become more of a natural part of the logistics, by trying to avoid waste material being collected at the site and instead can be utilized in another project. What makes it a challenge is the lack of data over what kind of reuse material it may be and what volumes it will consist of. If there would have been an average data over excess material that is reusable in the industry, the business case would have been much more secure by being able to calculate the overhead costs. Today there may be experienced exchange within the same working group in projects but there are unfortunately lack of experience exchange between construction projects. Thus, there is a need of gathering data from scratch, knowing, what is left over, in what quantities which may facilitate the purchasing departments work. It is only when the quantities of left-over material can be visualised using the terminal, as it can be considered a problem among others. It can then actually reduce these surplus purchases that are made, as the need will no longer exist. It also becomes clear what has been viable in the secondary market, i.e., which can be used in other projects, alternatively by turning to the private market or a combination of both.

4.8.2 Logistics Manager for the terminal

Logistics works different in every construction project, but a common problem is that construction materials are ordered in large volumes for large sections of the construction at the same time. The result of this is that a lot of materials are left lying around at the construction site. These materials get in the way on site and causes problems. Therefore, the terminal serves as favour for the construction sites in the close geographical proximity to the terminal. The advantage of using a terminal is that planning is made easier with the buffer of materials. Materials can be delivered according to a set schedule and set volumes with more accuracy due to the shorter distance between the construction site and the terminal compared to the supplier. If materials are needed urgently then a truck can make that delivery quicker than if it would travel from the supplier.

Today there is a gap between what purchasing does and what is the best logistical solution. Purchasing focuses on lowest price and an example of this is that materials are purchased so that shipping is included no matter what volume. This means that a large volume of materials will end up at the construction site at the same time which then has to be moved around on the construction site, maybe several times. The costs of moving materials on site are not something that is visible on any invoice, but it takes time from the construction workers to do what they are skilled at, which in the end costs more money than was saved from the free shipping. When considering reuse of materials, the purchasing department would be an important part since they would be involved with being able to see stock balance of reusable materials available at the terminal and making sure that accurate amounts are ordered to the construction site. The digital system that will support the process of reusing materials, such as keeping track of stock, will be available to the purchasing department but it also important that the right people can take part of the right information.

In the future a service will be provided that involves retrieving materials, keeping an inventory balance over materials and then reusing that material in a new construction project. To finance this service, a fee will be charged based on how much space the stored materials take up, if special equipment is needed to handle the material and possibly an insurance fee for more sensitive materials. The right personal is also required at the terminal, personal with the right knowledge and the right state of mind in order to deliver the correct material to the correct construction site. The long-term goal is to not use the terminal, but the terminal is a step on the way that is better than the current options. The terminal will feature several value adding activities such as heated storage, weather protection, consolidation of materials as well as the opportunity to plan deliveries for both materials and equipment combined. Specific labelling of products to track deliveries to specific parts of the construction site is also a future possibility with the terminal consolidating deliveries and labelling them according to specific construction phases. Deliveries will be optimized to fill up the trucks as much as possible to avoid unnecessary deliveries as well as trucks bringing back various equipment to the terminal to reduce the number of trips back and forth from the site to the terminal.

The biggest incentive to reuse materials today is the environmental aspect of it. The construction industry is one of the industries that has the most waste per produced item. Reduced amounts of waste and less use of materials will make construction cheaper. The construction industry is driven by financial aspects which is also an incentive to reduce waste and reuse materials. Additionally, environmental awareness and legal demands has made a big difference in reducing the amount of waste. Reuse of materials with the aid of a terminal solution is a future step and therefore there will be some trial and error in the beginning. One thing to figure out is what kind of materials are fit to reuse and also what amounts are profitable to reuse. At the start of the trial period, the terminal would focus on standard materials in order to figure out the working procedure until the operation is running smoothly and then the reuse function would have to be evaluated in order to see if it is worth keeping or if some things have to be done differently. In order to get site managers to first look towards what is available for reuse before ordering extra materials, communication and education about the reuse function of the terminal would be an important aspect. If the people on site are not aware of what is already available, then they are likely to order new materials that are already available at the terminal.

To ensure that the reusable material is of enough quality to be reused, the right competence, equipment and tools are required at the terminal in order to ensure supplier level quality of the materials. If materials are left over at the terminal with no one in the target organisation interested in the materials, then a possible solution would be to sell it to companies outside the target organisation as well as giving it away to municipality owned reuse companies. Since the project is in its infancy, a lot of configurations will be tried. One issue however is the question of ownership of the reusable material. A business model would have to be agreed on with the target organisation regarding ownership of the reusable materials in order to determine what can be done with the reusable materials if the target organisation is not interested in it.

The future business case for the terminal is for the owner to become the sole provider of services that are related to everything in the construction project except for the construction itself. Services such as rental of machinery and equipment will be part of the service provided and the reuse of materials through the terminal will also be such a service along with using the terminal for logistical solutions as well. The possibility to establish a logistics terminal with a reuse function are seen as most likely in the most populated regions in Sweden since a terminal need to have continues use and in these regions, there are enough construction projects to make the terminal viable.

5. Analysis

The analysis is structured into three sections to provide the answer to the research questions presented in this paper. The *first part* is an outlook on the current status of recycling of construction materials, the logistical configurations surrounding the construction site, and the waste management of construction materials today. Data from the empirical enquiry as well as theory and concepts from the theoretical framework are combined, compared and analysed in order to establish the flow model of today. The flow model originates from the construction site and takes into consideration the material-, information-, and economic flows in relation to the construction site within a logistical and recycling context.

The *second part* investigates the obstacles and challenges that stands in the way of reusing construction materials today. These challenges have been identified from the empirical enquiry and in combination with material from the theoretical framework. This is done in order to establish what additional flows are needed in the current flow model or changes to the current flow model that are required to resolve the challenges with reusing construction materials.

The *third part* combines the first and second part to present the future flow model to enable reuse of construction materials. This flow model originates from the logistics terminal and using primarily empirical data. Challenges and critical points of interest with the suggested model are also explained and discussed as well as the impact of the suggested solution for the involved actors.

5.1 Actors in the flow models

In the following section, the actors who are involved in the current- and future flow models are presented. All actors are the same in both flow models. Exempted from this is *construction consolidation centre. Part of the logistics service provider* which will be replaced by *Logistics Terminal. Part of the Rental company* in the future flow model. This will be described in section 5.4.

Construction site - part of the Construction company

The construction site represents the physical location in a temporary project that is carried out by the main contractor, the construction company in the study. The construction site is thus the designated place for which the production of the construction is taking place. Different flows of materials and resources necessitate either being delivered to or removed from the site on a regular basis during the construction process. In the context of logistics, the construction site encompasses the on-site logistics operations, such as material movement and storage, that support the production activities as the primary value-adding activities of construction workers. The construction site undergoes different construction phases, which alters the types of materials and equipment needed at the site.

Purchasing department - part of the Construction company

The purchasing department is responsible for procuring all initial materials and equipment that are needed during the production of the construction. The purchasing department chooses supplier targets through either framework agreements or project agreements. All necessary materials are quantified based on the construction documents and further sent to different suppliers.

Supplier

Suppliers are organisations that are contracted to provide and supply materials and equipment to the construction site. Suppliers can be contracted by either the main contractors or the subcontractors. In most cases, the supplying companies are fully responsible for the transportation of goods until delivery at the site.

Recycling centre - part of the Waste service company

The recycling centre in a construction context is generally contracted by the main contractor. The recycling centre is the destination for the for all disposal of waste from the site carried out by the waste service company. Different containers are placed at the construction site for the sorting of different types of waste categories. Furthermore, the containers are retrieved on request by the person in charge for further disposal at the recycling centre.

Reuse centre - part of the Reuse company

A reuse company is a business that reuse and sell different sorts of material to both private people and businesses. Lately, reuse companies have, in some regions of Sweden, established agreements with larger construction companies for taking care of excess construction material.

Construction Consolidation Centre - part of the Logistics service provider

Construction Consolidation Centres (CCC) are facilities that are intended for intermediate storage of construction goods and equipment. All supplies of materials are transported to the CCC, whereupon they are consolidated and further delivered to the site. The CCC works as a buffer system for material deliveries to the construction site by relieving storage capacity on-site. Through the utilisation of a CCC, value added activities can be provided such as consolidation of material, co-loading, tracking, labelling, kitting, etc. The service of using a CCC is currently not in the business area of the construction company or the rental company. The mentioning of a CCC in this section and in the current flow model is an example of a general service that could potentially be used in a construction project. This service would be procured from a logistics service provider as part of their business area.

5.2 Developing the current flow model

This section presents a brief description explaining the different actors who are incorporated into the flow models. Then the current flow model will be visualised with the related flows explained in Table 2. Finally, based on the empirical data, there will be a discussion of how the present flow model has been developed and functions. A critical approach towards the flow model is taken with support from the theoretical framework.

5.2.2 The Current Flow Model

Figure. 8 illustrates the current flow model for materials, information, and economic flows between different entities along the supply chain and on the construction site. As shown in Figure. 8, sporadic contractual arrangements between the main contractor and reuse companies may be established, implying a flow of reused material distribution to the reuse company. Also, a construction consolidation centre (CCC) may be utilized on some occasions, generally through a third-party logistics (TPL) service provider. Thus, as illustrated in figure 9, rearranging the flows between suppliers, the building site, and the CCC. The flow model in figure 9 uses the definition "CCC" since it is referring to a general case of using a consolidation centre. However. Figure 10 uses the definition "logistics terminal" as it is referring to the specific case that is studied in this paper.

In the current flow model, depicted in the purchasing department procures materials from the supplier. The supplier then notifies the construction site about material delivery and then the materials are delivered to the construction site. After the construction project is finished, leftover materials are most often thrown away into dumpsters that are then transported to the recycling centre. The removal of waste from the construction site to the recycling centre is a service that the construction company is paying for. In rare cases, leftover materials can be given away for free to a reuse company who then sells the materials to private individuals.

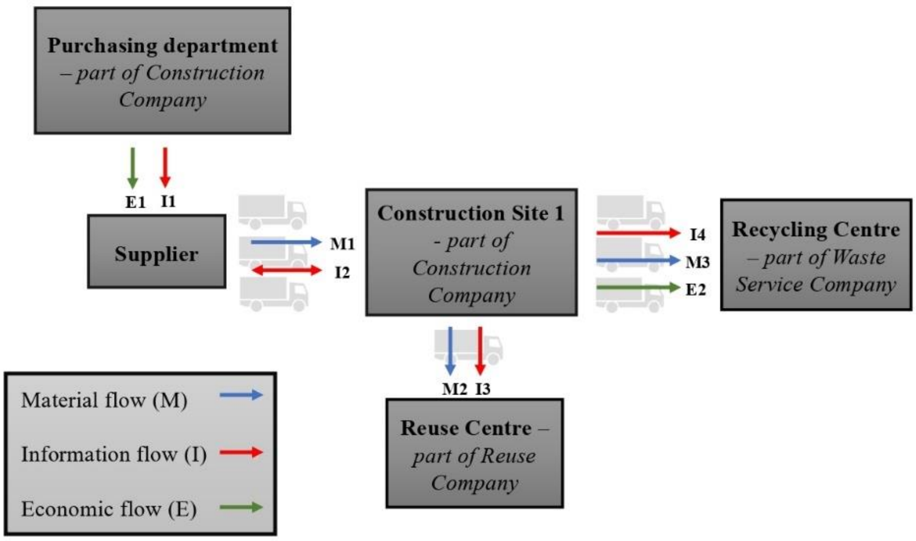

Figure 8: Current model of materials-, information-, and economic flows between different entities.

Table 2: Description of the flows in the current flow model

Current flow model	
M1	*The supplier delivers construction material to the construction site.*
M2	*A limited amount of reusable construction materials is sent to reuse companies free of charge.*
M3	*Recycling centres picks up waste material from the construction site.*
I1	*The purchasing department places orders on materials from different suppliers.*
I2	*The supplier notifies the person responsible at the construction site when materials are due and the person responsible call-off materials from the supplier.*
I3	*The responsible person notifies the reuse company regarding excess material which can be reused.*
I4	*The responsible person at site notifies the recycling centre once containers for waste materials needs to be emptied.*
E1	*The construction company purchases different materials from suppliers.*
E2	*The construction company purchases the service of waste management from the recycling company.*

In occasional projects, a specific logistical solution, a CCC, can be used to consolidate materials to avoid direct deliveries of materials to the construction site. This is not a service that is owned by either the construction company or the rental company, but a service that is purchased by another actor that provides this service. This could be for example a logistics service provider. In the flow model in figure 9, the specific flows that occurs when using a CCC is depicted. The supplier informs the CCC of pending materials and then deliver materials to the CCC instead of the construction site. The construction site then notifies the CCC when materials are needed and the materials are consequently delivered to the construction site. The remaining actors and flows that are depicted in figure 8 are still active when utilizing a CCC, such as purchasing, reuse company and recycling centre. For simplicity, only the flows that are added or changed when utilizing a CCC are depicted in figure 9.

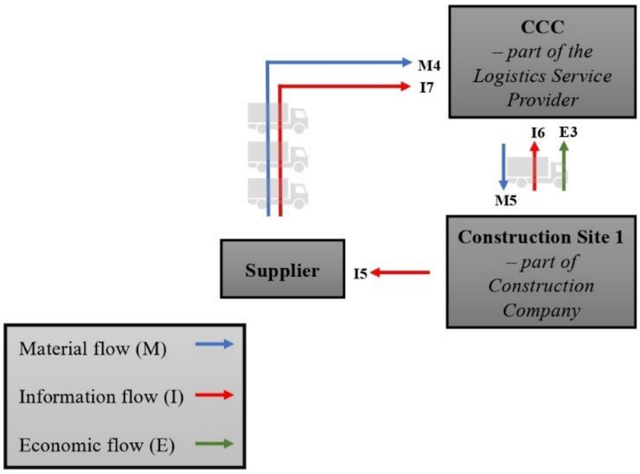

Figure 9: With a CCC: Current model of materials-, information-, and economic flows.

Table 3: Description of the flows in the current flow model incorporating a CCC.

Current flow model – Incorporating a CCC	
M4	*The supplier delivers construction materials to the CCC.*
M5	*The CCC delivers the requested materials to the construction site.*
I5	*The person responsible on the construction site call-off materials from the supplier.*
I6	*The person responsible on the construction site notifies the CCC that certain materials are needed.*
I7	*The supplier notifies the CCC when the material deliveries are due.*
E3	*The main contractor is paying for the service of using a CCC, which includes storing and consolidation of materials.*

5.2.3 Mapping the challenges of the current flow model

Purchasing of construction materials

There is consensus that each project is unique and situated in a specified region for which supplies of goods and the disposal of waste are required. Initiating any project requires a purchase order for several categories of supplies from various suppliers. All purchases of goods fall under the responsibility of the purchasing department [E1]. These goods are further distributed to the construction site by haulers [M1]. From the interview with the *purchasing manager*, it appeared that construction materials may be either procured trough framework agreements or project agreements [E1]. In general, the framework agreements control the acquisition of materials used in every project. The framework agreements imply a longer contractual relationship in which the agreed price of supply across several projects applies. In contrast, project agreements include a predetermined price negotiated with the supplier. The *purchasing manager* asserts that despite the importance of pricing, other parameters such as acquiring the correct and quality-assured material play a significant role when choosing suppliers. This argument is reinforced by Brenton & McHenry (2010), who, prior to the cost issue, emphasise the significance of factors such as suppliers' ensuring fast delivery, quality, customer service and locality.

Issues related to quantifying construction materials

Several interviewees addressed the issues related to the purchasing department in the quantifying process when acquiring construction material [I1]. The *purchasing manager* asserts that in addition to calculating the quantity of required construction materials, a spill percentage is added to accommodate for unexpected material damage and loss which may risk interrupting the production process. Additionally, the *purchasing manager* imply that the framework agreements generally entail annual sales discount i.e., a lower price is provided for larger quantities of purchased goods. In project agreements the negotiated price applies and may be adjusted based on the resources and labour contributions of both parties. Thus, the purchasing department is given flexibility to influence the price of purchased goods, both in the framework agreement and in project agreements to obtain better pricing levels. While this may be seen as beneficial from the purchasing departments point of view, this has induced various issues that is highlighted by several interviewees.

This is considered problematic especially when the topic of waste during production is raised. For instance, *logistician B* highlights the issue of purchasing, which is more applicable for generating economic gains by acquiring larger quantities of goods, which may include bulk discounts and free delivery. Thus, material becomes stored at the site, where it is exposed to the risk of being damaged, resulting in waste. Additionally, the storage-issue is highlighted by Agapiou et al. (1998), who imply that that the lack of consideration of different types of material e.g., the vulnerability to weather, delivery method and packaging etc. during purchasing will result in waste due to e.g., damage or loss. Similarly, the *logistics manager* highlights that the purchasing department, who prior to a total cost principal works according to "the lowest price principle". Thus, focusing on the direct cost of materials while ignoring how materials are packaged and organised on e.g., pallets once arriving to the site. Thus, affecting the delivery process and level of material handling required. The *logistics manage*r's argument is aligned with Wang & Wang's (2010) assertion, meaning that the cost issue depends on the focus on direct cost and neglection of the total cost. Thus, the purchasing department must consider the total cost by incorporating the associated costs of purchased goods to be profitable. Similarly, the *logistics manager of the terminal* highlights the discrepancy between how the purchasing department operates and what is logistically effective. Also, implying that the purchasing department focuses on the lowest price with conveniences of e.g., free shipping by suppliers.

Surplus of construction materials at the construction site

Furthermore, the *logistics manager* mean that the surplus of materials accumulated at construction sites may depend on miscalculations in the quantifying process or potential changes during the production. Additionally, this issue has made itself apparent for the recycling centre, were the *unit manager for recycling and reuse* asserts that materials that are left over during production are mostly gypsum boards and wood-based sheet materials. These materials count as bulk materials and will have detrimental effect if coming short during production, which explains the added spill percentage to cover for possible damages or loss. Further, the *unit manager for recycling and reuse* implies that the responsibility lies with the persons in charge of quantifying the different materials. A more experienced person may have better understanding of how much material may be needed during the project compared to an inexperienced person.

Looking further into the adverse effects of large quantity orders of materials on the construction site, which create problems in terms of storage capacity, this is highlighted by several interviewees. Usually, the person in charge at the construction site e.g., the supervisors, gets notified once suppliers are upon arrival to the construction site [I2]. Further, the supply of different construction goods is delivered to the site whereupon they are unloaded. According to the *purchasing manager,* the delivery of goods in terms of logistical specifications are generally agreed on a basic level. From the interview with the *purchasing manager*, it appeared that the fill rate of the lorries delivering the material to the site depends on the available space of the construction site. Thus, if there is enough space for storing construction goods, the lorries will usually arrive with full load, implying a lower price for the purchasing department. The economic profit made by the purchasing department by ordering, to what could be perceived as full storage capacity on-site, implies a backlash. This problem is raised by several interviewees, e.g., the *logistics manager of the terminal,* the *business development manager* and *logistician B* who asserts that a prominent logistical problem at construction sites is a result of materials being ordered in large volumes to supply large sections of the construction at once. As a result, materials are frequently left on the site awaiting assembly. Thus, deliveries of material should, as Sezer & Fredriksson (2021) asserted, continuously be coordinated with the ongoing production activities to avoid material being stored waiting to be assembled. According to Wang & Wang (2010), the cost of materials constitutes a large portion of the overall project cost. Thus, factors that are crucial for saving costs are the accuracy of the material quantity needed, waste elimination, minimising the consumption of material and material inventory on-site. In addition, Agapiou et al. (1998) infer that larger quantities of purchases of materials may result in waste during inventory, handling, and transport.

Lack of communication and feedback

The communication between the purchasing department and the construction site is currently lacking. Thus, meaning that feedback about every single purchase of excess material during production is not transferred further to the purchasing department. This issue is also raised by several interviewees who consider this a disadvantage in terms of information transfer and experience feedback between projects. This issue is e.g., raised by the *site manager* who means that there is currently no information feedback to subsequent projects in terms of the quantity of material ordered and wasted. At the same time, the *business development manager* meant that the exchange of experience is currently occurring within the same working group in projects, but as the *site manager* implied, lacking between projects. Also, the *purchasing manager* confirms this, saying that there is a lack of structured way in transferring experienced feedback back to the purchasing department for every single project. Consequently, the purchasing department is most likely unaware of the situation on-site in terms of excess material at the end of projects. Also, the *purchasing manager* mentions that there is generally a person from the purchasing department team which will work on-site, forming a team with the site manager and the supervisors. The purchaser has the responsibility of making call-off on additional material supplies if needed during the production which is conducted directly on the site. Furthermore, the purchaser will continuously gather inputs from the site manager and the supervisor. Here, the *purchasing manager* highlighted that it would be beneficial if the purchaser would receive feedback on excess material due to possible faults in the early quantifying process that could be reported back to the purchasing department team. Thus, despite having a person from the purchasing department team, there is a lack of information exchange between that person and the purchasing department or the site manager and supervisors, which would have valuable implication on future projects.

Materials handling at the construction site

Materials handling is another issue that has been brought up as a result of large amounts of materials being brought to the construction site at once, not considering how deliveries are packaged, delivered and organised. This may, according to the *logistic manager* and *logistician B*, directly affect the amount of material handling that is needed on site. The *logistics manager* means that the material handling is often conducted inefficiently due to lack of coordination on-site, thus resulting in an ineffective unloading process. Simultaneously, the *logistics manager* highlights that the large volumes of materials that ends up at the site implies significant costs due to the need of material handling. Material handling, which is often performed several times on site, is generally handled by construction workers, which means interference in production. According to *logistician B*, the cost of material handling is another factor that is overlooked when considering the total material cost. Thus, the associated material costs i.e., material handling may be far more expensive than having free delivery when ordering large quantities. Referring to the three models explained by Dubois et al. (2019), this structure of managing logistics is currently a correspondence to the decentralised coordinated configuration. The decentralised coordinated configuration implies a disjoint configuration and is the most common today, necessitating considerable material handling by construction workers.

Waste management

In theory, the topic of waste management has been raised as currently being insufficient. Generally, the waste management, mainly disposal of waste from the site are managed by recycling centres. According to the *site manager*, the main contractor generally stands for all cost related to waste management for which is contracted with the recycling centre providing containers [E2]. Further, the main contractor-team having an agreement with the recycling centre has the responsibility of demanding emptying of the containers. Usually, one of the supervisors has an overview of the containers, whereupon they reserve the emptying of containers once full [I4] and the recycling centre comes and picks them up [M3]. What has appeared as most common by the respondents but also from the theory is that the largest quantity of unused material during production is wasted and further disposed of at landfills. In terms of returning material back to the suppliers, meaning avoiding materials ending up being disposed of, the terms of contract are generally clearer about this in framework agreements compared to project agreements. This was emphasised by the *site manager*, who indicated that unused supplies may be returned to the suppliers for monetary reimbursement provided that they are unpacked and in good condition. However, goods with opened packaging cannot be returned and are instead discarded. However, the *purchasing manager* meant that despite the possibility of returning materials in framework agreements this is most of the times not utilized. The material is generally disposed of and only economically compensated, being unprofitable for the suppling company to take back the material. This shows that unusable material is seen as an extra expense owing to the need for its management, transportation, and disposal. Due to the costs of handling and shipping, unused supplies whose packaging has solely been opened are nevertheless wasted. This indicates an inefficient and expensive strategy for managing excess materials during production. Similarly, the *logistics manager* implied that at the end of a project, any leftover materials are dumped immediately into waste containers without further consideration. The *logistics manager* further indicates that leftover material always incurs extra costs and, if intended for reuse, is invariably broken or obsolete. Additionally, Teo & Loosemore (2001), highlighted that the contemporary waste management method of disposing waste in landfills are the most cost-effective solution. This indicates that there are presently insufficient methods for conserving and storing materials. The *business development manager* explains this as there currently has not been further deliberation on efficient waste management during the production phase. Thus, the project team, once finishing the project, intends to “close the book" and move on with the next project. This again can be explained as a result of projects being unique and temporary and as Lindén & Josephson (2013) noted, implies a constantly new set of supply chain actors.

Statistics of waste

From what has been reported by some of the respondents, there are currently measures for monitoring and reporting the quantity of waste in the projects. However, it appears that where the collected data goes and what is done with it is uncertain. This stands in line with the assertion from the *business development manager* who means that the industry as a whole is ignorant in terms of saving data and statistics from projects. Today, the only method for documenting the waste disposed of in containers was according to the respondents by weighing it. According to the *site manager*, the waste is sorted in different waste containers whereupon they are weighted and registered in the waste statistics. According to the *purchasing manager*, the invoice of the waste collected by the recycling centre is based on the weight and transportation. According to the *purchasing manager* and *site manager*, the weight of the waste is a crucial parameter which is continuously reported in the waste statistics. However, the waste statistic is only applicable for material categories such as e.g., gypsum, plastic, packaging, wood etc. The *purchasing manager* means that many of the containers such as combustible waste and even containers for wood waste are uniform composition of different materials. Thus, it increases the complexity of distinguishing different material categories and therefore there are no annual follow-up reports on materials disposed of in the projects. Additionally, the waste containers that are kept at the construction site can let rainwater into the vessels, which can cause the measured weight to be miscalculated in the annual waste reports.

Requirements on waste management

It has become clear that the requirements for implementing measures to reduce waste in landfills are primarily motivated by economic reasons. The *purchasing manager* means that, besides having one person in charge of the statistics of waste, there is also an annual occasion where the environmental data is aggregated upward in the organisation. Further, there have been internal requirements within the main contractor company that have put up goals for minimising the amount of waste that is disposed of. Thus, reducing the weight of the waste in containers is part of the objective to bring down the cost of waste management, managed by the recycling companies. This, despite the absence of any formal requirements today. At the same time, the *site manager* means that the waste statistics are used to evaluate the number of needed containers in the projects. This shows that environmental reasons for effective waste management are not as prioritised compared to economic factors. This is once again in line with the statement of the *business development manager*, who means that as long as the profit margins are reached, no further considerations are taken, and the construction team proceeds with the next project. Thus, there is no further reflection and consideration of whether the project could have been conducted more efficiently. However, although no radical environmental measures have been taken to implement environmental principles for efficient waste management, material recycling has become more in focus in recent years. The *site manager* and the *logistics manager* have seen a positive trend in improved recycling, which has been evident from the waste statistics. Both respondents highlighted the service of waste management implying reduced costs if the sorting of material is executed properly, meaning it becomes cheaper to recycle. According to the *site manager*, there is currently a movement toward the reuse of materials due to an increased emphasis on the environment. However, the *business development manager* emphasised that, in construction, thinking along a reuse path is still in its infancy. The *purchasing manager* meant that despite discarding of excess material being the fastest and cheapest method, the view towards the environment has changed due to the internal requirements of decreasing overall carbon dioxide emissions. Moreover, some of the respondents highlighted the increase in requirements from the client side. According to the *site manager*, certain projects have more stringent requirements for recycling and reuse because of obtaining environmental certification being part of the clients demands. However, the *purchasing manager* meant that being on the cutting edge of working under environmental conditions could give a business an edge over its competitors. This argument is aligned with the statement of Pero et al. (2017), stating that actions towards reducing the environmental impact may engender competitive advantages, a "green image," and a good reputation.

Agreements with reuse companies

The main contractor company has currently, like several other major construction companies, entered into an agreement with a reuse company that receives surplus of reusable building materials during and at the end of projects. The material is either transported to or retrieved by the reuse company [M2]. According to the *unit manager of recycling and reuse*, the responsible person at the construction site contacts the reuse company at the end of projects to hand over the surplus of material [I3]. The reuse company then receives the material based on what they consider to be reusable and what is in good condition. The material is received for free, whereupon it is sold to private individuals and smaller construction companies. However, despite the potential of reusing material prior to discarding it, the *purchasing manager* states that this is project-specific and occurs sporadically among projects. Moreover, *logistician B* points out that the reuse company solely accepts a limited quantity and kind of material categories but also materials that are intact. The reuse company only being interested in certain types of material is also highlighted by the *business development manager* as a current problem. The reason for only accepting a certain type and quantity of materials is, according to the *unit manager of recycling and reuse*, because of limited storage space but also the demand from the customers.

Incorporating a CCC

Today, construction consolidation centres (CCC) have been utilized occasionally in projects that have had it as a requirement. Generally, according to *logistician A*, a CCC is utilized in conjunction of appointing a third-party logistics (TPL) service. However, the *purchasing manager* means that there is currently no requirement of appointing a third-party logistics provider. Depending on the size and complexity of projects, an external logistics manager can be appointed managing and coordinating logistics activities [E3]. According to *logistician A*, the CCC Is generally located proximity to the construction site which enables more efficient deliveries during times that doesn't interfere with the production on site. Implementing a CCC implies that the majority of construction goods from suppliers are delivered directly to the CCC [M4]. Generally, the supplier notifies the CCC about the upcoming deliveries [I7]. The material entering the CCC is further consolidated before being delivered to the construction site according the just-in-time (JIT) principle [M5]. As described by Pheng & Hui (1999), the JIT-principle allows for utilizing the space of storage on construction sites optimally. According to the *purchasing manager,* it is not uncommon that not sufficient materials come to the construction site. There is one responsible person, generally the site manager or the supervisors who call-off material from the suppliers in cases where materials are insufficient [I5]. However, the materials that are stored at the construction site are delivered in sequences to maintain a time buffer. When the material is needed, the responsible person, which may be the site manager, supervisors or a subcontractor notifies the CCC for delivery [I6].

5.3 Current challenges and obstacles for reusing construction materials and suggested solutions

The following chapter will present the main challenges and obstacles for reusing construction materials that were identified in the empirical part and the literature study. These will be discussed and suggested solutions for the obstacles will also be presented. This chapter is divided into three parts with the first part discussing challenges with material flows, the second part discussed challenges with information flows and the third part discussing challenges with economic flows.

5.3.1 Challenges with material flows

Material damage

Some challenges that stands in the way of reusing construction materials has been identified. As brought up by the *purchasing manager*, the materials used in construction needs to be up to a certain standard to pass inspection. This makes it difficult to reuse materials since there is a bigger uncertainty when it comes to inspection if the materials used has some sort of damage to it. The implication here is that reused materials more often has damages to them because of the materials being transported and handled more times than new materials. The *site manager* also brings up the point of damages to materials and states that materials that are sensitive to weather are not suitable for reuse with the implication that materials are often exposed to different weather conditions on site. Linden & Josephsson (2013) agree with the point that materials on site often suffer damages from both weather conditions and handling by construction workers. The cause of this, according to the authors, is the lack of storage space on site. This leads to multiple movements of materials as the construction phase progresses as well as construction materials being left on site without weather protection. Based on the responses from the *purchasing manager* and the *site manager* we can conclude that once materials arrive on site, the material quality starts to deteriorate which greatly reduces the possibility to reuse the same material in another project because the material still needs to be up to a certain standard in the new project.

This rases the question of why try and reuse materials that are sensitive to damages from handling and weather? There seems to be differing views of this question in the empirical data with the *site manager* saying that sensitive materials should not be reused. Others, such as *logistician A* says that standard materials that are in good conditions should be easiest to reuse. Standard materials are materials such as gypsum boards and wooden joists that are bought in bulk and almost every project uses them, hence the name standard materials. The standard materials are however, sensitive to damages from weather and handling, so there is not a complete consensus on what materials should be reused. As stated by the *logistics manager for the terminal*, there will have to be a process of trial and error in order to find out what materials are most suitable for reuse. However, if there is a process of trial and error, even though bulk materials will not be reused in the end, the challenge of preserving materials from damages still needs to be addressed and solved in order to optimize the reuse process.

Potential of utilizing a CCC

As stated earlier, the lack of space on site is a factor when it comes to damage occurring to construction materials. To solve this problem, Moussaoui et al. (2021) suggest delivering materials just-in-time (JIT) to the construction site which would remove the need to store materials on site. Delivering JIT is a desirable concept but not easily executed as described by *logistician A*, who describes suppliers that are far from the site as hard to plan for and more unreliable. Utilizing a CCC for consolidating materials from different suppliers and then delivering them to the construction site would allow for easier planning and more control over deliveries according to *logistician A*. The *business development manager* also suggests utilizing a milk run to transport waste from several construction sites to the CCC for consolidation and final transport to the recycling centre. A CCC would also allow for delivery of materials JIT to the construction site as explained by Moussaoui et al. (2021). If materials were delivered from different suppliers to the CCC then the CCC would work as a buffer for materials and substituting the storage on site. Enabling materials to be delivered on shorter notice but more often, will remove the need to store large quantities of materials on site since the CCC will be the storage instead. The *logistics manager for the terminal* agrees with the statement from *logistician A* about larger control of deliveries and describes the advantages as deliveries can be made "according to a set schedule and set volumes with more accuracy due to shorter distance between the construction site and the terminal compared to the supplier" (*logistics manager for the terminal)*. The solution of using a CCC will therefore remove the risk of damages to the materials from several handlings by construction workers, delivering materials only when needed so that there is adequate space close to where the installation is happening. Thus, removing the need to move the materials several times, because of the materials being in the way of other things, before being installed. The principle of using a CCC as a buffer storage can be seen in the example of SRS as showcased by Janne & Fredriksson (2021). In the SRS project, the buffer function of the CCC was seen as a big positive by many of the project managers as it allowed for materials to be delivered to the different construction sites when needed. The issue of protecting materials from weather damages can also be resolved through a CCC. Although not expressed explicitly by most of the interviewees, a CCC is implied to have some sort of protection against the weather such as a roof. Described by *logistician B* when mentioning previous projects, the CCC used had heating which allowed for storage of certain materials. A CCC with heating implies that there was a solid weather protection, such as a confined building, which allowed for the area of the building to be heated. Heating and weather protection as a part of a CCC is also mentioned by the *business development manager* when describing the services provided by the suggested logistical terminal. If a CCC can offer protection from weather, then it allows for more sensitive materials, such as gypsum boards and wooden joists, to be stored and kept from being damaged by weather. Thus, increasing the chance of being able to reuse those materials as the issue of sensitive materials not being suitable for reuse, will be solved.

Suggested flows

As previously discussed, using a CCC will reduce the risk of materials taking damage due to multiple handlings as well as offer protection from unfavourable weather conditions. This will resolve one issue mentioned by the interviewees as an obstacle for reusing construction materials. To reflect the solution to this problem in a flow model a permanent and specific type of CCC, named as a (Logistics Terminal), will need to be added as a function in the model. A material flow picturing the materials being delivered from the supplier to the logistical terminal will also be added and named as [M7]. As a direct consequence, an information flow illustrating suppliers notifying the logistics terminal of deliveries is added with [I11]. Since the construction materials are now being delivered to the construction site according to JIT after storage at the logistics terminal, this will require a visual representation in the form of a material flow named [M6]. [M6] will also represent the material flow of the waste being transported to the logistics terminal with the use of a milk run. Information on when material is available at the logistics terminal as well as when the construction site needs it, is a prerequisite for the material flow to be possible. Therefore, an information flow [I8] will depict the flow of information between the two actors. To adapt the solution of waste consolidation through the logistics terminal a material flow [M10] is introduced to illustrate the waste being consolidated and transported to the recycling centre. Information flow [I14] shows the communication required for the waste to be picked up from the logistics Terminal.

5.3.2 Challenges with information flows

Uncertainty revolving type and quantity of reusable materials

After implementing a CCC, the hurdles of reusing construction materials are not solved, there are other issues that was brought up by the interviewees that obstructs the process of reusing construction materials. One of these issues is the challenge of creating and distributing the correct information about what is available for reuse to the correct actors. The *site manager* says that “the problem with storing reused materials is that it is hard to keep track of what is in store” (*site manager*) while referring to storing reused materials if there was such as solution that materials could be reused. If there is no way to provide the information about what is available for reuse to other actors, then the materials will be thrown away after a while since no one knows where they are according to the *site manager*. *Logistician A* also raises this problem, saying that often no one knows what materials are left over, how much and on what construction site the materials are situated at. If materials were to be delivered to construction projects through the logistics terminal, as suggested in the previous paragraph, then the left-over materials would already be stored at the terminal at the end of the project. This would at least resolve the issue of having reusable materials left at several different construction sites where no one would be able to use them as mentioned by *logistician A*. However, if the reusable materials are stored at the logistics terminal, then the problem of spreading the information about what materials are available for reuse at the terminal to other actors that could potentially use that material, remains.

Using a logistics terminal in the way suggested by this paper, corresponds with the supply network coordinated configuration explained by Dubois et al. (2019), in which the logistics specialist is in charge of planning and coordinating logistics activities. Through the definition of construction logistics from Usman and Ibrahim (2015), we can see that coordinating information associated with materials is within the realm of construction logistics. Thus, the logistics specialist, in our case, the actor in charge of the logistics terminal, would be responsible for providing and distributing the information about what materials as well as reusable materials that are available. As established, there is a need to spread information about what is available for reuse, and it is reasonable for the actor in charge of the logistics terminal to be responsible for the distribution of that information since the reusable materials are stored at the terminal. This creates two questions, what information needs to be distributed and how should it be distributed?

Logistician A says that in order to enable reuse of materials then it is important to know what kind and what quantity of materials are left after a project ends. If we look at an example from current reuse of materials in the case of the municipality owned reuse station, we see similar information. From the answers provided by *the unit manager of recycling and reuse* we can tell that they receive information from construction companies on how much materials are left and of what quality the materials are. In combination with the experience of what materials are most sought after, so that the reuse station does not keep materials for too long, the reuse station makes a decision on whether to accept the provided materials or deny them. This example shows that the three pieces of information that are needed from potentially reusable materials are quantity, quality and type. This example is aligned with the perception of *logistician A*, with the addition of the quality factor that also needs to be considered. The question of quality has been discussed in chapter 5.3.1 so the additional information pieces of quantity and type are the ones that are left to be dealt with.

What type of material and in which quantities are reusable has been questionable and the empirical study has not given a conclusive answer as discussed previously. However, in this section we are only focusing on the problems of distributing that information and what solution could be necessary instead of determining what type and what quantities of materials are suitable for reuse.

Creating information

Logistician A points out that a common problem, making tracking materials that goes through a CCC difficult, is insufficient labelling and lack of knowledge within construction among the people working at the CCC. The issue with labelling, according to *logistician A*, is that different suppliers use different labels with different information. The labels are fitted according to the suppliers' own systems so that it is easy for the supplier to track the shipment of materials. However, this does not translate well, especially when the people handling the materials at the CCC do not have sufficient knowledge about construction materials to distinguish what is what and is forced to rely on labels that are very different from each other. This makes it apparent that combining different labelling with lack of knowledge among staff makes it hard to track material deliveries. When considering that information about reusable materials needs to be distributed in an efficient manner then difficulty keeping track of what pallet contains what type of material and in what quantity is a substantial issue. In the project where *logistician B* transported unused material back to a CCC, a delivery note was required with information about the type, quantity and changes made to the material on site, before being delivered to the CCC. This would create a uniform system of information to make the processing and distribution of that information easier. However, in the case suggested in this paper, the material would already be at the terminal which would mean that all the materials that were available for reuse at the terminal would have to be relabelled at the logistics terminal. This again raises the issue of the knowledge of the personnel working at the terminal, who would be responsible for labelling the materials. Therefore, the personnel working at the logistics terminal needs to be knowledgeable within construction or get that training for them to perform the job at the terminal to a reasonable level. The *logistics manager for the terminal,* also addresses this as an important factor, saying that the right personnel with the right knowledge is necessary to run the logistics terminal. If personnel with knowledge of construction materials can relabel materials, that are left at the logistics terminal, with information about what quantity and type of material that are available, then a foundation for a uniform system enabling tracking of reusable materials can be laid. If construction material specialists can relabel materials left at the logistics terminal with information on the quantity and type of materials available, a basis for a uniform system for tracking reusable materials may be created.

Distributing information through a digital system

In order to create a functioning system of information, a way to the distribute the information is necessary. The *site manager* emphasises that if one construction project is to make use of materials from another project, then the flow of information back and forth from where the materials are stored to the next project, needs to be fast. This is to make sure that the project who wants to use the reused materials gets them in time for when they need to be installed. As suggested by the *logistics manager for the terminal* and theorised by *logistician A*, some sort of digital system that allows for information about reusable materials to be distributed would be the optimal solution. Dubois et al. (2019) suggest that the interface between on-site logistics and the supply chain needs an information system in order to schedule deliveries. A system with that function is something that already exists and is in operation as explained by the *business development manager*. The optimal solution would be to implement the functions suggested by the interviewees in the already existing system because then the system would not have to be built up from scratch. The delivery plan function is something that several of the interviewees has viewed as necessary and by implementing the reuse function in the same system, the delivery planner would already be there. The available material will also need to be made visible as suggested by the *logistics manager* and the *business development manager*. Preferrable would be some type of internal and external marketplace. If the materials are not made visible there, then the problem of not knowing what materials are available would still exist. The external market is suggested to be used for materials that are not of interest for reuse because of various reason but are still in good condition. One suggestion is to have the external market available for reuse stations whose, as explained by the *unit manager of recycling and reuse*, target clientele is private individuals. They might be interested in materials that are not suited for big construction projects but more fitted to private renovations. If materials were available on an external website, then the reuse station could more easily find those materials instead of the traditional way of a limited number of site managers communicating to the reuse station that they have materials left over. The internal market is suggested to target individuals that are interested in reuse materials within the main contractor's organisation. The primary target are site managers within the geographical vicinity of the logistics terminal that needs complementary materials. By using a digital marketplace, the issue that the *site manager* brought up regarding fast information flow, is resolved. Materials can be made visible on the internal marketplace with information such as pictures, quantity, type, enabling site managers to look at the internal marketplace and call off those materials from the logistics terminal.

Accessing information through the digital system

As suggested by the *business development manager & logistics development manager* the internal marketplace should be made available for the purchasing department as well. This is to enable the purchasing department to check the reuse availability of certain materials before they order completely new materials for a project. However, the *purchasing manager* does not think that the reuse function of a logistical terminal will affect the purchasing department. It is more likely to affect site managers and the smaller amounts of materials that are ordering through call-offs and not the large volumes that the purchasing department is responsible for through framework agreements and project agreements. The *purchasing manager* also states that it is crucial that the purchasing process of new materials and reused materials is smooth and transportation of the two is coordinated. This is likely to avoid unnecessary transports with multiple deliveries arriving at the construction site without full trucks which is in accordance with Wang & Wang (2010), pointing out that procuring needs to take into consideration transportation costs in addition to material costs. Using a logistics terminal would aid this coordination by consolidating both new and reused material transports and delivering with one transport to the construction site. This example shows that it is still important for the purchasing department to have access to the information about what is available for reuse. Even though the larger amounts of material might not be available for reuse, a reasonable amount might still be available and easily consolidated with the new materials. Considering that the most likely and essential application of the digital system for viewing and using reusable materials, is for the site manager to make call offs for complementary materials. The *site manager* comments on changes that are made in the construction industry and says that there is often some resistance since it involves additional work. *Logistician A* also comments on the fact that it needs to be very easy to use a new solution otherwise it simply will not be used due to the initial resistance to doing something new. Creating a simple interface which allows the site manager to easily call-off reused materials and providing important information about the materials, is therefore crucial for the solution to be implemented. As suggested by *logistician A*, it would be preferable if the site manager could use their phone to place the order for reused materials, as within e-commerce, since site managers are often moving around on the construction site and do not always have access to a computer.

The problem, raised by several interviewees, of creating and distributing information about what is available for reuse creates a two-part solution that both needs to be implemented and function correctly to solve the problem at hand. The first is addressing the creation of information which can be aided by having personnel that are knowledgeable within construction material that can label pallets of material at the logistics terminal with the correct information. The correct information includes quantity of material, type of material and additionally pictures to improve the conveying of information. The second is the distribution of said information which ideally would be transferred to a digital system to allow for fast transmission of information. The digital system would be built on top of the already functioning delivery planning system and would add functions such as an internal and external marketplace from which involved actors could collect information. Involved actors would be site managers, who could place orders from the logistics terminal through their phone, purchasing department, who could track inventory, and external actors who could reuse unwanted materials.

Suggested flows

To reflect the suggested solutions in a flow model, an information flow depicting projects gathering information about reusable materials from the logistics terminal is added and named [I12]. The reused materials are delivered to the construction site after ordering them from the logistics centre which creates a material flow [M8]. With regards to actors such as reuses companies checking the external marketplace, an information flow is added and named [I13]. If such materials are delivered to the reuse company. It creates a material flow [M9]. The possible use of the digital system allowing the purchasing department to see what is available for reuse, creates an information flow [I9]. Within the [I9] flow, there is also communication from the purchasing department to the logistics centre about what materials have been purchased for the project which allows for delivery planning and scheduling for the logistics centre. As discussed, this planning can also take place within the suggested digital system.

5.3.3 Challenges with economic flows

Attitude towards reusing materials through a logistics terminal

When combining the previous suggested solutions, a reasonable system for reusing construction materials has been established and several factors has been taken into account. However, there is one factor that is missing from the discussion which has a major implication on the reuse system. That factor is the financial sustainability and profitability of implementing the suggested solution. Current practises make it both easier and cheaper to discard excess materials according to the *purchasing manager* and continues with statements saying that there is no guarantee that reusing materials will be economically beneficial. The *unit manager of recycling and reuse* also hypothesize that there is no economic incentive for the main contractor to adopt a reuse solution since there are profit margins to be made in buying new materials. Using a logistics centre is an expensive solution that is hard to justify, and the current practise of recycling is relatively very cheap if it is done correct according to the *site manager*. What can be interpreted from this is that the roles interviewed that have no experience working with logistics and have no connection to the case of the logistics centre have many concerns about the profitability of implementing a logistics centre with a reuse solution. The same concerns are put forth by other interviewees as well but with a more positive spin on them. *Logistician A* recognises that a logistics centre is seen as an expensive solution but continues with saying that there is money to be made if planning for logistics is made correctly. Continuing, *logistician A,* also recognises that there might be resistance for reusing materials considering the costs but states that not only cost should be of concern. The *logistics manager* raises the point that actors, especially site managers, might not realise the financial advantages of using a logistics centre and the potential of reusing materials.

Potential economic benefits from using a logistics terminal

Considering the money spent on materials, there should be an alternative to only throwing it away says the *logistics manager*, while also admitting that the most cost-efficient way of taking care of unused materials is throwing it away. If data and statistics for costs related to transportation, storage and handling of materials were more easily available, then it would be easy to illustrate the costs that can be saved using a logistics centre and implementing a reuse solution according to *logistician B*. What we can see is that there are mixed opinions between different roles about the profitability of adopting a reuse solution. Although most of the interviewees recognise that there are costs associated with using a logistics centre and a reuse solution, the potential savings created from that solution is debated. As seen by Dubois et al. (2019), there are potential economic benefits of making construction logistics more efficient. By making transportation more efficient through logistical planning, overall project costs can decrease by 20 per cent according to Sezer & Fredriksson (2021). Logistics costs for materials account for a significant portion of purchasing costs which shows potential savings if construction logistics could be made more efficient. These are the benefits that some of the interviewees have seen and the reason why they believe there are potential economic benefits to using a logistics centre and those ideas are supported by the theoretical framework. The reason some of the interviewees that did not see these economic benefits could be their lack of experience in working with construction logistics. The *logistics manager* expresses that logistics lag behind in production which often depends on the uncertainty of implementing something new which discourages from putting focus on logistical solutions. Even though there is uncertainty from some groups of actors when it comes to using logistical solutions, such as a logistics centre, there are studies that show that potential economic benefits of using such solutions as well as actors who realize those same benefits.

Economic uncertainty when reusing construction material

However, when it comes to adopting a reuse solution of construction materials, there is a bigger uncertainty among almost all of the interviewees. There are several uncertain factors identified that makes the profitability of a reuse function within the logistics centre a matter of speculation. One factor that is brought up by the *logistics manager for the terminal* is the question of what material types are reasonable to reuse and what amount of those materials would be profitable. What material types is an uncertainty factor that has been continually brought up throughout the research. As discussed previously, none of the interviewees are quite certain about what material types would be best to reuse although there are some suggestions. Because of the relatively new topic of research, there is limited theoretical arguments for why any particular construction material would be beneficial to reuse from an economic viewpoint. The number of materials available for reuse also creates uncertainty. According to the *business development manager*, the general volume of excess materials is uncertain and especially for reusable materials. Smaller amounts of reusable materials might not be of interest for construction projects which would limit the use of the reuse function. Additionally, if not enough materials are reused then it is hard to justify the added costs for supporting the reuse solution. The mentioned factors affect the profitability of the reuse solution and profitability is an important and deciding factor as stated by the *business development manager & logistics* *development manager*. Even though the profitability of the reuse solution is outside the scope of this research, it is crucial to recognize its importance and to illustrate the economic flow for the logistics centre with the reuse solution, a possible business case must be discussed and established in order to depict the economic flow between actors.

Two potential business models

As realised by the *business development manager,* there are two actors to consider when discussing the idea of implementing a logistics centre with a reuse solution, the customer and the service provider. In this case, the customer is the main contractor who purchases a service from the service provider, which is the rental company. The rental company already provides services such as rental of machinery and equipment according to the *logistics manager of the terminal,* wanting to expand their service to include handling the construction logistics for the main contractor. In addition to construction logistics, providing a reuse solution is a desired service to include in the offering of services from the rental company. Considering the answers of the interviewees who are involved in the case of the logistics terminal, the logistics terminal will be owned and operated by the rental company. This means that the rental company absorb the costs for the facility, personnel, facility management and digital systems that are connected to the logistics centre. The main contractor pays a price for the provided services that, according to the *business development manager & logistics development manager,* covers all the costs and also provides a profit margin for the rental company. The question is then, what value does this solution bring the main contractor in order to cover the cost of the service? The answer seems to lie in the ownership of material where there are two scenarios.

The *business development manager* says that one possible model is that the rental company takes ownership of the reusable materials from the main contractor for free. The main contractor will make up for the cost of the service by not having to pay for removal and transport of the material. The rental company will make a profit by charging for the service and selling the material to the next construction site, however, to be profitable the rental company might need to reach out to the private market. The problem with this configuration is that there are legal issues with a main contractor selling materials, as pointed out by the *business development manager*. This means that the main contractor selling the material to the rental company is not a viable idea. The second scenario is that the rental company only holds the reusable materials for storage and, as suggested by the *logistics manager for the terminal,* the rental company charges rent from each project based on how much materials are stored there. The main contractor therefore has an economic incentive to use the reused materials in another project and will save costs from not having to order as much material in the other projects. This model would avoid the legal issues of the main contractor selling materials as well as the rental company not having to rely on the public to make a profit. The rental company will have to avoid charging too high of a price for rent and their services, otherwise it might make no financial sense from the perspective of the main contractor to use the service instead of throwing materials away. As stated by the *business development manager & logistics development manager,* there must be a model that is economically sustainable from the perspective of both parties. Even though there are environmental gains from reusing materials for the main contractor, there must be some economic sensibility. If a zero-sum game can be achieved, then that would be the ideal scenario according to the *purchasing manager*, because then the environmental advantages would be enough to make up for the fact that no economic profit would be gained from the reuse solution.

Suggested flows

However, to calculate if the suggested reuse solution could achieve a zero-sum game is hard to tell with the uncertainty that exists within the different factors previously discussed. Based on the empirical data gathered and the reasons discussed, the business model where the rental company holds the reused materials for storage seems the most reasonable for both actors to achieve as sustainable business model. To illustrate this service being provided and the economic flow that results from the purchase of such a service, an economic flow [E4] is added to the suggested flow model.

5.4 Suggested future flow model

Combining the current flow model with the suggested flows discussed in 5.3, result in the suggested future flow model presented below in Figure 10. Some flows remain the same as in the current flow model. These flows will not be discussed further for that reason.

There is one new actor introduced in this chapter that was not used in Figure 8 or 9. As explained in 5.3.1, the suggested flow model includes a Logistics Terminal that removes the need for a temporary solution such as a CCC. The new actor in the flow model is presented below.

Logistics Terminal. Part of the Rental company

The Logistics Terminal is the planned logistical solution between the construction company and the rental company. This entail a terminal that will be able to consolidate construction materials and provide the same value adding activities as a CCC would. CCC is the general term for this sort of logistical solution, and it is temporarily used by construction companies during the construction of one project and it is not used in every project but used and procured sporadically. This is different from the Logistics Terminal that will fulfil the same purpose however, it will be a permanent solution owned by the rental company and used by the construction company for all construction projects in the geographical vicinity of the Logistics Terminal. The Logistics Terminal is the specific logistical configuration studied in this case and it is intended to possibly have a function for reusing construction materials from one project and distributing those materials to other projects operated by the construction company.

5.4.1 The future flow model

Figure 9 illustrates the future flow model for material, information, and economic flows between different actors along the supply chain and on the construction site. In contrast to the current flow model, the future model incorporates a logistics terminal, which enables the reuse of excess materials on construction projects. All initial flows of material are distributed to the logistics terminal, whereupon materials are distributed to the construction site in the needed quantity for production. Surplus of material is further transported to the projects (site 2 part of construction company), the reuse company, and recycling centre.

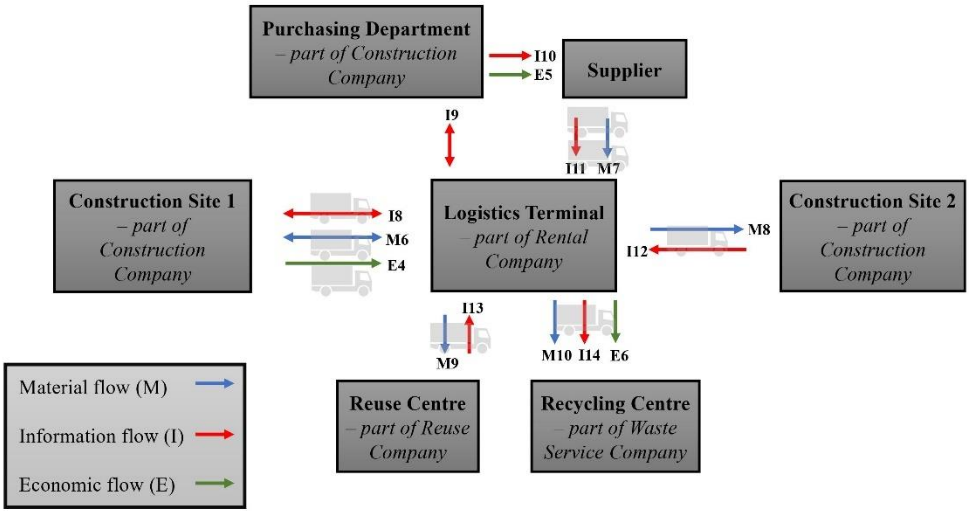

Figure 10: Future flow-model incorporating material, -information, and economic flows between different entities.

Table 44: Description of the flows in the future flow model.

Future Flow Model	
M6	*Construction material is delivered from the logistics terminal to the construction site. Construction waste is transported from the construction site to the logistics terminal.*
M7	*The suppliers make all material deliveries to the logistics terminal.*
M8	*Construction material available for reuse is delivered to another construction project.*
M9	*Excess construction material, not reusable in other projects, are sent to reuse companies.*
M10	*Construction waste is consolidated and picked up for transportation to the recycling centre.*

I8	*The logistics terminal updates on material in store. The construction site informs the Logistics terminal once material deliveries is needed.*
I9	*The purchasing department notifies the logistics terminal what materials have been purchased for the construction project. The logistics terminal gives feedback to the purchasing department on what is available for reuse.*
I10	*The purchasing department places orders on material at the supplier companies.*
I11	*The supplier notifies the logistics terminal when the materials are expected to be delivered.*
I12	*Other projects have access to the internal digital service enabling checking the reuse balance.*
I13	*The reuse company have access to the external market, enabling them to check the available reuse balance.*
I14	*The logistics terminal notifies the recycling centre when waste is available for pick up.*
E4	*The main contractor is paying the rental company for the service of using the logistics terminal and all of the services that are included.*
E5	*The construction company purchases different materials from suppliers.*
E6	*The service providing company in charge of the logistics terminal buys the service of waste management from the recycling centre.*

5.4.2 Critical flows

Taking into account the previous discussion and the figure of the suggested flow model, there is a lot of information flows depicted and were information plays an important part in the suggested reuse solution. The information flows and the possibility to coordinate all of the logistical activities that are included into the suggested reuse solution are deemed the most critical for the suggested solution to be viable. Traditional construction logistics is complex and requires a lot of coordination when only having one construction site to consider. In the case of the reuse solution, multiple construction sites are connected in the same supply chain through the logistics centre, which further complicates the logistical coordination and information flows associated with the logistics centre and construction projects. If the flow of information [I12] does not function properly, *(construction site 2)* will not know what is available for reuse and will therefore not order that material. This leads to the material flow [M8] not happening which defeats the purpose of the reuse function. Considering that material is still coming to the terminal through [M7] then the terminal will start to fill up with left over materials leading to the storage capacity becoming full. This could lead to several consequences, firstly, the rental company may not be able to accept new projects that wants to store materials and use the logistics terminal for their new project. This will hinder new business for the rental company who will have to make up for the loss of income from not taking new projects in some way, for example increasing rent for existing materials that are stored for a long time.

The second consequence of [I12] not working properly is that the main contractor will not save any money by having reused materials used in other projects. In combination with possibly increasing rent from the rental company, the price that the main contractor is paying for the reuse service and rent of space as well as not making any money back, will make the solution economically unsustainable for the main contractor. Considering the doubtfulness of the reuse solution making any money for the main contractor and the optimal solution was to break even, the economic sustainability is very important. If the economic losses become too big, then the main contractor will probably revert to throwing materials away, since the environmental gains cannot make up for the economic losses. This would defeat the purpose of the reuse solution and a lot of money and time will have been spent for very incremental gains. The logistics centre can still function as a regular CCC which will generate more efficient construction logistics and coordination which will generate economic gains. However, the reuse function would not be considered worthwhile and other solutions would be considered in order to achieve the same environmentally friendly result. Therefore, coordination and information are considered a crucial part of the reuse solution and one of the challenges for the rental company, to create and maintain the flow of information.

The prerequisites for this are very promising with the current platform of delivery planning to build a bigger digital platform on featuring the reuse solution and spreading the proper information. The rental company is not the only actor responsible for the spread of information. The main contractor and organisation need to be acceptant of the information and educate the people working in the organisation on the use of the reuse solution. The actors most concerned would be the purchasing department and the site managers. Site managers needs to have the mindset to use and consider reused materials when ordering call-offs. As seen from the *site manager* there is some resistance to adopting more environmentally friendly solutions because of the work it adds for people on site. The *logistics manager* also points out that the construction industry is not the most agile and it takes time to implement solutions. By educating people working on site in the new functions and implementing them in a smooth way, the chance of success increases, and less resistance could be encountered. The purchasing department of the main contractor would also be a key actor to get involved with information about the reuse solution. Not only to consider ordering reused materials, but to solve one of the biggest question marks and challenges that the reuse solution is facing, profitability. As discussed earlier, a gap in the current knowledge when considering reuse is the question of what materials are left over and in what quantities. If construction projects and the logistics centre could transfer information back to the purchasing department, then proper data could be gathered on these questions. The purchasing department is in an excellent position to compile that information since they know how much material was ordered for the project from the beginning and in what quantities. If information got back to the purchasing department about how much material and what type was left at the project after completion, then they could compile that data in order to find out the necessary data. According to the empirical data gathered in this project from actors both within and outside the main contractor organisation, the purchasing department are in the best position to do this than any other actor. So, the information transfer from projects and logistics centre back to the purchasing department for compiling of data is the most reasonable way to find out the unknown factors which would determine the financially sustainability of the reuse solution. This again shows that the information flow is one of the most critical factors when it comes to making the reuse solution viable and it is dependent on both the main contractor and the rental company.

5.4.3 Potential advantages

If the reuse solution is successfully implemented and the above issues sorted out, then it would bring several benefits for both the main contractor and the rental company. Environmental regulations are becoming more common in the construction industry as mentioned by Pero et al., (2017), and the shift towards CE is a valuable aspect to consider when meeting those regulations. If a main contractor has a reuse solution in place, then it is more likely that the main contractor will already meet the future requirements set on environmentally friendly construction. This can be seen as a competitive advantage in a time when more and more construction companies are moving towards environmentally friendly construction, to already have a solution in place. As pointed out by the Business Development Manager & Logistics Development Manager, the exhibition of how waste is handled with regard to environmentally friendly construction, will be part of the procurement's evaluation. If a reuse solution is already in place and a company is the first one to have it up and running before it becomes a demand, then that company will have a big advantage when it comes to winning procurements in the future. This is because they can work out all the issues with implementing a new solution and make the process more efficient, e.g., what type of materials to reuse. This in turn will produce an efficient reuse solution that will be a big advantage over competitors when winning procurements in the future. This is by far the biggest advantage for the main contractor to implement a reuse solution, even though all the exact configurations are not worked out just yet. The investment that is made now might not be a profitable one in the short term but if the main contractor can win procurements in the future, the investment will probably be very profitable in the long term.

If the logistics centre with the reuse solution can be established and run by the rental company, then they will be able to provide a complete range of services for construction companies. This is in line with company goals for the specific rental company in this case and it will give them a competitive advantage as well towards other rental firms. The expansion of their business areas into logistics and providing a reuse solution will allow them to take on more projects that will bring on more business for them and to offer their clients a whole range of services that no other rental company can offer. The main objective for the rental company is to make a profit and the motivation for introducing a reuse solution is to increase the profit which would be the result of providing a wider range of services to acquire more business. Due to the close relationship between the main contractor and the rental company in this case, a secondary effect of the reuse solution could be an even closer relationship and collaboration. With the implementation of the logistics centre with the reuse solution, the rental company enables the main contractor to achieve their company goals and increases their competitive advantage. The two companies enable each other's success by collaborating in creating a reuse solution, which could further increase the close relationship between the two companies.

6. Conclusion

The objective of the thesis is to design a flow model that takes into consideration the information-, material-, and economic flows associated with developing a logistics terminal solution for the reuse of construction materials. In the following chapter, conclusions drawn from the discussion will be explained and the research questions answered. Future research will also be suggested to further investigate the topic.

6.1 Challenges and opportunities with reuse

In conclusion, the current logistical flows of surplus materials are characterised by the decentralized coordinated configuration explained by Dubois et al. (2019). The decentralized coordinated configuration, being the most general today, lacks a joint coordination between on- and off-site logistics activities. This has been obvious from the interviewees' responses which shows a lack coordination between the site activities, the purchasing departments process of procuring material, and the suppliers process deliveries. This disconnection of every actor focusing on their effort has led to various issues in the logistics flow. Issues such as uncoordinated deliveries coming on irregular basis, lack of storage capacity, material handling leading to damage and waste, poor material management and requirements, etc. are all results of insufficient logistics management throughout the supply chain. As mentioned by one of the respondents, the construction projects being unique with a temporary organisation and need of distinct logistical setup, requires the joint effort of all actors to be successful. Additionally, the communication and feedback experience between actors being rigorously inadequate has been a hinder for better coordination of logistics activities on- and off-site. Conclusively, in the current flows, the main challenges and for reusing construction materials in relation to construction logistics are, firstly, the insufficient storage and handling of materials due to underwhelming logistical configurations. Secondly, the lack of informational infrastructure to facilitate the creation. Lastly, the distribution of relevant information regarding construction material and the uncertainty of the economic viability for reusing construction materials.

Due to the decentralized logistical configuration of the current flow model, there was not any means to properly handle materials to avoid unnecessary wear on construction materials. Therefore, materials were rarely deemed fit to be used in other projects to meet the standard that is set on construction materials. The lack of information surrounding unused construction materials did not allow for the opportunity to retrieve the materials in a manner that would make it worthwhile to use it. If such information was available, then it was very localised and was not applicable to a greater scale. Therefore, materials fit to reuse were rarely distributed in a manner that allowed for sharing them with other construction projects in a broader context and were therefore thrown away. Due to the many question marks that surrounds the economic viability of reusing construction materials, the initiative to attempt reusing materials has rarely been taken. The uncertainty in combination with the profitability requirements of temporary construction projects has caused few to venture into reusing construction materials.

The potential solutions that were discussed was, firstly, to use a logistical solution, which in the case studied would be a Logistical terminal, this would potentially reduce the risk of materials taking damage due to multiple handlings as well as enabling protection from unfavourable weather conditions. Secondly, to create a digital system which allows for the creation and distribution of information concerning what materials are available for reuse. A digital system would allow the information to be distributed to all key actors in a sufficiently fast manner. Lastly, because of the many unknown factors surrounding the profitability of reusing construction materials, a hypothetical business model for reusing construction materials was suggested that could potentially be profitable if the unknown factors were produced.

Taking into account the current business model and the suggested flows that followed as a solution to the challenges discovered, the future logistics flow model was developed. This flow model shifted in focus from the construction site to the logistics terminal, creating a more centralized coordination of construction logistics. With the suggested flow model, the authors assesses that there is a reasonable possibility that a reuse solution for construction materials could be implemented and sustained.

For the rental company, the challenge is that due to the multiple unknown factors and the investment that would be required to introduce a reuse solution as a service, there is some risk for a rental company. This is a question for the rental company to decide if it is worth investing in since the upside is big but there is also substantial risk. The benefit for a rental company would be competitive and economic advantages with offering a reuse service since today, this is very rare in the rental market

For the construction company, the challenge is to spread the knowledge and educate the organisation about reuse of construction materials. This has previously been difficult but if it is not adopted on a basic level, the resistance due to increased time and effort will be too big for the practise to stick. If those challenges could be overcome and a reuse solution was successfully implemented, then it could bring huge benefits in the form of competitive advantage for the construction company if adopted in an early stage. Considering the environmental demands that are put on the construction industry through legislation, adopting a reuse solution early on could give the construction company a first mover advantage leading to increased business.

To sum up, the establishment of a logistics terminal and the direction of logistics flows through the terminal, including the reuse of construction materials, in the collaboration between the construction company and the rental company, appears to entail several benefits. Not the least will the ability to reuse surplus materials increase. However, in order to reap such benefits, it is crucial to develop a logistics solution that adhere to the necessary physical- and information flows, while at the same time adapting the business models of the companies to avoid financial losses. In addition, management must also consider how to support the various construction projects to adhere to the logistics solution to facilitate the transition towards an increased use of reused materials and utilizing the logistics terminal.

As discussed throughout the paper, there are several unknown factors surrounding the suggested flow model that needs to be investigated further. These are suggested as topics of future research in the next section.

6.2 Future studies

There are a few aspects that was discovered to be of interest during the research, but since they were out of the scope for the study, they are left for future research. Following suggested future studies are of interest to investigate further. The study focused on investigating the possibility of reusing construction materials during the production phase by implementing a logistics terminal. Thus, it would be of interesting to investigate how materials may be reused also during the demolition phase, and how that would affect the possibility of using a logistics terminal, as this constitutes the largest quantity of material being disposed of. Furthermore, in this study, the various flows i.e., material, information and economic flows required when reusing construction material have been subject to research. However, it would be of value to look further into what specific types of material that are most optimal or suboptimal being reused based on their characteristics, including various implications for physical-, information-, and economic flows. Another interesting future study which was highlighted by one of the respondents was to identify the total cost of logistics i.e., transport, handling, labelling, storing throughout the whole supply chain when implementing a logistics terminal in comparison when not doing it. Lastly, future research of interest would be to make an ABC-analysis when evaluating different materials in order to see what material in relation to the quantity purchased are most profitable. Thus, being able to identify which material that are more profitable to be reused and worth investing time and effort to recover to a larger extent than materials with lower (or no) economic margins for reuse.

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