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Four perspectives on urban construction logistics:  
Why it matters and how to make it a priority

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## Abstract

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The construction industry has suffered from low productivity for decades, and more recently, researchers have connected this to being a result from poor execution of logistics. Methods to achieve more efficient logistics exists, but construction logistics is often overlooked, and therefore not used. This thesis identifies what can be done to excel in construction logistics, and how and why it should become an integral part of every construction supply chain. To fulfil the purpose of this thesis, four case studies based on in-depth interviews with different actors in the construction supply chain were conducted. The results revealed that the production manager was a major barrier to the implementation of efficient logistics, together with the difficulty in assessing the cost of logistics. Moreover, the results suggest that efficient construction logistics helps to create a more sustainable environment for urban stakeholders, which adds to the importance of promoting it. The results further suggest promotion by external requirements on construction logistics posed by the client.

**Keywords:** *construction logistics, construction supply chain, construction consolidation centres, construction logistics plan, third-party logistics*

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From the start, our top priority has been to conduct research within a relevant problem area, and to learn as much about the problem as possible, so that we can guide future researchers and decision makers. Studying construction logistics has truly provided us with a treasure chest of different topics to research further, as the subject is tremendously interesting while still rather untouched.

In the process of selecting a suitable research area we were lucky to meet with Jon Svensson from Skanska AB, who gave fuel to our idea about the importance of construction logistics both for companies and the society. He was truly an inspiration for us, as his motivation for changing the traditional view of managing construction logistics seemed endless.

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## Abbreviations

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CCC	construction consolidation centres
CLP	construction logistics plans
DMS	delivery management system
EDI	electronic data interchange
GDP	gross domestic product
GHG	greenhouse gas
HSLC	Hammarby Sjöstad LogistikCenter
JIT	just-in-time
LCCC	London Construction Consolidation Centre
SOT	System och trafikföringsprinciper
TPL	third-party logistics

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# 1. Introduction

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*This chapter starts with a brief introduction of the Swedish construction industry and some of the current market developments. It continues by displaying some of the challenges of efficient construction and a motivation for studying construction logistics to improve the productivity, and thus the overall efficiency and sustainability for companies, stakeholders and the industry. The purpose and research questions (RQs) are then introduced and outline the direction of this thesis. Lastly, this chapter concludes with accounting for some of the delimitations that were made to complete this study.*

## 1.1 The construction industry

The construction industry is looking at a bright future. According to research presented by McKinsey, global investments in infrastructure projects will double in the next fifteen years (Changali, Mohammad & van Nieuwland, 2015). Taking part of this development, is the Nordic region which have experienced rapid growth in 2016 which is forecasted to continue in 2017, with Iceland and Sweden in the lead (Sveriges Byggindeindustrier, 2016). The industry contributes to the economic and social development of cities and nations. It is labor intensive and in 2015 the Nordic construction industry employed 849.000 people, a number expected to grow by 42.000 in the following two years.

As urbanization continues to be a trend in Sweden (The World Bank, 2017), most of the future construction work will take place in major cities. Boverket (2016a) estimates that 70 per cent of the population increase will take place in urban areas, which means that infrastructure projects and service facilities, shopping centres and office buildings need to be constructed, not to mention residential areas for the people who intend to live in the city. But urban construction brings many concerns and challenges. Boverket (2016b) highlights the importance of a pleasant urban environment, and while living next to a construction site is not fetching, it is still the reality for many urban stakeholders, that can last for several years. Therefore, effective urban construction, that can ease the negative impact on the surroundings and limit the disruptions of the everyday life for the people that inhabit the local area, should be sought after.

For a novice, construction projects might seem complicated enough, with millions of bits and pieces in different shapes of steel, concrete and glass that need to be assembled with precision engineering, into a building (Behera, Mohanty & Prakash, 2015). Each step in the building process must be planned and organized in detail. Work must be delegated to, in some cases, up to hundred different subcontractors, scattered across the construction site (Dainty, Millet & Briscoe, 2001b). Pressure from completing on schedule and to remain within budget requires the operations to run without disruptions to the workflow. But the fact that the construction take place in an urban environment add to the complexity (Isaacs et al., 2010). In particular, the logistics process of supplying construction sites with building material, a process which normally is conducted by trucks. Interfering with urban stakeholders are bound to happen as trucks navigate through densely populated inner city areas, contributing to congestion, air and noise pollution.



For every incoming vehicle to the construction site, an outgoing vehicle movement is generated, which doubles the impact on the local environment. A sustainable construction process requires an effective and efficient logistics operation, that plan and coordinate incoming and reverse flow of goods to minimize the number of vehicle trips to and from the construction site. The literature on construction logistics specifically has been growing since the early 21<sup>st</sup> century, and much of the same principles and concepts offered in general urban freight transportation literature, applies to the field of urban construction logistics. For instance, the use of consolidation centres, which have been widely accepted as the norm for efficient freight distribution, has recently been recognized to be an effective approach to reduce the number of vehicle movements in urban construction (Robbins & Thomas, 2013). On a similar note, construction companies today contract dedicated logistics personnel and collaborate with third-party logistics (TPL) providers (e.g. Ekeskär & Rudberg, 2016; Hulthén et al., 2017), to improve logistics performance at the site as well as before shipments reach the site. Much of the results from these actions point at higher productivity, less waste and more cost-efficient logistics activities. However, introducing additional actors in the supply chain requires effective supply chain management to maximize the gains.

Despite the bright future of the construction industry, with increasing investments and a rising demand for infrastructure, service and housing projects, a great challenge remains in how construction companies and other supply chain partners will tackle its footprint in the urban environment, especially in the process that concern the logistic activities. Urban areas are particularly sensitive to disruptions and complex in the way that they are home to a wide variety of stakeholders. One argument that will remain throughout this thesis is that it is in the public domain's interest to facilitate and promote more efficient construction logistics, to accommodate a more sustainable urban environment. However, current literature, like the collected data of this thesis, show little evidence that this is true. With this said, construction companies that have the resources and knowledge to, in an early state of project development, organize and plan the logistic activities to minimize the impact on the environment, will not only have a competitive advantage, but also reap the benefits associated with effective logistics. Therefore, it is interesting to investigate the operational and sustainable benefits of efficient construction logistics, as well as gathering a deeper understanding of how external interests can influence the construction industry to improve its logistics performance.

## 1.2 Problem discussion

Since the 1960s, the productivity in the construction industry has regularly been the subject of research (Dacy, 1965; Stokes, 1981; Allen, 1985). In comparison to the manufacturing industry (Teichholz, 2001), the construction industry has lagged considerably, which fuel many questions why this is the case. While much of the poor productivity measures appear to be linked to unreliable and insufficient data, or inadequate models (Ganesan, 1984; Goodrum et al., 2002; Briscoe, 2006; Bröchner & Olofsson, 2012), some researchers link low productivity to poor performance of supply chain management and logistics (Agapiou et al., 1998; Vrijhoef & Koskela, 2000), thus, resulting in different types of waste being identified (Vrijhoef & Koskela, 2000; Strandberg & Josephson, 2005; Josephson & Saukkoriipi, 2007) which undeniably impair on construction productivity.

When considering the low productivity of the construction industry from a societal point of view, it gets problematic. The construction industry's contribution to society is great as it accounts for a great deal of the economic development, in terms of sources of investments and as an employer. The Swedish construction industry surpassed 300.000 employees in total during 2016, well over 6 per cent of the working Swedish population (SCB, 2016b). In 2015, the Swedish construction industry contributed to 5 per cent of the GDP, the highest level since 2007, according to primary figures presented by SCB (2016a). The greatest contributor to this development is the increasing development of housing construction, especially that of residential dwellings and apartment buildings. Investments that can be traced to the development of infrastructure projects, service facilities and other buildings have also increased, albeit, at a slower rate. Between 1998 and 2015, the latter category of construction projects increased by 44 per cent in volume. A rather modest growth opposed to that of residential housing constructions which increased by 244 per cent during the same period.

According to Konjunkturinstitutet (2017), the situation in the Swedish construction industry is described as “much stronger than normal” (Swedish: “mycket starkare än normalt”) (p. 5), with increasing order books, despite shortage in the work force. This development can easily be explained by the current economic situation, with low rates and moderate inflation (Riksbanken, 2017), which have thrust the Swedish economy into an economic boom. An ideal situation for investing in construction projects. At the same time, the construction industry is negatively affected if the economy swings the other way, with rising interest rates to cool high inflation and lower demand.

The favorable economic development in the construction industry is of less interest if the gains cannot be reaped due to inefficiencies, e.g. low labour productivity. A prerequisite for achieving high labour productivity is obviously to keep workers occupied with construction activities, or tasks that add value to the construction process. After studying the construction of a Swedish housing project, Strandberg and Josephson (2005) found that construction workers performed value-adding activities on an average of 17.5 per cent of an 8-hour day. Almost half of the work day was spent on preparing value-adding activities, material handling, and indirect work (e.g. preparing equipment). The low percentage of value-adding activities is worrisome, but at the same time it helps to visualize the underlying problems in the “construction productivity debate” (Sezer & Bröchner, 2014, p. 565). More so, it helps divert focus on better construction supply chain coordination and management.

Waste in construction projects do not just contribute to low productivity, it is also considered to be the main driver for increasing construction costs, according to the study by Josephson and Saukkoriipi (2007), in which waste corresponds to between 30-35 per cent of a project's production cost. Defects caused by unauthorized personnel, searching for defects, thefts, and waiting time are main sources of waste and constitute about half of the above figures. Josephson and Saukkoriipi (2007) continues with addressing the space restriction on site as one of the main problems for subcontractors. Either too little space is available, or, the space that should be available is covered with inventory to add up for the material that is being wasted due to defects. Space restriction is a particularly sensitive issue in an urban environment, where space should be considered a scarce resource.

Vrijhoef and Koskela (2000) analyze the supply chain of three independent construction projects and conclude that waste is a major problem. An important finding is that most of the time, waste is created in the beginning (upward) of the supply chain, but found later, in the subsequent stages of the supply chain. Another valuable finding was the short-term opportunistic behavior in procurement processes. Despite taking advantage of lower prices when ordering higher quantities of supplies, the benefit was offset by increasing material handling costs due to lack of proper on-site logistics. The opportunity to improve productivity was lost because it was not supported by the management of the supply chain. Still, the study by Vrijhoef and Koskela (2000) is important in the pursuit of highlighting the importance of construction supply chain management and logistics, to improve construction productivity.

More support for the importance of construction logistics is found in Agapiou et al. (1998). In construction, the supply of building materials is essential for the progress of the project, without materials the construction cannot continue, hence, material supply is important for productivity. In the same manner as construction productivity is often compared to productivity in the manufacturing industry, Agapiou et al. (1998) argues construction logistics to be equally important as logistics in the manufacturing industry. Results from the study show several benefits. Cost savings can be achieved by better logistics management, that is, planning of material handling, transport and stock keeping. It also improves coordination between the participants of the project through enhanced flow of information.

This section has briefly explained some of the current market developments of the construction industry, as well as what can be expected in the future. Despite the important role that the construction industry plays in the society, the industry has for a long time been associated with low productivity and inefficiencies. Research suggest that this is the result of an industry that have consistently overlooked the potential of efficient logistics. The recurring argument of this thesis is that many of the industry's problems can be mitigated by focusing resources on logistics. Moreover, while urban construction will continue to be a major portion of construction projects, efficient construction logistics will reduce the negative impact on urban stakeholders.

### 1.3 Purpose and research questions

Following the rationale of the aforementioned research, this thesis will investigate the impact construction logistics has on the construction performance, hence, the purpose of this study is to outline *how* construction companies can benefit from existing logistics practices that have proved to be successful in urban freight distribution. It will further shed some light on the link between efficient construction logistics and the benefits of the society, particularly in an urban environment where logistics in general is thought to be complex to execute effectively. Part of the purpose is also to identify the current demand on efficient construction logistics, and *if* a future requirement will result in a change towards more sophisticated construction logistics practices.

In line with the purpose of this thesis, the following RQs have been constructed to guide the investigation in the right direction:

**RQ1:** *What are the barriers and incentives for construction companies to implement more efficient construction logistics?*

The first question (RQ1) focus on the construction and its immediate supply chain actors, and will address the following:

- The methods that exist to improve construction logistics.
- Why construction supply chain optimization is difficult.

**RQ2:** *How can construction consolidations centres (CCC) contribute to a more sustainable environment for urban stakeholders?*

The second question (RQ2) takes a holistic view by introducing stakeholders, and will address the following:

- The stakeholders of urban construction.
- How efficient construction logistics helps to improve the environment surrounding construction sites.

**RQ3:** *How can more demanding requirements on logistics ensure efficient construction logistics?*

The third question (RQ3) investigates a solution for how the construction industry can focus more on logistics, and will address the following:

- The need for higher requirements on construction logistics.
- What the effects on the industry would be.

The first question will address the barriers and incentives associated with efficient construction logistics. For the construction companies to successfully adopt logistics, there must be a considerable benefit. However, logistics may impact supply chain actors differently, hence, primary data will be collected from different industry actors (see section 3.5), to provide a broader understanding of how actors are interconnected. Previous research that investigate how logistics affects more than one type of actor has not yet been found in the current body of literature. In that regard, this study may alleviate from previous studies.

The second question will address how urban stakeholders benefit from construction companies to adopt CCC. Even though there are several ways for construction companies to improve logistics in projects, RQ2 has deliberately been limited to only include CCC (also referred to as terminals), because this approach has been proved to effectively reduce the amount of vehicle movements to and from construction sites. With this comes many benefits

and great potential to result in win-win situations for all urban stakeholders, construction companies included.

The third question will answer how a requirement on construction logistics can be the way forward for the construction industry, and make logistics an important part of the construction process. The requirement could take two forms: internal or external. An internal requirement could come from the main contractor, while an external requirement could be stated by the client, which in turn could be a private or public actor. Any previous research with the aim to solve a similar question has not yet been found, and therefore the discussion around RQ3 will make a novel contribution to the current body of research.

#### 1.4 Delimitations

Several delimitations have been made to increase the practicality and comprehensiveness of this study. The term ‘construction industry’ is frequently used in this study. The focus of this study is mainly on the Swedish construction industry, although international studies and examples from other countries appear in the content to widen the subject and call for discussion and comparison. The construction industry has further been limited to only include construction of buildings. The reason for this is that most of the literature on construction logistics refer to this type of construction, more specifically the construction of residential dwellings. It is also worth mentioning that not all construction companies have the investment needed or the scale to benefit from construction logistics. In 2014, the Swedish construction industry comprised of approximately 41.000 business owners, the majority with net sales under half a million SEK (SCB, 2016a). Therefore, when referring to construction companies in the context of construction logistics, this study specifically care to the largest construction companies in Sweden (see Appendix 1).

## 2. Literature review

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*In four sections, the literature review starts by developing the concepts of supply chain management and logistics from general to industry specific. It continues by outlining contemporary views on efficient construction logistics and how it is practiced. Lastly it identifies urban stakeholders and the impact construction logistics has on them. This chapter concludes with a summary of the most important topics found in the literature, which will act as a base for the discussion.*

### 2.1 Construction supply chain management and logistics

To increase the performance of the construction industry and to improve the productivity of the construction process, some researchers suggest that construction companies should focus resources to improve supply chain management as well as addressing the logistics activities of the company (Agapiou et al., 1998; Vrijhoef & Koskela, 2000). The concept of supply chain management can be described by a vast variety of definitions. The Council of Supply Chain Management (CSCMP, 2017) define supply chain management in the following way:

*Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies. (§3)*

Moreover, Simchi-Levi et al., (2007) define supply chain management as:

*(...) a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and the right time, in order to minimize systemwide costs while satisfying service level requirements. (p. 1)*

The two definitions above in combination suggest that supply chain management takes a holistic standpoint in the way that it incorporates all activities of the supply chain - from sourcing and production to distribution of finished goods to customers - while including channel partners through close participation and collaboration. The idea of extending the range of activities to outside companies would suggest that information is shared across organizations, hence, supply chain management is not limited to solely physical flows but flows of information as well (Christopher, 2011). Supply chains in general are prone to a high degree of uncertainty and the role of effective supply chain management deals with reducing and mitigating this uncertainty (Simchi-Levi et al., 2007; Shao, Sun & Noche, 2015). Increasing information sharing throughout the supply chain is suggested to reduce variability, improve forecasting, reduce lead times, enhance problem solving and provide better coordination and a higher service level (Simchi-Levi et al., 2007). Furthermore, to integrate the supply chain and minimize system wide costs requires planning and management of activities as well as a logistics system for efficient distribution (Gupta & Maranas, 2003). Logistics management is a part of supply chain management and defined by CSCMP (2017) in the following way:

*Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements. (§5)*

The concept of construction logistics goes beyond the transportation of construction material to the construction site. Albeit, the transportation to the construction site is an important leg of the material supply process, however, it does not stop when the material reaches the boundaries of the site. An equally important part of construction logistics is the distribution of material within the construction site (Moone, 2015). A prerequisite for not interrupting the workflow is to make sure that materials reach the destination of where it is needed, when it is needed. Therefore, the transportation of materials within the construction site may require vertical, as well as horizontal transportation (Moone, 2015). The mode of transportation used in construction extends from trucks and forklifts, to also include site confined equipment such as cranes and construction elevators. Since these resources are normally limited, adequate scheduling is an important part of construction logistics.

A central part of supply chain management and logistics is to optimize inventory levels, which require a balance between lowering system wide costs and maintaining a satisfactory service level (Simchi-Levi et al., 2007). The need for inventory is dependent on the level of uncertainty regarding supply and demand, lead times and cost structure. In construction, inventory include construction materials, construction equipment, e.g. tools and scaffoldings (Mossman, 2008; Moone, 2015). Goods in need of storage are normally assigned to a predetermined storage area on-site. The same applies to equipment. However, the requirement for on-site storage will change throughout the course of the project. A common evolution of the storage requirements is to handle high volumes with low variation in units during the early stages of the project, to lower volumes with high variation in units towards the later stages (Robbins & Thomas, 2013). In dense urban areas, on-site storage can be very limited. Therefore, off-site storage areas, or, CCC (see section 2.3.2), are also used in construction (Robbins & Thomas, 2013). The idea behind consolidation centres is to set up an intermediary warehouse in the proximity to the project site, for faster replenishment and more secure storage.

What has not yet been introduced is the flow of materials that need to leave the construction site, i.e. the reverse flow of logistics. The aforementioned definition of logistics excludes the reverse flow of goods and materials, which is covered in Rogers and Tibben-Lembke (1999):

*The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal. (p. 2)*

The value of the reverse flow can be hard to estimate, as well as the cost of handling it and to forecast and standardize the procedure (Rogers & Tibben-Lembke, 1999). However, reverse logistics has the potential to increase profit if waste is treated as a resource (Cherrett et al., 2015). Effective management of the reverse flows of construction projects is important since most construction projects starts by excavating the site and transport away huge amounts of

landfill material, and therefore a natural step in the construction process. However, organizing the reverse flows in urban environments could be problematic.

## 2.2 Characteristics of the construction supply chain

As the above section suggest, the construction supply chain is characterized by several factors that make efficient logistics hard to achieve. Factors that needs to be taken into consideration when designing the logistics plan of a construction project. To see how improved logistics activities can influence the productivity in construction projects it is important to understand the underlying factors behind the supply chain of construction projects. This section will address some of the main characteristics of the construction supply chain and how it affects the management of logistics planning.

Behera et al. (2015) argue that the level of complexity involved in construction projects is at its highest point yet. The investments that are put into construction projects are increasing, meaning bigger projects, but also an increasing variety of construction projects, resulting in a more disperse collection of project participants. Simultaneously, project managers are facing time pressure, rising cost levels, and safety and quality requirements that need to be fulfilled. Adequate planning is crucial for the project's success.

As described by Vrijhoef and Koskela (2000), a construction supply chain can be viewed as a “construction factory” (p. 171), with the goal to produce a single product. Like the make-to-order supply chain of a manufacturing company, the construction supply chain's objective is to make sure that the finished project conforms to what the customer ordered. Hence, the customer is free to make changes and modify the specifications, which can lead to problems for the builder. However, most of the problems that occur, not just in construction, but in make-to-order manufacturing supply chains in general, are of internal nature, i.e. due to poor coordination and execution of internal processes (Vrijhoef & Koskela, 2000). Still, the construction supply chain is characterized by several features that are traditionally not found in manufacturing supply chains, but contribute greatly to the complexity of construction projects.

The reason behind the high level of complexity in the construction supply chain stem from three components (Gidado, 1996). First, there is an inherent complexity factor involved in construction projects right from the start. Special skills and knowledge are required, e.g. construction engineering and project management. The main client partner with engineering firms or other special service providers long before the construction takes place. Second, construction projects are prone to factors that raise uncertainty (Gidado, 1996). This can be incomplete specifications or unstandardized input resources which lead to unconventional solutions. It can also be the lack of standardized material handling processes which result in damaged or lost material. Changing weather conditions or other unforeseeable environmental changes are also factors that give rise to high uncertainty. Third, the operation of construction supply chains relies on the interdependence of different activities (Gidado, 1996). The workflow follows several activities that are to be performed in a predetermined order and to save time and cost, activities can be planned so that they overlap. Therefore, one minor disruption can cause a chain reaction of problems across the construction site.

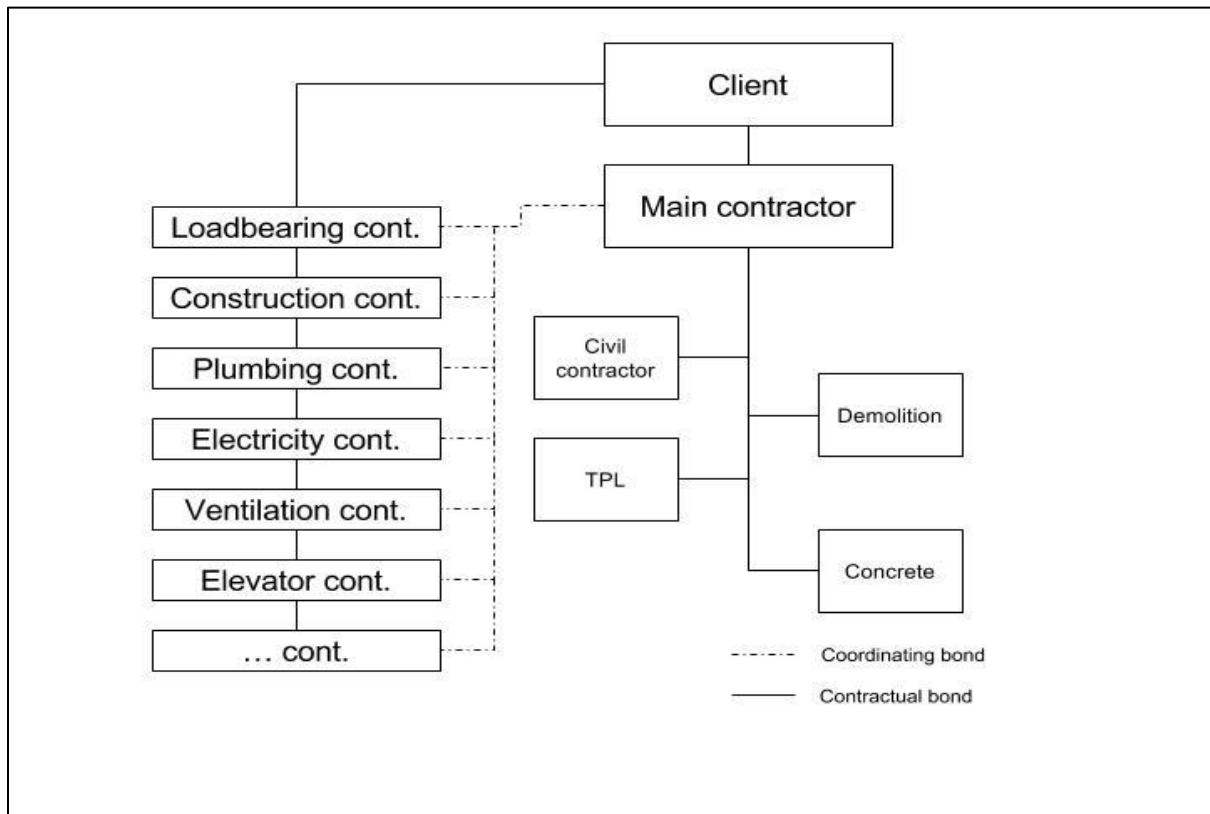


While acknowledging the complexity of construction supply chains, Dubois and Gadde (2002) explain the construction industry network as a loosely coupled system (Glassman, 1973; Weick, 1976) with both tight and loose couplings between network actors. According to Dubois and Gadde (2002), couplings within the supply chain (e.g. between construction sites and suppliers) share the characteristics of a loose coupling, i.e. a relationship that lacks coordination, inspection or regulation (Weick, 1976). Standardized procedures may exist in the network but are rarely followed up, resulting in inconsistency. It is also unresponsive to changes. On the contrary, a tight coupling is a connection or relationship that is the opposite to that of a loose coupling. Instead, the relationship is characterized by high level of monitoring and regulation, follow-up and consistency. According to Dubois and Gadde (2002), tight couplings can be found between actors on the construction site, due to the inherent complexity, uncertainty and interdependence of construction activities.

While the tight couplings between activities on-site are motivated by the importance of not disrupting the workflow, loose couplings between supply chain actors can be described by the material supply process of construction projects (Dubois & Gadde, 2002). It is common practice to send shipments direct from the supplier's factory or distribution facility, however, long lead times are expected. To avoid shortage and an inevitable disruption of the workflow, the main contractor orders more than what is needed, thus, leaving some leverage to deal with uncertainty. The take on describing the construction supply chain as a loosely coupled network is interesting, as loose and tight couplings in construction supply chains appear to complement each other. However, the loose coupling between material suppliers is problematic and leave much to be desired if the goal is to achieve efficient logistics and minimize supply chain costs.

The construction industry is further characterized by a cluster of different organizations that work together. Even the most typical construction project consists of a network of numerous participants (Cheng et al., 2010), which part from the obvious main contractor and client include specialist service providers like architect and engineering firms (Dainty et al., 2001b; Behera et al., 2015). Figure 2.1 shows the network of project actors in a Swedish hospital project. The main contractor was found in the middle of the network and linked with all other contractors as well as with the client. In this project, there were two types of links found between the actors: coordinating and contractual bond, and the main contractor was responsible for coordinating the work. Subcontractors and material suppliers are to be found in the tertiary around the main contractor, but the number varies depending on the size of the construction project, from a dozen to a couple of hundreds (Dainty et al., 2001b). The need for subcontractors varies depending on the progress of the project and the specialization of the subcontractors, but finding multiple subcontractors that are active daily is common. High number of subcontractors add to the complexity of the supply chain, as more actors involved impair coordination and information flows.

**Figure 2.1** Overview of construction project actors. Adapted from Ekeskär and Rudberg (2016, p. 182).



While the main client acts as an intermediary hub between all other participants, the level of integration between the rest of the actors is thought to be low, and varies depending on how far the project has progressed. Some participants are only involved in certain phases, which creates a fragmented supply chain (Vrijhoef & Koskela, 2000). A common separation is that of design and construction (Vrijhoef & Koskela, 2000; Dainty et al., 2001a). Sometimes a participant return to the project at a later stage of the construction process (Behera et al., 2016). Sporadic involvement hampers the coordination and integration between participants even further, and it is a great challenge for the main contractor to keep all participants on par with daily announcements and changes. Results of poor coordination and information sharing regarding on-site deliveries is observed by Thunberg and Persson (2014), who help to visualize some of the problems that might occur. Despite the main contractor's efforts to implement a standardized procedure to handle on-site deliveries more efficiently, some subcontractors decided to disregard this fact and did not participate in this collaboration. Consequently, unexpected deliveries arrived simultaneously which caused complications.

The observations made by Thunberg and Persson (2014) shows that even with rigorous planning by the main contractor, subcontractors can still act on their own. This behavior could be explained by the fact that construction projects are, in the end, project-based, and therefore only exist for a limited amount of time. Hence, the construction supply chain is often referred to as being temporary by nature (Baccarini, 1996; Vrijhoef & Koskela, 2000; Aloini et al., 2012; Cheng et al., 2010). This is clearly problematic, since it undermines trust in the relationship between the main contractor and subcontractors (Cox & Thompson, 1997). Without trust it is easy to fall for an opportunistic behavior and base decisions on a myopic

mindset. However, as found in Pettersen-Buvik and Rolfsen (2015), the level of trust very much relies on experience between the parties involved, which falls naturally in an industry where it is easy to evaluate the performance of subcontractors regularly, due to the project-based environment. The temporary nature of construction projects is also one of the reason behind the unwillingness to adopt and spread new technologies or innovation to other projects (Dubois & Gadde, 2002; Bygballe & Ingemansson, 2014), which indicates that construction projects are treated separately and in isolation.

### 2.3 How to improve construction logistics

The literature on how to effectively counter the complexities associated with construction supply chains are scarce. However, previous research on the logistics of construction projects present some practical solutions that can help mitigate some of the complexities. Three practices of efficient construction logistics will be discussed: TPL providers, CCC, and construction logistics plans (CLP).

#### 2.3.1 Third-party logistics providers in construction

A development that started during the 1990s include main contractors to outsource logistics activities to dedicated specialist firms, or, TPL providers (Robbins & Thomas, 2013). The concept behind TPL is to outsource some, or the entire range of logistics activities, to an external partner (Lieb & Randall, 1996), leaving in this case, the construction company to focus on its core competencies (Bagchi & Virum, 1996). The level of integration in the collaboration varies, from arm's length distance agreements (Stefansson, 2006), suggesting a short-term relation with low integration, to a long-term partnering alliance with "win-win arrangements" (Bagchi & Virum, 1996, p. 102) for both parties.

In the construction industry, the TPL provider could be responsible for material handling, on-site distribution, waste management, and other support and safety functions such as first aid and fire safety, security, marshalling and reception services (Robbins & Thomas, 2013). Assigning the management of logistics to professionals would not just result in higher quality of the performance, but it would also allow construction workers to focus on construction work (Strandberg & Josephson, 2005). A natural development would be to see more and more construction logistics outsourced to logistics professionals. A hint of this is found in the study by Sobotka and Czarnigowska (2005), which shows that Polish construction companies are reluctant to perform logistics activities internally. Instead, tasks such as transportation are assigned to a professional transportation company or a specialized wholesaler. According to Sobotka and Czarnigowska (2005), an increasing number of construction companies avoid buying directly from the manufacturer, as freight is often excluded. Warehousing is performed by storing goods at the supplier, and on-site storage are kept to a minimum. The study can also show cost savings by centralizing transportation to a dedicated service provider, as well as higher quality of the performance. In some cases, planning and scheduling is delegated to a logistics professional which indicates high integration between the construction company and the logistics provider.

There are more benefits for construction companies to leave logistics to professionals. Lindén and Josephson (2013) identify hidden costs of on-site material handling activities at a Swedish construction company, arguing that these costs are often forgotten in the cost estimations and

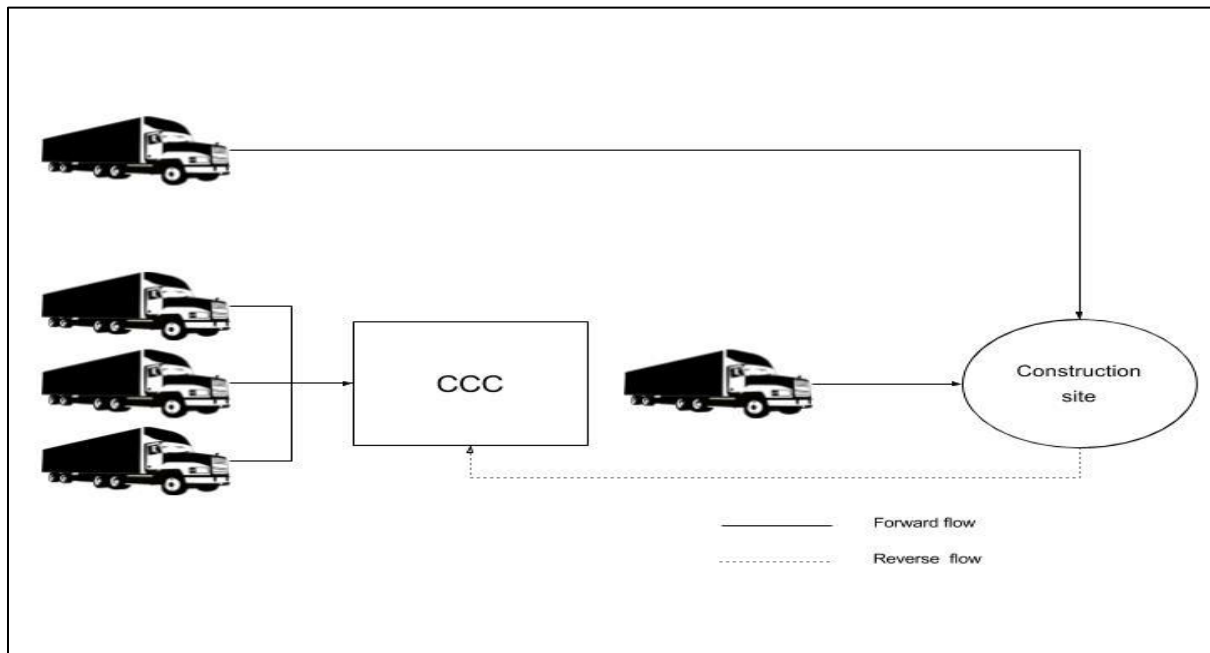
in the planning of whether material handling should be conducted in house or to be outsourced. To answer the question of outsourcing material handling, Lindén and Josephson (2013) compares the material handling cost of letting construction workers do these tasks, with the costs of using a TPL provider. The result show that there is great savings potential in letting a logistics professional be responsible of the on-site material distribution. Also, better planning can reduce the amount of wastes (e.g. Josephson & Saukkoriipi, 2007) by allowing workers to focus on their main tasks (Robbins & Thomas, 2013).

The most extensive use of a TPL-setup is found in Ekeskär and Rudberg (2016), during the construction of a major hospital in Sweden. In this longitudinal case study, the TPL provider was responsible for all logistics activities, including planning of storage, operating cranes and construction elevators, handling incoming deliveries, gatekeeping, as well coordinating all project participants. A maximum level regarding on-site storage of materials was set by the TPL provider, as well as other restrictions, such as pallet type used for deliveries. The main contractor's and subcontractors' incoming material deliveries had to be booked five days in advance using an online planning tool provided by the TPL provider. Each delivery had to be specified, e.g. size, weight, on-site destination, and required offloading equipment. This allowed for better planning and coordination by the TPL provider. The dedicated logistics setup can be described as a strategic alliance (e.g. Bagchi & Virum, 1996) that continued during a 10-year period. However, most of the integration was between the TPL provider, main contractor and subcontractors. The relationship between the TPL provider and upstream suppliers were non-existing in the project, according to Ekeskär and Rudberg (2016).

### 2.3.2 Construction consolidation centres

Consolidation centres in the construction industry share many of the same principles of designated storage facilities found in freight distribution, of which the literature is rich in, albeit, different names and acronyms are used depending on the area of research. For more general freight literature, Olsson and Woxenius (2012) mention freight consolidation centres, while Bubholz et al. (2015) use logistics centre. For freight distribution in an urban environment, the literature mentions urban consolidation centres (Browne, Allen & Leonardi, 2011; Allen et al., 2012) or urban distribution centres (Sopha et al., 2016). In construction-specific literature, the terms construction logistics consolidation centre (Robbins & Thomas, 2013) or construction consolidation centre (Browne, 2015; Lundesjö, 2015) are used. However, the concept remains the same objectively of the industry or freight composition; to offer storage and consolidation of materials or goods at a remote location that can easily be accessed.

**Figure 2.2** Overview of the operations of CCC. Adapted from Lundesjö (2015, p. 226).



An overview of the basic operations of a CCC is found in Figure 2.2, where the CCC is located off-site, ideally located within a 30-minute radius with access to major highways (WRAP, 2011). Suppliers deliver to the CCC, where shipments are consolidated and dispatched by a single truck (Lundesjö, 2015). To appropriately fit an urban environment, the truck responsible for the final leg of the route can be smaller, or fitted with special loading equipment, e.g. a crane if shipments need to be lifted into the construction site. However, it is important to note that not all shipments are consolidated. Some shipments are delivered directly to the construction site, e.g. trucks that are already full. It is also important to incorporate the reverse flow of goods in the CCC-setup, with sufficient handling inside the premise of the site and at the terminal.

CCC offers plenty of benefits. Not only does it allow for more storage capacity, it also makes sure that materials are stored in the right condition, sheltered from weather or temperature changes (Bubholz et al., 2015). Shipments are consolidated by professional personnel, leading to better utilization of vehicles with improved loading factor (Browne et al., 2011). Fewer trucks needed mean fewer deliveries to the site. With a CCC in the proximity to the site help when dealing with unexpected events occur or with short-term changes in material demand (Robbins & Thomas, 2013). Night time deliveries are more accessible since site deliveries are no longer restricted by the supplier's delivery hours. This also helps for better implementation of just-in-time (JIT) coordination (Mossman, 2008).

In a degree project paper, Ekerlund and Stuhmann (2003) set out to calculate the environmental benefits of the operations of the Hammarby Sjöstad LogistikCenter (HSLC) consolidation centre. The HSLC was jointly operated by the participating contractors and the city of Stockholm, in the construction of 8.000 residential dwellings in the Hammarby Sjöstad project. The project started in 2001 and was expected to finish a decade later. Emission targets had been set prior to the start of construction. To reach these goals, the HSLC had three main objectives; to offer consolidation and storage of material deliveries using a terminal in the

local area, to plan and coordinate delivery bookings through an online platform, and to provide trucks equipped with special exhaust system to lower the emissions of deliveries within the Hammarby Sjöstad area.

The HSLC consolidation center generated low environmental economic gains, albeit, the project resulted in many improvements regarding lower emissions (Ekerlund & Stuhmann, 2003), and the results appear to be in line with much of the discussed literature. The consolidation of goods reduced the number of vehicle movements within the construction area, which in turn, led to a cleaner local environment with less air and noise pollution and improved local mobility. The results further point out that the HSLC contributed to reduced waste generation and less damaged material.

In 2005, the 2-year trial of the London Construction Consolidation Centre (LCCC) started, and like the construction of the Hammarby Sjöstad, the aim of the LCCC was to supply an entire block of multiple construction projects simultaneously (Allen et al., 2014). The project was jointly operated by a group of industry actors, and logistics and site management specialists (Transport for London, 2008). The objective of the collaboration was to investigate the benefits of such an operation, and to create a valid business case for the industry to adopt. The LCCC supplied four major construction sites in central London (Transport for London, 2008). The warehouse building was acquired through a short-term lease agreement, and was localized approximately 3.5 kilometers (2 miles) in South-East London. Contractors would order material in the usual way, normally direct from the suppliers, which in turn were instructed to deliver to the LCCC, where goods were handled, checked and stored by dedicated personnel. An own vehicle fleet distributed material JIT to each specific construction site.

Results from the project show that the LCCC project was successful. The setup with the CCC reduced the number of vehicle movements by 60-70 per cent according to Transport for London (2008), which is a substantial reduction. It should be noted that the setup allowed some shipments to be delivered directly from the supplier, bypassing the LCCC and a potential consolidation. The project further contributed to a delivery precision of 97 per cent. And with incoming material deliveries arriving JIT construction workers spent less time waiting for orders to arrive, which improved on-site productivity.

### 2.3.3 Construction logistics plans

To support better planning and coordination of vehicle movements in combination with construction projects, and to minimize negative impact on the local environment, the Transport for London (2013) developed the CLP framework for the U.K. construction industry. The CLP is a document that explains the expected and/or full detail of the logistics activity of a construction project. It should include a description of how material delivery will be booked and managed during a construction project, and it is becoming a requirement for the builder to submit. It helps the main contractor, and all project participants, to better plan and coordinate the logistics activities, ensure safety on and off-site, as well as a tool to inform the local stakeholders (e.g. local authorities, residents and business-owners) how much the project will interfere with the daily life in the local area. With better planning the CLP framework can help reduce local congestion, to achieve improved climate goals, and

minimize disruptions to the construction workflow. Transport for London (2013) presents an overview of the contents of a CLP document in Table 2.1.

**Table 2.1** Example of the contents of a CLP document (Transport for London, 2013, p. 6).

<b>Section</b>	<b>Description</b>
<i>Overview</i>	Brief description of the project, site location and the development phases Summary of the phases and the construction techniques used
<i>Introduction of the supply chain</i>	Incoming material flows Waste material reverse flows Primary products description: Source Mode of transportation Waste recovery Integration and consolidation with nearby construction projects
<i>Planning of the supply chain</i>	Expected type of material used Use of CCC or prefabrication Integration with nearby construction projects Route planning Staff travel arrangements

According to Robbins (2015), the U.K. construction industry has not yet fully adopted the CLP framework despite the potential benefits that come with it. Local authorities state different requirements regarding main contractors to produce a CLP (Transport for London, 2013). It does not just allow for better planning, but it also acts as an important local guidance for the project participants to acknowledge and focus more on the logistics activities, as well as an educational tool that explain the current logistics set-up (Robbins, 2015). For instance, the CLP could contain an overview of the logistics operations when using a CCC, or an overview of the special material ordering process if the construction site is managed by a TPL provider. If special equipment is required for offloading, then this information is noted in the CLP. This is especially important for new subcontractors or subcontractors that are only active for a short period. Hence, CLP act as an important document to improve the integration between site participants.

#### 2.4 Stakeholders of urban construction

The impact construction has on the society cannot be overestimated. In 2015, the industry accounted for 5 per cent of Sweden's GDP (SCB, 2016a). A majority of the investments took place in the most populated counties, Stockholm (37 per cent), Västra Götaland (16 per cent) and Skåne (12 per cent), as a direct consequence of the population growth concentrated in these regions (Sveriges Byggindustrier, 2015). Not only does the industry provide residential

buildings, but also the infrastructure and facilities for services needed in the community. However as has been described throughout this thesis, the industry suffers from low productivity which is partly explained by poor logistics performance, thus, better logistics is a means to make the industry prosper.

Industry development as part of city development cannot be discussed without the inclusion of sustainable development which is an integrated part of every modern city today. Only by meeting “(...) the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987, §27) can industries prosper with the acceptance from stakeholders. It is rational to believe that the survival of the planet should be in everyone's interest, however as companies survive by profit and are dependent on social structures it is essential to integrate the environmental aspects with economic and social as well, which is the fundament of the triple bottom line (Elkington & Burke, 1998). The Global Alliance for Buildings and Construction (GABC) argues that the opportunities for the construction industry for sustainable development by following the triple bottom line are immense. By reducing the environmental impact and improving health and the society, companies can reduce cost and in the same time improve its image (GABC, 2017).

GABC was founded to speed up the transition to more sustainable practices within the construction industry, since approximately 30 per cent of global greenhouse gas (GHG) emissions are buildings-related, and continuously growing (GABC, 2017). The goal is to reach the 2-degree target in 2050, however a major problem identified by GABC is the lack of stakeholder engagement and governmental policies. Tools and techniques to deal with construction logistics in a more efficient manner exists but are evidently not fully exercised, which gives reason to present how industry development by improved logistics performance creates value for all stakeholders involved, a need also highlighted by Robbins (2015). During a construction project, multiple stakeholders are affected, either for the better, or for the worse (Olander, 2007; Isaacs et al., 2010), and as urban construction involve more risk, the need for stakeholder interests' involvement is even greater (Isaacs et al., 2010).

There are mainly two definitions of stakeholders that are discussed in the literature. The first being Stanford Research Institute's definition, traced from a memo from 1963 and first cited by Freeman (1984, p.31-32) which identify stakeholders as “(...) groups without whose support the organization would cease to exist”. Contrasting to this constricted definition, Freeman (1984, p.46) develops the definition and offers a generous scope for stakeholders as “(...) any group or individual who can affect or is affected by the achievement of the organization's objectives”. While the first is commonly viewed as too narrow, the latter is often argued to be too wide (Philips, 2003; Sternberg, 1997; Mitchell, Bradley & Wood, 1997). In this study, the latter definition acts as a guide, thus urban stakeholders of construction projects can be almost anyone.

Winch (2002) offers an overlook of potential stakeholders of construction projects in general, as described in Table 2.2. This description is detailed and will be used for developing the urban stakeholder impact framework in this chapter. Stakeholders are divided into internal and external (Winch, 2002). Internal stakeholders are those who have contractual arrangements within the project, while the external stakeholders have other stakes involved.



Internal stakeholders are separated by demand and supply side, and external stakeholders are broken down to private and public.

**Table 2.2** Overview of construction industry stakeholders. Adapted from Winch (2002, Figure 4.1).

Internal stakeholders		External stakeholders	
<i>Demand side</i>	Client Sponsors Financiers Client's employees Client's customers Client's tenants Client's suppliers	<i>Private</i>	Local residents Local landowners Environmentalists Conservationists Archaeologists
	<i>Supply side</i>		Consulting engineers Principal contractors Trade contractors Material suppliers Employees of the above

On the demand side, it is by nature the client that is the voice of all stakeholders, since the client employ, supply and finance the project (Winch, 2002). Still, the demand side represents a wide range of stakeholders which unarguably could have different opinions and expectations, for instance regarding functionality or budget, which can result in problems at later stages in the project. In contrast to the demand side, the actors on the supply side are more prone to care about their own success, than perhaps the client's wishes. This is most apparent amongst the firms that thrive for reputation, e.g. architecture firms, who could try to direct the design towards something that would improve its reputation. Overall, there is an ongoing conflict between the supply side and demand side, that concern cost and revenue, and an ongoing work to stabilize that, to create the best scenario for both sides.

The most striking difference between internal and external stakeholders is that some external might not even approve of the project, or at least be indifferent about it (Winch, 2002). That creates other sorts of tensions. Within even the same interest group, there can be multiple opinions due to, e.g. proximity to the project or different underlying principles. Public stakeholders tend to approve on projects if they are in line with all legal requirements, however there are also situations where they try to push the development of cities. In some cases, lack of coherence within the public organ can appear, as different entities have different agendas and objectives.

2.5 Possible effects of construction logistics

To assess how efficient construction logistics contribute to a more sustainable environment for urban stakeholders, this chapter outline the impacts (grouped into economic, environmental and social) construction logistics has on urban stakeholders.

2.5.1 Economic

There are several economic benefits of using more efficient logistics practices. It can increase productivity (Lindén & Josephsson, 2013), lower the total cost of building (Sveriges Bygginstitut, 2016), become a competitive advantage (Olsson, 2000) and increase

innovation (Hulthén et al., 2017). Because the construction industry is such a large employer and developer of cities, it is also very much in the interest of national and local authorities that the industry prospers in the right direction (Sveriges Byggindustrier, 2016).

The initial cost for adapting to new methods can be high, but will gradually be offset with greater cost savings in the long run (Lundesjö, 2009). Sveriges Byggindustrier (2010) presented a project that reduced the total building cost by 20 per cent by improving the logistics operations. For instance, waste due to defects is estimated to represent 6-11 per cent of the total project cost, hence by minimizing waste, there are great savings potential (Josephson & Saukkoriipi, 2007).

It is commonly said that the construction industry is customer focused, however when looking at the numbers on waste from different projects, it can be questioned if this is true, since it is ultimately the customer who pays for the wasted material and time (Josephsson & Saukkoriipi, 2007). For instance, material suppliers tend to keep an unnecessary high service level towards the contractors, which consequently reflects on the price due to cost of stock keeping at the supplier's (Hulthén et al., 2017). Additionally, on typical construction projects, on-site workers can be disrupted multiple times per day, to help unload materials, move materials or stumble over material that have been ordered in excess and well in advance (Lindén & Josephsson, 2013). By implementing more sophisticated planning for logistics, these disruptions can be minimized extensively, and the construction workers can focus on completing the project, thus the productivity will increase, which ultimately should benefit the client.

The material suppliers could arguably be worse off by improved logistics performance of their customers, as the nature of over ordering, not demanding efficient packaging and ignorance towards transportation cost, would be reduced. A study from Thunberg and Persson (2014) found that only 40 per cent of the material deliveries to construction projects were accurate in terms of time, quality, volume, and documentation. However, the lost profit could be mitigated by the opportunity for the suppliers to add value to the products by efficient packaging and extra services (Hulthén et al., 2017), thus the change enables business model innovation (Chesbrough, 2010).

Since 2015, the demand for green buildings has increased dramatically which indicates the increased awareness amongst clients of sustainable buildings as a means of creating a green image (Dodge Data and Analytics, 2016). This illustrates that contractors build what the customer wants, hence could also adapt to more sustainable building practices, if only the customers asked for it (IVA & Sveriges Byggindustrier, 2014). Moreover, as cities strive to become more sustainable, and urbanization limits space available, those companies that have a deliberate logistics plan, will also have a competitive advantage in the future (Dodge Data and Analytics, 2016; Tan, Shen & Yao, 2011; Olsson, 2000).

### 2.5.2 Environmental

The environmental impact of construction is severe as the industry by nature is not environmentally friendly (Shen & Tam, 2002). Therefore, by increased resource allocation, several environmental footprints can be reduced. The construction industry is responsible for affecting wildlife, causing pollution (Curran & Spillane, 2016) and congestion (Kim &

Kim, 2010), changing land surface and air temperature (Weng & Yang, 2004), while creating substantial amounts of waste (Stubbs, 2008).

It was long estimated that the environmental impact occurred mainly during the use of the building. However, recent research from Swedish construction suggest an equal impact deriving from the construction phase as the using phase, which is a result of performed energy efficiency in the built houses, together with neglected energy efficiency in the building process (IVA & Sveriges Byggindustrier, 2014). Goods are transported inefficiently at long distances, machines and equipment on the sites are often run with non-renewable fuel and much energy is needed for the dehumidification process which is becoming increasingly shorter as the time has such significance for the success of the projects. In 2012, the construction industry accounted for 17 per cent of the total CO<sub>2</sub> emissions in Sweden.

A large concern about construction work amongst local residents is the traffic (Spillane et al., 2013). The uncoordinated material delivery that is currently representative of the construction industry, results in higher congestion on and off sites (Pheng & Chaun, 2001; Kim & Kim, 2010) as the heaviest truck movement on the construction site often is at same time as the heaviest city traffic (Ekeskär & Rudberg, 2016). In addition, the lack of planning for construction worker commutants adds to the already congested urban areas (Spillane et al., 2013). By reducing the number of vehicles entering the sites, the negative impacts transportation has on cities will be reduced. Thus, except from less greenhouse gas (GHG) emissions and congestion, there will be less noise, air pollution, visual intrusion, less resource exploitation by reduced fuel consumption and less safety risks (Allen et al., 2015).

Noise levels from construction is hard to control, and can cause major dissatisfaction amongst nearby residents (Spillane et al., 2013). It causes great annoyance and can result in problems with sleeping, communication and concentration amongst other risks (Piecyk et al., 2015). Furthermore, employees and local residents are also affected by vibrations and dust that results from construction work (Curran & Spillane, 2016).

In addition, waste generation is a large problem in the construction industry. Based on U.K.-statistics report that the industry stands for 24 per cent of the total waste of the country, where 13 per cent of that is not even used material, hence a result from poor material planning and handling (Stubbs, 2008). Lindhe's (1996) study revealed that between 4-21 per cent of the material ordered to construction projects went to waste. As material is delivered ad-hoc and often in too large quantities to the sites, they are exposed to damage due to weather conditions and poor packaging (Lindén & Josephsson, 2013). Furthermore, the lack of control and supervision of material on the site results in disappearance and theft of goods (Josephson & Saukkoriipi, 2007). Thus, the material cost increases as well as the amount that goes to landfill (Lindén & Josephsson; Formoso, De Cesare & Isatto, 2002).

### 2.5.3 Social

Effective logistics has a major stake in improving the health and safety for multiple stakeholders (Behm, 2005; Curran & Spillane, 2016) as well as increased living comfort by the nearby residents (Spillane et al., 2013). A construction worker confronts many riskful situations in the daily work, that can lead to accidents or in the worst case, fatalities (Behm, 2005). Not only is this devastating for the people occupied in this industry, but it also has

costs related to it, thus the planning for a safer material supply should be a top priority amongst most stakeholders (Pinto, Nunes & Ribeiro, 2011).

Furthermore, the local community find it troublesome when sufficient sidewalks are not provided, when the regular ones are occupied by the construction project. Also, traffic disruptions by road closures and temporary access are typical external effects of construction projects (Curran & Spillane, 2016). Mitigating traffic, noise vibration and dust will improve the environment but also the social impact, by reducing the health and safety risks, on and off site, thus actions that help to achieve this should be favored, also by the public stakeholders (Curran & Spillane, 2016).

Moreover, urban construction projects cause dissatisfaction of surrounding esthetics and comfort in living, which can arise because of unnecessary signs, walls, fences, waste etc. that often is assembled for a purpose but is not dismantled when the purpose is fulfilled, leaving the construction site untidy and taking up unnecessary space (Spillane et al., 2013). By carefully managing the surrounding esthetics of the construction project, the negative impact on urban stakeholders' comfort of living can be mitigated.

## 2.6 Summary of the literature review

The literature review starts by briefly discussing the logistics' role in supply chain management. It continues by focusing on the construction supply chain and what sets it apart from the 'traditional' production supply chains, by addressing some of the challenges that are typically found in construction projects. A summary of the most important topics discussed in the literature review on construction supply chain challenges and solutions is found in Table 2.3.

**Table 2.3** Summary of the challenges of construction supply chains and how to mitigate them with logistics solutions.

<b>Construction supply chain challenges</b>	<b>Author(s)</b>	<b>Results</b>	<b>Possible solution (based on the literature review)</b>
High level of inherent complexity	Gidado (1996); Vrijhoef & Koskela (2000)	Poor coordination and execution of internal processes  Difficult to optimize internal processes	TPL provider
Loose couplings between external supply chain actors	Dubois & Gadde (2002)	Difficult to optimize delivery processes  Difficult to utilize JIT delivery	CCC
Fragmentation of actors	Dainty et al. (2001a); Behera et al. (2016)	Obstruct coordination of project participants  Difficult to implement standardized procedures that are followed	TPL provider  CLP
Temporary supply chain	Baccarini (1996); Vrijhoef & Koskela (2000); Bygballe & Ingemansson (2014)	Short-term optimization  Lack of innovation diffusion	Not found

The second part of the literature review discusses the role of stakeholders and how they are affected by the construction industry. As has been outlined, the implications from urban construction projects goes far beyond the sites and affects more people than the client, main contractor and workers of the site. Urban stakeholders are many and have varied objectives, however it can be said that when the industry prospers in a sustainable way, urban stakeholders generally benefit. The literature describes several benefits related to construction logistics, which captures all three categories of sustainable measures (economic, environmental, and social). Table 2.4 lists the potential sustainable effects when construction companies adopt to more efficient construction logistics.

**Table 2.4** Summary of the sustainable impact from construction logistics.

<b>Sustainability measures</b>	<b>Potential effect</b>	<b>Author(s)</b>	<b>Stakeholders affected</b>
<i>Economic</i>	Increased labour productivity	Lindén & Josephson (2013)	Mostly Internal
	Lower cost	Lundesjö (2009); Sveriges Byggindustrier (2010); Josephson & Saukkoriipi (2007)	
	Competitive advantage	Dodge Data Analysis (2016); Tan et al. (2011); Olsson (2000)	
	Innovation	Hulthén et al. (2017)	
<i>Environmental</i>	Less pollution	Curran & Spillane (2016); Weng & Yang (2004)	Mostly External
	Less congestion	Pheng & Shaun (2001); Kim & Kim (2010); Spillane et al. (2013)	
	Waste reduction	Stubbs (2008); Lindhe (1996); Lindén & Josephson (2013); Formoso et al. (2002)	
<i>Social</i>	Improved health and safety	Behm (2005); Pinto, Nunes & Ribeiro (2011); Curran & Spillane (2016)	External and internal
	Higher comfort of living	Curran & Spillane (2016)	

The body of construction logistics literature has been growing since the beginning of the 21st century. It is possible to divide the literature from the literature review into two distinct categories of research. The first category, and perhaps the majority of the presented research, originates from supply chain management literature. The second category of research originates from the field of logistics literature. What these two bodies of literature have in common is that they show examples of an industry that is struggling to optimize supply chain processes while lacking a focus on logistics activities. Thus, the construction industry is facing issues with productivity, inefficiencies and waste generation. Another interesting factor to consider is how surrounding stakeholders are negatively affected by suboptimal construction supply chains, especially in urban environments where efficient construction is particularly hard to achieve. Therefore, the purpose of this thesis is to investigate how and why construction companies can solve some of the above issues by giving logistics more room in the industry.

### 3. Research Methodology

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*This chapter accounts for the methodology used to conduct this study. It starts with a discussion around the research philosophy appropriate for this type of research, by connecting it to the aforementioned RQs. It continues with presenting the research outline, which is based on multiple case studies, hence, a qualitative method approach has been used to collect primary data. This chapter concludes with a discussion around the integrity and quality of this research method.*

#### 3.1 Research philosophy

An essential part of a thesis is to explain how and what the author(s) perceive as knowledge. This is because what constitutes knowledge, does not necessarily mean the same thing to everyone. Results can be interpreted differently depending on how the research has been conducted, or how the reader relates to knowledge. Therefore, explaining the epistemological orientation, that is, how researchers behave around knowledge (Bryman & Bell, 2015; Dawes-Farquhar, 2012), is a key step in the research process. By explaining the epistemological orientation of a thesis, researchers will argue how they perceive knowledge, i.e. the nature of knowledge or the sources and limitations of knowledge (Dawes-Farquhar, 2012). There are two main branches of epistemological orientations: positivism and interpretivism (Bryman & Bell, 2015; Dawes-Farquhar, 2012).

Positivism, which is deeply rooted in natural science, relies on the testing and development of theories (Bryman & Bell, 2015). Through research, scientists can create and strengthen theories by the testing of hypotheses. When hypotheses are tested, laws that help explain why certain events occur can be established. According to positivists, laws constitute knowledge. The main idea behind the epistemology of positivism is that knowledge originates from what can be measured and observed (Collis & Hussey, 2014).

A central idea of positivism is the principle of phenomenalism. This means that knowledge, or what can be referred to as knowledge, is dependent on human senses' ability to observe (Bryman & Bell, 2015). Theories that cannot be measured or observed are placed lower in the scientific pecking order. At the same time, the scientist is supposed to be emotionally as well as physically decoupled from the subject that is being observed, hence, positivistic research is characterized as value-free, and the researcher does not interfere with the research in any way.

With the development of social science, the shortcomings of applying a research approach clearly influenced by the logicity of natural science techniques became evident. Researchers, preferably from the field of social science and business, opposed the appliance of the positivism epistemological in social science context (Bryman & Bell, 2015), which lead to some criticism towards positivism. According to Collis and Hussey (2014), the description of a value-free researcher only exists as a concept. It is not possible for a researcher to be truly objective, as interests and values will unintentionally interfere with the research. This criticism is valid even when applied in a natural science environment. Furthermore, the positivistic research design is thought to be clearly mapped out and structured, and deviations from the original research process are not allowed (Collis & Hussey, 2014). This may result in

other relevant findings being disregarded. Hence, a strict positivist epistemology does not suffice when studying a social environment.

As a consequence of the lacking ability of positivism when trying to understand and explain social science environments, another methodology that would constitute a second research philosophy was developed (Collis & Hussey, 2014). Opposed to positivism, which is traditionally rooted in natural science, interpretivism originates from the social science (Bryman & Bell, 2015). According to interpretivists, knowledge is the result of a subjective interpretation of data, through interaction with participants (Collis & Hussey, 2014), and contrary to the axiological stance of objectivity, interpretivism embraces the need for subjective interpretations of social interaction, which will lead to a deeper understanding of the studied event (Dawes-Farquhar, 2012).

The ambition of this thesis is to find answers the following research questions:

**RQ1:** *What are the barriers and incentives for construction companies to implement more efficient construction logistics?*

**RQ2:** *How can construction consolidations centres (CCC) contribute to a more sustainable environment for urban stakeholders?*

**RQ3:** *How can more demanding requirements on logistics ensure efficient construction logistics?*

The research questions have deliberately been formed in a way that would require a research methodology that follows the assumptions behind interpretivism. The reason behind this rationale is twofold. First, it is common to see similar approaches in logistics research. Second, construction projects are characterized by high supply chain complexity. In addition, construction projects are often treated as isolated companies with very low degree of interaction or sharing of knowledge with other projects. A research approached based on positivism would tell very little about construction projects in general. Understanding how efficient construction logistics can be used in construction projects require a method that can go beyond what is quantitatively measurable. Therefore, this thesis takes a strong interpretivist stance.

### 3.2 Research approach

According to Bryman and Bell (2015), research impacts theory in two ways: collected data can be tested using pre-existing theories, or, data is collected to create new theories. The first relationship between research and theory refers to deductive theory, while the latter refers to inductive theory. By making a conscious decision in either direction, and by acknowledging the difference of the two research logics, the researcher can minimize the risk of making mistakes, while strengthening the integrity of the study (Dawes-Farquhar, 2012).

But it is incorrect to say that research can exclusively be either deductive or inductive. Research is often influenced by both the deductive and the inductive approach (Bryman & Bell, 2015). Abductive reasoning is a third research approach, which forms a bridge between



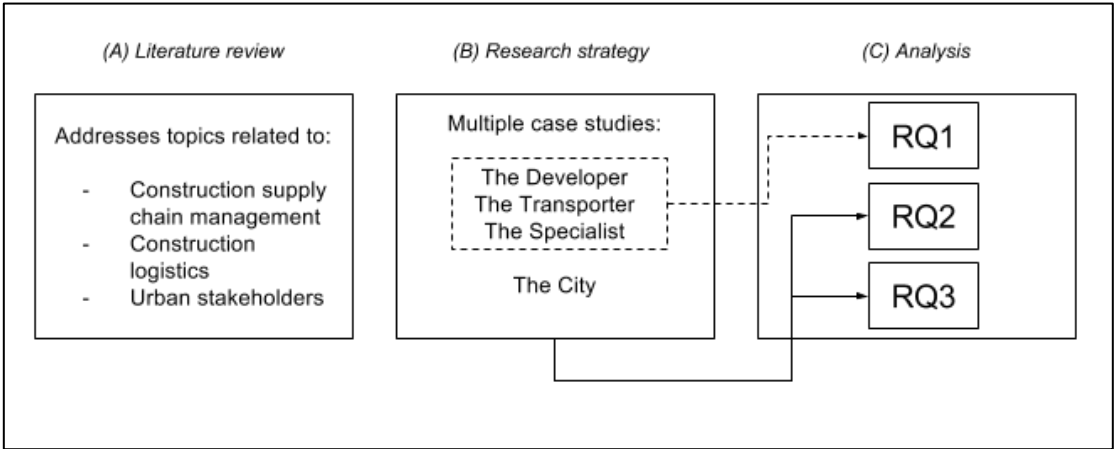
deductive research and inductive research, allowing the researcher to move back and forth between theory testing and theory developing (Dawes-Farquhar, 2012). Abductive reasoning starts in theory with the identification of a phenomena of which the researcher is trying to understand, but still allow for building new theories. The abductive reasoning approach has become frequently used in case study research.

The main objective of this thesis is to answer the above research questions by analyzing the results from multiple case studies. To successfully achieve this, it was a prerequisite to gain a thorough understanding by conducting a literature review based on the current body of literature. By acknowledging prior research as a first step, this thesis begins using the deductive approach. But unlike the deductive research approach, this thesis continues to add to research by displaying conclusions about the empirical findings, like the inductive research approach. It is not possible to claim the underlying research approach to be strictly in one way. Therefore, the research approach behind this thesis is best explained as abductive reasoning.

### 3.3 Research design and outline

The research design and outline consisted of three objectives which are visualized in Figure 3.1. The first objective (A) was to establish a conceptual framework. A literature review was conducted to understand the environment of construction logistics. The literature review acts as the theoretical background of this thesis. The second objective (B) was to establish a research methodology and strategy that would suffice to answer the research questions. For the sake of this thesis, an empirical study was conducted from multiple case studies using semi-structured interviews. Each case study represents a different actor in the construction industry, thereof they have received an individual title that help to keep them separated throughout the thesis; the Developer, the Transporter, the Specialist and the City. Finally, the third objective (C) was to interpret the results from the study and to answer the aforementioned research questions. The results from the Developer, the Transporter, and the Specialist have been used to answer RQ1. All four roles have been used to answer RQ2 and RQ3.

**Figure 3.1** Research objectives and design.



This cross-sectional research has investigated construction logistics in four different contexts, thus by four different case studies (Yin, 2014). It was suitable to conduct case studies as they

are particularly useful when the researcher is in pursuit of capturing real-world events in depth. The study objects were divided into different case studies because they are separated and represent different roles in the construction supply chain. Conducting *multiple* case studies in the same research is useful in the search of replication across cases (Yin, 2014). In this context, replication can take two forms. If similar case studies are predicted to provide the same results, it is known as literal replication, and if cases with varying underlying contexts are predicted to provide different results due to that is known as theoretical replication. When the results are as predicted, and both replications take form, the results should unarguably be very strong. This is an important aspect considering the generalizability of this research because the construction industry is very project-specific.

### 3.4 Secondary data collection

The literature review is based on secondary data, which were mainly collected from published articles sourced electronically using the University of Gothenburg library search engine. The search engine allowed to systematically sort out relevant articles by searching for specific keywords such as “construction industry productivity”, “construction logistics” and “construction supply chain management”, in renowned research databases, e.g. Emerald and Business Source Premier. Articles were critically assessed by relevance to topic, quality of journals and times cited, which are recommended criteria to determine trustworthiness of articles (Yin, 2014). Abstracts were first screened to select those that were relevant enough to keep and read thoroughly and the keywords became more specific as the literature review became deeper. Furthermore, the methodology and purpose of the studies were carefully reviewed to understand the validity, reliability and generalizability of the results. Articles were also found based on the recommendations from other articles. The process of collecting secondary data came to the point when articles and other sourced material shared a lot of references. It suggests that the collected literature had been sufficiently reviewed to back up the research (Yin, 2014).

### 3.5 Primary data collection

The primary data were collected through semi-structured interviews with people of different professions in construction, logistics, and traffic planning. The interviews provided in-depth knowledge and opinions about *what* is currently done in construction logistics, and *how* that affects supply chain actors, urban stakeholders and the construction industry. Answering “what” and “how” questions are typical for exploratory research (Saunders, Lewis & Thornhill, 2016). To gain deeper and wider knowledge about a subject, semi-structured interviews are preferred. In contrast to structured interviews, which leave little room for deviations from the predetermined interview guide, semi-structured interviews give the researcher freedom to adjust the questions throughout the course of the interview and to ask follow-up questions. This way, the researcher can control the direction of the interview to get the most valuable information out of the interviewee. On the other hand, semi-structured interviews are preferred over unstructured interviews when there are some topics that must be covered to be able to answer the research questions.

The interview respondents were selected by the snowball/networking method, i.e. they were introduced or passed on by someone in contact with the researchers beforehand (Collis &

Hussey, 2014), by the premise that they could provide useful knowledge about the topic of research. An overview of the interviews is shown in Table 3.1. Three out of four interviews were conducted in Swedish and took place at the interviewee’s offices, hence, the interviews are categorized as face-to-face interviews. Two of the face-to-face interviews are labeled “Group” because they involved more than one interviewee and one interview was conducted in English over telephone. All interviews were recorded with permission from the interviewees.

**Table 3.1** Overview of interviews.

Company	Interviewee	Position	Type	Date	Duration (approx.)	Language
Skanska AB	Jon Svensson	Logistics Manager	Face-to-face Group	17-01-31	2 h	Swedish
	Henrik Liljedahl	Production Manager				
Fraktkedjan Väst AB	Jaana Rankanen	Environmental and Quality Manager	Face-to-face	17-01-30	1,5 h	Swedish
Wilson James (the U.K.)	Stephen Robbins	Operations Manager	Telephone	17-01-31	1,5 h	English
Trafikkontoret (city of Gothenburg)	Peter Näslund	Traffic Coordinator	Face-to-face Group	17-04-28	1,5 h	Swedish
	Pernilla Sott	Traffic Planner				
	Magnus Jäderberg	Freight Traffic Manager				

The interviewees all come from different fields, with different experiences of construction logistics, and could reflect on a variety of different projects. But more importantly, they contributed to this thesis by sharing their perspective on construction logistics since their respective organization are actors in construction supply chains. Each perspective work to complement the others to present a holistic view of construction logistics. Furthermore, each actor represents a case study in the thesis. The actors, based on the respective companies, are introduced below:

- Skanska AB is one of Sweden’s largest construction company in terms of revenue and capacity. Skanska takes the role of a main contractor in the construction industry, and will hereinafter be referred to as *the Developer*.
- Fraktkedjan Väst AB is a haulage contractor with great experience from working with customers in the construction industry, amongst other industries. Fraktkedjan Väst supplies transportation solutions, and will hereinafter be referred to as *the Transporter*.
- Wilson James is a U.K.-based logistics, security and business service provider specialized in construction logistics. Wilson James offers complete logistics services to construction projects, and will hereinafter be referred to as *the Specialist*.

- Trafikkontoret is the local authority for transport in the city of Gothenburg, and operate with the mission to facilitate accessibility and connectivity in the city through the freight network, and will hereinafter be referred to as *the City*.

To avoid interviewer bias, a thorough literature review and an analysis of the respondents' profession and potential knowledge was conducted, which is recommended by Saunders et al. (2016). A mix of open, closed, probe and hypothetical questions were prepared before the interview, and e-mailed to the respondents. The respondents answered most of the questions during the interviews, although, some questions were left out and new questions were generated during the interview sessions. A selection of the discussed topics is presented below:

- The actor's role in the supply chain
- Managing construction logistics and the inherent challenges
- Coordination and consolidation within construction projects
- The impact of construction logistics on stakeholders
- Requirements on construction logistics

A complete interview guide covering all themes discussed during the interviews is found in Appendix 2.

### 3.6 Data analysis

The data were analyzed in accordance with Miles and Huberman's (2004) three-step method, where the first step is to reduce the data; the second step is to display it in a more comprehensive way; the third step is to draw conclusion and verify the validity of those conclusions. Reducing the data was a critical task as it consisted of six and a half hours of transcribed records, turned into fifty pages of text. To reduce the amount of data, a couple of themes were identified as recurring and followed to act as categories under which similar data could be collected. These categories were planning, construction logistics, infrastructure, consolidation, stakeholders and external requirements. Each case study had a separate spreadsheet in which all data was compiled under the different categories. From that point, the data was summarized and translated to turn into useful information that was easy to comprehend. Finally, the results were analyzed by comparing them to the results of the literature review. Similarities were discussed and labeled as verified findings and when differences occurred, the reasons for those were discussed. Before settling the data analysis, the conclusions were discussed with Viktoria Sundquist, senior lecturer and researcher at the construction management division at Chalmers University of Technology, who confirmed that similar results have been found from research carried out at the university.

### 3.7 Research quality

Research quality is typically measured by validity, reliability and generalizability. However, while these measures derive from quantitative research, it is important to distinguish what provides quality to a qualitative study (Saunders et al., 2016).

#### 3.7.1 Validity and reliability

Traditionally, validity deals with how suitable the method is to predict the outcome, correct interpretation of the findings and the level of generalizability (Saunders et al., 2016). Lincoln

and Guba (1985) express this as credibility and transferability. Credibility being the substitute to internal validity, and transferability the substitute to external validity. Credibility of this research is established by different means. The evaluation of the respondents' experience of construction logistics assured credibility of their answers. Furthermore, the profound review of the literature with carefully selected articles ensures fact-based interpretations of the data collected. Semi-structured interviews allow for follow-up questions and the ability to adjust questions in a way that ensures the respondent to understand the question the way it was intended. This is a great advantage when performing qualitative studies, which directly enhances the credibility of the research. Two of the interviews were performed in groups, which required focus from the interviewers to include all interviewees to the conversations, and by doing so the information will be enriched, which is one of the strengths with a group interview (Saunders et al., 2016). A disadvantage with the group interview, would be if the respondents felt uncomfortable sharing experiences in public. Furthermore, the dynamic could change since the respondents might have multiple roles in the organization, with opposing objectives. These kinds of problems were mitigated by asking more in-depth questions (Lee, 1993).

Reliability deals with consistency and level of replicability of the study (Lincoln & Guba, 1985). One major implication to the reliability when studying phenomenon in the construction industry, goes back to the temporary and myopic project-based aspect of construction projects. No project is treated the same, which implicitly results in new findings and other discussions. To provide sufficient level of reliability, each step of the research process is documented, including transcription of all interviews, summaries of all literature used and notes from internal and external meetings. Moreover, the respondents are presented by name in the report and the results from the interviews are well separated from other sources of information in chapter 4.

### 3.7.2 Generalizability and relevance

Generalizability is commonly claimed to be low in case studies (Dawes-Farquhar, 2012; Tsang, 2014), and for that reason the primary data have not been collected from a specific construction project in focus. Instead, the collected data is based on a general discussion of the research subject, by combining the views of different actors active in the construction industry. The combination of findings is a crucial step in multi-case study research because the level of generalizability can be stronger if some cases have matching results. Furthermore, by providing thorough descriptions of the different contexts found in the different cases, the reader is given the possibility to transfer the results based on that (Lincoln & Guba, 1985).

For the sake of comprehensiveness, this thesis is deliberately delimited to incorporate the Swedish construction industry. However, a discussion of whether this study is relevant to other countries is valid. Not only because one of the interviewees is based in the U.K., but from the fact that the findings from this interview witness of similar experiences as the findings from the Swedish case studies. The principles of the topics that are discussed in this thesis (e.g. the construction supply chain management, urban logistics, and urban stakeholders) are generally applicable, independent from the geographical location. With this said, the relevance of the results from this thesis should extend beyond the confinement of the Swedish industry.

## 4. Results

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*A qualitative research method was used in this thesis, whereof the results from the interviews are presented in this chapter. An overview of the interviews is shown in Table 3.1. Each interview is based on different actors of the construction supply chain, and is treated as an independent case study. Each respective actor has been given a role (see section 3.5) and the findings will be presented separately in the following order: the Developer, the Transporter, the Specialist, and lastly the City.*

### 4.1 Case study 1: the perspective of the Developer

The Developer is involved in two types of projects which are referred to as internal and external. Internal projects do not separate the client from Developer, while in external projects, the client is an independent entity by whom the Developer is appointed main contractor after a competitive tender process, and receives the main responsibility for the completion of the project. A cheapest-price-wins-approach is the norm of the tender process. The Developer coordinates subcontractors and suppliers to finish on time.

#### 4.1.1 Managing construction logistics and the inherent challenges

The planning of the construction project starts when the Developer has been granted the contract of the construction project. A production manager is assigned by the Developer and takes full responsibility of the outcome of the project. With the responsibility comes a lot of freedom, hence, production managers are free to organize and manage projects as they see fit, often relying on past experiences and achievements. With this said, there is no standardized approach to managing construction projects, instead, the planning stage of the project is very much dependent on the production manager. And while some production managers appreciate a high degree of planning of activities, some production managers appreciate a more flexible planning in that sense and relies on solving problems when they arise. The same goes for using internal support functions that are provided by the Developer.

One of these support functions is the logistics department which is a standalone unit that oversees all flows of materials to the projects, which requires a close connection with the procurement division. However, the level of interaction with each construction project is not obvious. It is up to the production manager to make the decision to involve the logistics department in the project, albeit, the logistics department will inevitably be involved in every project but only to a certain degree and only the production manager has the power to involve the logistics department at an early stage. Not all projects discuss logistics before the project initiates. Sometimes, the logistics department is first contacted when logistical issues arise, which could be some time midway through the project. In projects where the logistics department has been highly involved, a dialogue between the production manager and the manager of the logistics department starts a couple of weeks before the project initiates. The result of the discussion is a preliminary logistics plan.

Questions that arise from the early discussion with the production manager and the manager of the logistics department are regarding which suppliers to use and what types of transportation that will be needed. As the development of the project gets finalized, more information gets available and more specific decisions can be made. One of the first things to

discuss is also how to plan and manage the delivery of prefabricated building materials, since these are the first materials to arrive. Roads are planned, off-loading zones and temporary storage areas are mapped out, typically by making a simple sketching on a piece of paper.

Once the project starts the construction process advances in a systematic order. The project is divided into partitions, where each part contains a number of apartments. This approach allows for a stable production rhythm, and it is easy to get an overview of what is being produced at what time. When the system is working ideally, each apartment serve as its own storage area. This can be achieved by lifting construction materials into each apartment before the above floor has been installed. The subsequent floor works as a lid and construction workers can proceed by continue producing the inside of the apartments.

One distinct characteristic of the construction industry is the temporary process of construction as projects are only active for a limited time, which leave little room for improving any activity. This is often compared to the manufacturing industry, where the process of production allows more space for improvements and adjustments due the highly repetitive and long-term time frame of mass production. Despite the differences, the manager of the logistics department thinks that logistics planners at construction sites need to look beyond managing only the traditional unloading patch, and look at the whole supply chain and adjust it to the specific needs of the project. The goods are not delivered until they are in the exact right spot, which in housing construction projects mean the correct apartment number.

To be able to do this efficiently, the suppliers needs to specify how they package and mark the goods, so they can easily be identified by the goods receiver. It works well in internal projects, where it is easier to foresee long-term relationships with the suppliers. However external projects leave less room to choose suppliers, thus the process of collaboration and learning from each other starts over. The Developer is currently working with developing a label standard that can be used by all suppliers, that would allow each actor in the process of delivery to more efficiently interpret all necessary information of the where the shipment is wanted. The Developer has witnessed some resistance among its suppliers, but from experience, it usually takes some time before suppliers are convinced. It may sound as a trifle but the layout of the label is very important, as it may contain different types of information, such as the name of the project, address, building, floor level and apartment number.

What is also important for the efficiency of on-site distribution, is how to position shipments once it has arrived at the site. For instance, kitchens are normally delivered complete in bundles of pallets to the site, and then stored in the corresponding apartment. The installation process has been developed with care to simplify the installation process. First, pallets and boxes are positioned so that they do not interfere with the space left for the kitchen to be mounted in. Second, the pallets and boxes should be placed in the same order as the workers intend to install the cabinets (e.g. bottom cabinets are first installed from right to left). When properly executed it is an efficient method to deal with repetitive work. It saves time and improves the quality and performance of the process.

The internal know-how in logistics has developed rapidly the last five years, and is expected to continue to grow, as the need for sophisticated logistics increases due to shrinking storage areas at urban construction projects. But as has been outlined, it is up to each production

manager individually to decide how to manage logistics and the production managers are described as highly capable people with heavy responsibilities already. It is their responsibility to manage the budget, employees, health and safety, sustainable requirements, customer satisfaction and external stakeholder satisfaction. It is a complex role based on freedom and responsibility. The logistics department cannot force ideas on production managers, thus, the key for implementing new ideas or practices is the acceptance from the responsible production manager. Experienced production managers are highly demanded on the market, so pushing them too hard might be pushing them into another company.

There are alternatives for those production managers that want to use more sophisticated logistics practices. The Developer collaborates with a major international TPL provider which can supply a network of terminals, on-site distribution, and additional logistics services. It is important to note that the Developer does not own any infrastructure (e.g. trucks or terminals). Instead, the Developer owns the knowledge, processes and contracts that tie it all together. This provides a flexible organization, and makes sure that the Developer only pays for the used resources. In addition, the Developer has adopted a quite untraditional approach to procurement, which is to buy goods undelivered, thus they 'own' the freight. This gives them leverage towards the carrier which also owns the consolidation centres, which means that they can use these services cost efficiently.

#### 4.1.2 Coordination and consolidation within construction projects

The benefit of consolidated shipments became apparent from an example of a soon-to-be finished project. The Developer explained that instead of receiving 400 vehicles, the project introduced consolidated shipments, which resulted in only 60 deliveries to the site (a reduction of 85 per cent). If the work at the project was disrupted somehow, deliveries could be paused at the terminal by making one phone call. The ability to pause the work is very important, not only to make the time to correct mistakes that are made in the production process, but also because the construction site is exposed to the weather. Heavy snowfall will affect the ground operations at the site, e.g. offloading trucks, which will cause the production to stop because construction materials run out. Sometimes the work must wait for the snowing to stop before the site can be made accessible. Heavy winds may disable the tower crane - the heart of the site and the greatest bottleneck of the supply process - which also results in a total stop in the construction process. On a traditional site, there is less controllability of the inflow of material and with a stop in production, material would continue to pile up on the site.

The main concern in the above project was the high cost that came with the CCC-setup and the difficulty of assessing the potential savings. A reason for this is that the cost of transportation is not originally separated from the price, hence, each production manager needs to calculate the cost of using consolidation. However, the above example showed better financial result than expected, which is the most important part. How to practically solve the consolidation solution was never an issue since the only affected project participants were the suppliers. Instead of making deliveries at the site they were re-directed to the CCC.

Many people are involved in the decision about where and how to place the goods in the best way, regardless of whether there are external lifters/carriers or internal. Every time the goods are handled, they are put to risk for damage, hence it is important to plan and not stress it.



Consolidation involves one additional on and offloading, which could mean a risk for damage, however, the overall assessment of CCC is very positive, and much of the risks are eliminated. It enables flexibility, more time and higher productivity when there is no need to worry about incoming material. Construction workers can focus on the construction work and improve internal processes. For instance, the quality of the material is checked in the CCC, and if not up to standard, there is time to order new material. Moreover, they always know what is in stock and what has not yet arrived, thus the control is much higher.

#### 4.1.3 The impact construction logistics has on stakeholders

The Developer has noted several benefits from adapting to more efficient logistics practices, that goes beyond the focal company. Firstly, construction workers' health and work satisfaction can be preserved by better working conditions, including less carrying of material. Secondly, less transportation on and off-site reduce emissions and pollution which disturbs the workers but also the surroundings (it should be noted that no official figures in savings were discussed). Furthermore, less transportation reduces congestion in the cities, and minimizes traffic disruptions. In addition, better logistics planning allows for better control over the processes, thus the Developer can choose to pause or speed up operations if needed. For instance, if a crowd of people are marching towards a football game, and there are risks with executing certain lifts, there is a possibility to pause that. Altogether this creates a safer and more sustainable environment on and off sites.

#### 4.1.4 Requirements on construction logistics

When it comes to the tender process the lowest bidder is almost always awarded the contract, as price is still the most important factor for the client to consider. Occasionally, other specified factors can be found to be on an equally important level, e.g. not to disturb ambulances at hospital projects, but it is very rare to find anything related to the logistics performance during a tender process, at least up until just recently. The Developer has noticed a change towards more focus on logistics, especially in competitive tenders related to urban projects, and the manager of the logistics department has even been part of the group responsible for the tender proposal, which required an overview of the logistics activities at that project. Another recent achievement is how the Developer won a tender despite not being the lowest bidder. In that case, the presented logistics plan was highly appreciated by the client and the main reason why the Developer was awarded the contract. After the success from the aforementioned project, a potential requirement for producing a similar logistics plan (e.g something that resembles a CLP document) is welcomed by the Developer, who sees this as an opportunity to gain a competitive advantage over the competitors.

## 4.2 Case study 2: the perspective of the Transporter

The Transporter is a TPL provider with a wide range of customers from different industries, albeit, a large portion of the customers are typically found in the construction industry. The Transporter offers a variety of logistics services, albeit, the focus is on transportation and warehousing.

### 4.2.1 Managing construction logistics and the inherent challenges

The collaboration between the Transporter and the main contractor starts early. It is common practice for the main contractor to reach out to the Transporter even before the official tender

process is over and the contract has been assigned to the winner. This pre-contractual agreement is based on contingent cost calculations conducted by the Transporter, that may be subject to change as the details of the projects are published. In larger projects, much of the early talks are an opportunity for the Transporter to reassure the main contractor (or in some cases even the client) that sufficient capacity is available and to the project's disposal. It is often in the main contractor's interest to know if the Transporter can provide the right number of trucks, or in some cases, trucks fitted with adequate equipment.

Once the project has been assigned the main contractor, which in turn contracts the Transporter, the planning of operations follows the steps of the building process. In the early stages of the project, the construction site is usually excavated and prepared, leaving excessive ground materials to be transported away from the construction site to surrounding landfills. This process very much depends on the geological condition and the scope of the project, which means that the prerequisite of the planning varies from site to site. The capacity available is based on standard calculations made by the Transporter. These calculations are separated from other types of transports, such as distribution of building materials, that are initiated once the site has been cleared.

The dialogue between the main contractor and the Transporter builds up as the project progresses and continues throughout the whole project. Much of the collaboration focuses on practical issues. In some cases, more often in larger projects, a work and health plan needs to be established. This plan can contain a section that covers transport-related matters, which acts as a guide for the employees of the Transporter and all other project participants. It should cover all the questions that may arise under the construction. However, since most construction projects tend to encounter unexpected events, this plan is subject to change. Often the plan changes from day to day. Therefore, a tight dialogue with daily check-ups are crucial for the collaboration to be a success. This allows the Transporter to make immediate changes and to schedule next day's order bookings.

Construction logistics is very much dependent on the progress of the construction project, and the type of shipments alters as the construction phases change. In the early stages of the project, the Transporter knows that the main contractor will be busy with pile work or casting the foundation. From a planning perspective, this stage of the project is considered straightforward because the Transporter knows that the main contractor will only book certain types of shipments for a week or two at a steady and foreseeable pace. This workflow is similar to the Transporter's experience with customers from other industries, e.g. general freight distribution, where the shipments are scheduled in a fixed interval with low variation. The later stages of the construction process are prone to changes in the shipments which requires a lot more efforts in the daily planning.

Coordinating all transport bookings is described as a daily 'puzzle' that needs to be adequately solved to be able to attend all customers. However, construction-related customers are more prone to complications. Most of the Transporter's problems occur when the construction site cancels shipments, and trucks that have been on standby-mode, or even already waiting in the proximity of the site, need to find other shipments to transport to cover up for the running costs of the drivers. The same goes for when customers place orders on

short notice. The Transporter is bound by contracts to supply customers with trucks, hence, unexpected order bookings often force the Transporter to re-allocate capacity from other customers, or hire capacity from competitors. The two above issues appear to be characteristic of construction industry customers.

After the completion of a project the performance of the Transporter is evaluated. It is important that the Transporter delivered what was promised. The evaluation is mostly based on financial indicators, albeit, environmental accounting reports and quality reports may be a part of the evaluation. It depends on the customer and what is stated in the contract. The Transporter allows its customers to use a web-based system that helps to record all transactions between the two parties. The customer can easily be sure that all shipments have been delivered and signed for. The system allows for full transparency in the collaboration. However, a prerequisite to fully evaluate the project requires an original plan as a benchmark.

#### 4.2.2 Coordination and consolidation within construction projects

The Transporter operates several terminals (or CCC) which are included in the offerings to the customers. Shipments from suppliers are delivered and stored over the night and consolidated the next day. Every shipment is scanned upon arrival and when it leaves the terminal. The supplier sends an EDI file containing all ordered items. The crew at the terminal run this file against the items that have been scanned, to see if items are missing. This procedure ensures incomplete shipments to be found in time, which occasionally is the case. Once the shipment is complete it leaves the terminal. The Transporter strives to maximize the load factor and to send full vehicles. In some cases, it requires shipments to be consolidated with a mix of different customers, all bound for different locations. These vehicles operate on an assigned network route, making deliveries at each specific location.

There are also several restrictions that the Transporter needs to be aware of when planning the operations. Most urban areas (in Gothenburg) are classified as emission zones, which only allow vehicles that fulfil certain emission standards, e.g. EURO VI class registered vehicles. This is to minimize the amount of emissions in dense urban areas. Low emission zones must be regarded in the planning of shipments. Another restriction in urban areas is weight limits on roads. Depending on the condition of the road it can only withstand a maximum weight, to not damage the road, restrictions limit the amount of tonnage on each axle of the vehicle. The same restriction applies for longer items that need to be transported in urban areas where roads can be narrow. For these transports the Transporter must apply for certain permits that grants the carrier permission to use the entire road if necessary.

#### 4.2.3 The impact construction logistics has on stakeholders

For the Transporter to minimize its negative impact on the surroundings, it is important that the layout of the construction site has been optimized to ensure fast on and off-loading. This includes the condition of temporary roads to withstand heavy loads and to be mapped out properly to make it easy to navigate on and to the site. Adequately planned sites mean that the drivers can minimize the time spent on the site, which results in less burning of fuel and less noise. It is important for all drivers to be aware of the site, how to navigate the surroundings, to be aware of local restrictions, and if there are any changes throughout the course of the project. Meetings with the main contractor are often held in the initial stage of the projects to

discuss the layout of the site. Follow-up meetings are continuously held to update if any changes are made.

Another important aspect to consider when trying to minimize the drivers' time spent on site is the interaction between drivers and construction workers. For the deliveries to run smoothly, drivers and construction workers must cooperate, as on and off-loadings are done by the construction workers, e.g. backhoe or crane operators. The better relationship, the faster the driver can leave the site. At larger sites this can be a real challenge since there are more workers with different wills, which may give rise to disagreements, e.g. where to place offloaded shipments. This problem can be avoided by the Transporter to only use a couple of drivers that deliver to the construction site on a regular basis. Dedicating a driver that knows the site and the workers will ultimately lead to more efficient deliveries.

Not only do elongated deliveries consume more fuel, it also increases the risks of congestion at the site. Congestion around the site is highly unwanted. Not only because it has a negative effect on the income stream of the drivers, but also because it disrupts the workflow of the project, which result in an evil spiral of complications to the daily planning. The negative environmental effects (air and noise pollution were brought up) that idling trucks have on the surroundings when queuing is something that the Transporter is aware of. This is another reason why congestion at sites should be avoided as much as possible.

#### 4.2.4 Requirements on construction logistics

In project with public clients, the requirements on transportation and environmental impact is more detailed than usual, and the Transporter needs to report on those. The requirements are perceived as complicated and sometimes detailed instructions on how to measure and report are missing. The total environmental effect of consolidated shipments is complex to calculate; thus, one item may travel a longer distance than necessary, but the overall environmental impact by the Transporter is reduced because fewer deliveries are made (and fewer vehicles are used). If there would be higher environmental requirements, e.g. a demand to only use alternative fuels, the success would be constrained by the infrastructure that supply vehicles running on that fuel. If you need to travel an extra distance to fuel, the environmental gain might be lost. Higher external requirement on more efficient construction logistics would need a more open dialogue between the actors on the site, and a well communicated plan containing restrictions on deliveries.

### 4.3 Case study 3: the perspective of the Specialist

The Specialist is a TPL provider that is specialized towards construction projects. In addition to construction logistics, the Specialist offer services related to security management and project management.

#### 4.3.1 Managing construction logistics and the inherent challenges

The competitive tender process is a key moment that decides the project's future. In most cases the contractor with the cheapest bid wins, and even though the logistics is an essential part of the construction project, the value of logistics is often overlooked. Not just in the tendering process, but in construction in general. The Specialist explains four major reasons for why logistics has been largely neglected in the industry. The first reason is that the cheapest price often wins the competitive tenders, and the client just expects the main

contractor to manage the logistical problems within that budget. The second reason is that, generally, people in the construction industry does not understand logistics, because there is no clear definition of what it is. The third reason is that logistics is a hidden cost. Freight is often included in the price of construction materials. The same goes for the warehousing cost, since the suppliers normally deliver on an agreed upon date. This means that an assessment of the cost of using, e.g. a CCC is very hard to achieve successfully. The fourth reason is that main contractors, in general, have not understood the importance of a good logistics manager.

This is explained by the fact that construction supply chains are project-based. The composition of work teams and subcontractors tend to change between projects, which give little incentives to collaborate or to develop new ways of working. In addition, the construction supply chain is very fragmented. There is a huge gap between the few large companies and the small subcontractors in terms of capacity. Thus, there is a discrepancy between what the main contractor tells its clients that they are going to do, and what the subcontractors can do, e.g. in terms of applying for permits, or reporting. Furthermore, fragmentation in procurement exists, which the Specialist explains by exemplifying the building of a brick wall. If five different subcontractors are working on the brick wall, they might have ten different suppliers who decides to deliver ad-hoc, at ten different time slots. It is a simplified problem, but still a very characteristic description of the coordination of actors at the site. A CCC could easily mitigate the risk of having ten different deliveries to the site, according to the Specialist.

#### 4.3.2 Coordination and consolidation within construction projects

The Specialist provides services related to CCC, and based on experience, customers contact the Specialist when there is an increased need to control the inflow of materials to construction sites. The Specialist has mainly two types of customers. The first type is typically the main contractor of a major construction project with 20-40 subcontractors active on the site. Normally, the project has certain constraints, e.g. when there is a lack of space available for storing materials or equipment. It can also be special restrictions, e.g. the Specialist describes an ongoing university project where the everyday university activities cannot be disturbed. In this case, materials are stored at a terminal, until they are delivered into the sites in a controlled and efficient manner. The second type of customer is a construction supplier that lacks the required vehicles to deliver in central London, where restrictions on vehicles are plentiful. In this case, the customer deliver to any of the CCC operated by the Specialist, who then takes over the last mile of transportation.

The Specialist operates an IT-based delivery management system (DMS), where all subcontractors on the site are required to register deliveries from all their suppliers through a form. The form contains lots of information; suppliers need to specify what is coming, when it is coming, on what kind of vehicle, how many pallets, and what type of material. Generally, there is a two o'clock cut-off for next-day deliveries. After that, a delivery schedule for in and out deliveries for the next day is planned. From that the Specialist knows how many deliveries are expected and all additional information needed to effectively handle the shipments. Problems can arise when main contractors want to use their own proprietary DMS. To mitigate this risk, the Specialist has just recently put together a standardized process which

will require customers that want to use the LCCC (the Specialist is now the operator of the LCCC that was introduced in section 2.3.2) to use the same DMS as the Specialist.

Upon arrival at the CCC, the shipment gets registered and if accepted, each pallet is given a unique reference number before being stored (which is usually between 1-2 days). The labelling is critical for the success of storing shipments at a CCC because of the high level of stored items. Suppliers and customers are notified when items are missing from the shipment. To avoid a dispute over damaged or lost goods, the Specialist photographs every incoming and outgoing shipment. The DMS keeps track of what is currently in storage at the CCC.

#### 4.3.3 The impact construction logistics has on stakeholders

There are great savings potential from proper construction logistics, however a main concern is that these savings are hard to estimate in value and difficult to identify due to the hidden cost structure of logistics. Furthermore, all projects are unique which makes it hard to compare the costs of two projects. The same principles would apply to comparing the perceived benefits of construction logistics. Despite the challenges to put a figure on the benefits, the savings can be witnessed by the improved productivity of construction workers due to less material handling, and the increased on-site safety due to the less inconveniently stored material. In addition, there are savings thanks to improved quality since the material is handled in a more controlled way, away from the sites which means less risk of damaging the material.

Proper construction logistics also includes reverse logistics, thus managing waste but also returning spillages, pallets and other packaging materials to suppliers. These packaging materials provide value to the supply chain, but instead of being returned to the suppliers they often just go to landfill which is a great cost for the supply chain as well as the environment. By managing the reverse logistics these costs can be saved as well.

#### 4.3.4 Requirements on construction logistics

The Specialist believes that higher requirements from the client is the only way to make construction logistics more prioritized. A feasible option could be to include a CLP as part of the tendering process. As of today, producing a CLP is optional in the U.K. (except for special projects). A CLP outlines how the assigned contractor is going to manage vehicles for deliveries, by specifying what kind of vehicle to use and what route to take. It would greatly enhance the communication between supply chain actors because all information regarding the logistics is visible can easily be accessed. Another option could be to impose a restriction that can make sure that more shipments are consolidated.

Based on experience, the Specialist believes that the performance of the logistics has been most successful in projects where the client has demanded a specific need for a CCC, but unfortunately, in most cases the client is not aware of the logistical processes of construction project, and leaves it to the main contractor to manage it.

#### 4.4. Case study 4: the perspective of the City

The City is the public authority that works to ensure the citizens and businesses transportation needs, traffic safety and to minimize the external impact transportation has on the people and the environment. Except from posing requirements to ensure this, they also need to invest in infrastructure and buildings to facilitate the needs of the society.

#### 4.4.1 Managing construction logistics and the inherent challenges

The City gets involved in the logistics of construction projects only if the project will interrupt the traffic network. The City requires all of those projects to hand in a traffic plan about two years before the project starts. The traffic plan should explain how the responsible manager of the project (i.e. the production manager) is going to re-direct pedestrians, cyclists, public transport, commercial transport, private transport, and public transport such during the construction time. The traffic plan is passed around to different sub-units at the municipality office to be evaluated from different aspects. If the plan is incomplete or not feasible, the main contractor can make the required changes. It should be noted that the traffic plan is not part of the competitive tender process.

Some traffic modes are prioritized by the City, which means that they are more sensitive to detours. The City of Gothenburg is keen on promoting more commuting by bicycle, which as a result has given bike lanes a maximum change factor of 1,25. This means that a bicycle path of 1000 m can be elongated to a maximum of 1250 m during the construction of the project. Due to the limitations of accessible roads these principles do not always hold, but the City is strict to enforce the principles. If a project requires any major redirection of the public transportation network the public transport operator needs to be informed eighteen months ahead. This is to ensure timetable accurateness and vehicle capacity.

The City has established a designated task force (System och trafikföringsprinciper, henceforth SOT<sup>1</sup>) with the mission to facilitate communication between construction projects in areas where a lot of construction is going on. Production managers from different projects can meet and jointly discuss and coordinate traffic plans. According to the City, main contractors are generally very good at working with existing requirements and are competent to solve the problems that may arise. However, they seem to have neglected the inflow of material and the disruptions they can face and create. It seems to have been a shift in this, there is great knowledge amongst the contractors, but perhaps the municipality has not been perceptive enough to the ideas. This can be the case due to the magnitude of projects that the City needs to manage which has different ownership structure, while the project manager in the contractor's firm only has one project to manage. There exists great knowledge and theory, but it needs to be compiled and put into the context of a business model, which perhaps is the greatest challenge.

#### 4.4.2 Coordination and consolidation within construction projects

The City does not have any experience from working together with construction companies to achieve efficient construction logistics, e.g. by co-operate a CCC, although the idea of public-private collaboration is feasible. Instead, the City pointed at some examples from the city of Stockholm, which has been more successful in collaborating with private actors. One of the examples was exactly that of a CCC, where the main contractor operated a temporary terminal on public-owned land, to achieve greater material supply efficiency. Another example from the City is an ongoing project in which private actors and the equivalent public authority collaborate. The latter was contacted by the former with a proposal of using barges on adjacent waterways to transport material for an infrastructure project. Early estimates show

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<sup>1</sup> Include the local authority of the city of Gothenburg, Trafikverket, and Västtrafik.

cost efficiencies, and by moving freight to the waterways the project spares the strain on existing infrastructure (the project is assumed to be one of the greatest infrastructure bottlenecks in Stockholm), thus, creating win-win situations for all involved parties.

The City has not encountered similar straightforward inquiries yet, but there are ongoing research and mapping of the potential of using inland waterways for various commercial activities, and just recently, a company specialized in construction logistics contacted the City to discuss how construction will impact urban stakeholders. The City is currently entering the most challenging time so far considering the number of projects that will occur simultaneously during the next 10 years, and explains how at this moment, it is about opening up the communication between the City and the project and also between different projects, to create the best solutions possible with the existing preconditions. During the interview, an idea about extending the usefulness of the traffic principles arises. It could be extended by adding the flow of material to and from the sites as well.

#### 4.4.3 The impact construction logistics has on stakeholders

Construction projects often require traffic to be redirected. When redirecting the traffic, peoples' everyday life is affected. Reactions from the citizens are a receipt on how well the City has handled changes in the traffic. Cyclists and pedestrians are most prone to complain while drivers seem to have higher tolerance. Apart from long detours with poor signposts, the most common complaints from people are regarding loud noises and vibrations. Environmental restrictions exist to mitigate the negative effects to the largest extent possible.

#### 4.4.4 Requirement on construction logistics

The City could require more efficient and structured construction logistics, but the competence has not existed within the organization. It is not until recently that the logistics around the projects is considered to have a severe impact on the surrounding environment. A flaw in the planning can have a considerable effect, e.g. unforeseen need for maintenance on buildings or infrastructure can overturn the whole situation in a carefully planned construction area. Moreover, poor planning of space for commuting construction workers to park can also become a major problem, because they are used to be able to park their cars in connection to the sites, and subcontractors normally store their tools in the vans.

Currently, the City is managing a couple of dozen infrastructure and housing construction projects (as a result of the expansive market developments in Gothenburg), that are either in the planning stages or post-planning. Most projects have already been assigned and approved, it is regarded as too late to force a requirement on construction logistics, thus it will be up to each and every main contractor to manage the problems as they arise. The above example of the CCC project in Stockholm was planned well in advance, and a logistics manager was employed to manage it. To manage more efficient construction logistics in the city of Gothenburg is not regarded as an unachievable task, but the initiative should have started five years ago. Back then, the City could have created an organization within the local authorities that worked with organizing construction logistics. A new system would need to be developed, and perhaps also new ways of transporting goods, and the infrastructure to facilitate that, e.g. quays to facilitate the use of barges. Another barrier to major changes is the way decision making is made within the City. A decision made within a task force in the



municipality unit for traffic has a long way to go before it is considered within the municipality executive board.

## 5. Analysis and discussion

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*This chapter starts by comparing the results from the case studies with the collected data in the literature review. Section 2.5 summarized several problems that are characteristic for construction supply chains and which make supply chain optimization specifically hard to achieve. Table 5.1 presents the problems and shows how these problems correspond to the results from the study. The following sections, 5.2-5.4, continues by analyzing and discussing the results from the literature review and case studies in relation to the three RQs respectively.*

### 5.1 Verified findings

By verifying some of the problems that are characteristic for the construction supply chain it is possible to justify construction companies to focus more on construction logistics. Table 5.1 shows an overview of construction supply chain problems and how they relate to the four roles of the empirical study. All problems were encountered in the findings, albeit, not necessarily by all actors, e.g. the City is excluded in the discussion of this section. In addition to the problems identified in the literature review, a new problem was distinguished in the findings. Each problem will be discussed separately.

The level of complexity involved in managing construction supply chains became clear after the interviews. It is evident that the construction supply chain is affected by a lot of contingency (Gidado, 1996), which sets off a chain reaction of consequences to all project participants when there are changes in the original construction plan. Another central part of the construction supply chain is how the construction process progress, which dictates the types and volumes of materials that need to be transported, either from or to the construction site. This became evident from the Transporter, who spends much time planning deliveries. Sudden and unexpected cancellations from the construction site could ruin the remaining day's schedule. The same goes for when construction sites place sudden orders without warning, which forces the Transporter to find available capacity. Due to the high contingency of the construction process, the Transporter and the Developer are very much dependent on each other. This risk of unexpected changes in the daily operations is greater with customers from the construction industry compared to general freight distribution customers.

Despite the Developer's ability to follow the project timetable, the results show how dependent the construction process is on the weather. Unfavorable weather conditions, such as strong winds or snowfall, have a high risk of forcing the production to stop. This risk is probably more evident in the case of construction projects, and not as likely to interrupt traditional manufacturing supply chains of which take place in a more controllable environment. The weather condition is a perfect example of the complexity of the construction supply chain, but it also show how crucial communication is between two supply chain actors. The main contractor of a project is perhaps more experienced in recognizing incoming weather conditions (e.g. strong winds) and can at an early stage counter a potential stop by re-allocating resources. However, the operations of a TPL provider are generally not vulnerable to the elements, and lack the capability to foresee an upcoming stop at the construction site. Without adequate communication, the complexity of the construction supply

chain will not only cause problems to the main contractor, but also to other actors, like the TPL provider.

The second construction supply chain problem that was identified in the literature was what has been described as the loosely coupled supply chain, with tight couplings between internal actors of the supply chain, and loose couplings between external supply chain actors (Dubois & Gadde, 2002). The tight coupling was identified by the Developer's systematic approach when producing apartments. The production system is carefully thought out and demands a strict sequenced production process, which qualifies as a tight coupling. On the other hand, loose couplings were identified by the arbitrary mindset of some suppliers to deliver goods days before what was originally scheduled, which caused construction workers to stop working and focus attention to unloading unexpected shipments. Another reason to explain the loose couplings in construction is the lack of knowledge about logistics, which according to the Specialist, is a result of an unclear definition of the concept and its benefits.

The fragmentation of construction supply chain actors was also verified in the study and caused implications to all actors. The Specialist made an important point in that there is a considerable gap between the capabilities of the main contractor and the capabilities of the employed subcontractors, particularly in the capability of understanding the basic principles of logistics. It has already been established that the construction industry - with only a handful of companies that have the capability and capacity to efficiently implement logistics - has for a long time not been able to embrace logistics as a priority. Therefore, it may seem too much of a demand to apply the same way of logistical consciousness on subcontractors, especially when contracting smaller firms. The Developer complained that the number of workers was too high and only a fraction would have sufficed. Instead, the site was crowded with workers that were unknown to the production manager. This also turned out to be a problem for the Transporter. For the drivers of the Transporter to unload deliveries as quickly as possible it is essential that the driver and construction workers can get along and have a relationship bound by trust and understanding. A diverse and high number of workers at the site works against this, and would cause disagreement on where to off load goods. This problem had occurred at previous sites, according to the Transporter.

The fourth verified construction problem was the temporary active construction supply chain (Baccarini, 1996; Vrijhoef & Koskela, 2000), that would lead to a myopic mindset among supply chain participants. For the Developer, it is a nuisance to build up trust and relationships with new suppliers when venturing into new projects. Instead, the Developer prefers to continue working with known suppliers that has proved to be successful in the past, however, this is not always possible as different projects use different types of materials. Another cause for concern regarding the temporary factor is how it offsets the willingness to collaborate with other project participants. This was noted by the Specialist, who pointed out that there are little incentives to develop improvements to any activities in the process, similar to what is described by Bygballe and Ingemansson (2014). Despite this, the Developer shows that it is possible to collaborate with suppliers with standardization of the label layout. This strengthens the relationship between actors and creates a stronger incentive to use the current suppliers in the future, but it also ensures more efficient logistics because it improves the communication of the label.

In addition to the four factors that were first presented in the literature review, and later verified in the study, another interesting insight was found throughout the study, namely how outside stakeholders impact the construction process. This is the opposite view of what has already been described in the previous sections, and how construction logistics negatively impact urban stakeholders. Instead, the interference between the construction supply chain actors goes both ways. The Developer pointed at a recent incident where the construction work had to be stopped because a potentially dangerous lifting maneuver outside the perimeter of the construction site could not be accomplished without risking the safety of nearby crowd. However, the lift incident lacks an assessment of the preparations (e.g. proper fencing that would have prevented unauthorized people to interfere) before it took place, but it is an interesting finding because it adds an additional layer to the problems of construction supply chains.

**Table 5.1** Construction supply chain problems verified in the study.

<b>Construction supply chain problems</b>	<b>Verified in the study</b>	<b>Results from the study</b>
<i>From the literature review</i>		
High level of inherent complexity	Yes	Sudden cancellations or new bookings (the Transporter) Construction must stop due to weather (the Developer)
Loose couplings between external supply chain actors	Yes	Suppliers deliver whenever (the Developer) Low knowledge about the concept of logistics (the Specialist)
Fragmentation of multiple actors	Yes	Gap in capability between main contractor and smaller subcontractors (the Specialist) Different opinions on where to offload goods (the Transporter)
Temporary supply chain	Yes	New suppliers obstruct continuous improvements (the Developer) No incentives to collaborate (the Specialist)
<i>New, based on results</i>		
Stakeholders	New	Stop all activity because of safety issues (the Developer)

The results are in line with the problems that were identified in the literature review. Three of the roles (case studies) show signs of being affected by one or more of the supply chain problems that are found to be typical for construction projects, i.e. high level of complexity, loosely coupled network, fragmentation of actors, and temporary supply chain. These problems make supply chain optimization hard to achieve. In addition, a new problem was identified in the results. Furthermore, the study show that these problems affect the whole

chain of actors. With the problems verified by the study, the following sections will continue with discussions around the RQs.

## 5.2 Barriers and incentives for efficient construction logistics

To more effectively counter the problems that are specific to construction supply chains the literature identifies several logistics solutions that can be used to improve the performance the construction process. This section includes a discussion around RQ1 (*What are the barriers and incentives for construction companies to implement more efficient construction logistics?*). Table 5.2 shows the incentives and barriers of the logistics solutions that were identified in the empirical findings. Each solution, with its respective incentives and barriers, will be discussed separately below. In addition, two new solutions were found in the study and provides excellent support to reduce the construction specific problems.

**Table 5.2** Barriers and incentives of construction logistics found in the study.

<b>Solutions for efficient construction logistics</b>	<b>Incentives</b>	<b>Barriers</b>
<i>From the literature review</i>		
TPL provider	Responsible for the flow of deliveries (the Specialist)	Drivers must get along with worker at the site (the Transporter)
	Focus on core business (the Developer)	Lowest-bid-wins, the contractor manages his own problems (the Specialist)
	IT-systems available (the Transporter, the Specialist)	
CCC	Control the flow of deliveries and allow to 'pause' (the Developer)	Production managers have the power (the Developer)
	Ability to early detect defects (the Developer)	Additional risks of damaging goods (the Developer)
	Maximize load factor (the Transporter)	No standardized cost template (the Developer, the Specialist)
	When there is limited space available (the Specialist)	Weight restrictions (the Transporter)
	Suppliers don't have to worry about special vehicles (the Developer)	
CLP	A preliminary logistics plan is discussed (the Developer)	The production manager must initiate (the Developer)
	Improve planning, 'puzzle' (the Transporter)	
	Improve communication for all project participants (the Specialist)	
<i>New based on findings</i>		
Flexible organization	Deals with complexity (the Developer)	
Collaboration with suppliers	Incentives for across-project collaboration (the Developer)	

### 5.2.1 Third-party logistics providers

Construction companies have become less interested in in-house logistics and instead seek alternative solutions. Outsourcing logistics to professionals have been increasingly common (Robbins & Thomas, 2013), and previous research shows that construction companies tend to avoid buying from suppliers that cannot provide transportation (Sobotka & Czarnigowska, 2005). In this study, it was found that the Developer does not own any vehicles and all shipments are transported by suppliers or TPL providers (depending on the project), which would suggest that construction companies are not interested in operating transportation but more interested in having transportation solutions that work.

Outsourcing logistics to a specialist firm gives the construction company time to focus on its core business. This means that it relieves the construction workers from the material handling process, who instead can focus on construction work, and thus spend more time on value-adding activities. Research shows that construction workers spend only a fraction of the total working time on actual construction work (Strandberg & Josephson, 2005), but with a logistics specialist the amount of effective construction time will increase. But with this enhanced focus additional benefits come along. The Developer noted that with less time wasted on non-value activities, there is more time to prepare work and more time to do the work, which improves quality and safety because workers do not have to hurry through work. More time also makes it easier to deal with unexpected events that may interrupt the work.

This study shows two examples of TPL providers in the construction industry. The Transporter acts solely as a provider of transportation between point A and B (where A is the supplier and B is the construction site). Occasionally point C is involved, which represents an intermediary terminal (CCC). Although, the Transporter offers additional services, e.g. consolidation of shipments and IT-system support, the setup of the operation is basic. The Specialist on the other hand (like the title suggests), is more integrated in the construction projects and collaborate on a closer level with its actors, and thus not limited to the boundaries of the site. Moreover, the Specialist offer services like on-site distribution or other security services, like the TPL-set up in the case by Ekeskär and Rudberg (2016).

What was also found in the results (but not brought up in the literature review) is that TPL providers can provide support for the logistics activities by offering IT-systems for better planning and overview of deliveries. This incentive was expressed by the Transporter and the Specialist, and verified by the Developer, who use this offer from its TPL provider. There are many versions of logistic management IT-systems which are often proprietary to an organization. However, basic setup allows suppliers to book timeslots for deliveries. All information is visible and accessible to all actors involved in the project by one shared platform. It increases the transparency in the relationship between the Transporter and its customers, which is an important part of the Transporter's offering to its customers.

Despite the benefits that come with a TPL provider, the results from the study point at several barriers. One problem that was recurring several times during the interview with the Developer was the inability to assess the cost (and to some extent the benefits) of logistics services. Projects are assigned to the main contractor that wins the competitive tender, usually by a lowest-price-wins approach. Therefore, from the main contractor's point of view, there are little incentives to pay extra for additional logistics services if the savings cannot be monetized, and because of this it is common to solve problems when they occur. One solution to this could be to increase the transparency using an IT-support system (e.g. like the Transporter does) where all information, including costs, are displayed.

Another barrier that was found in the study came from the Transporter. It is in the interest of the Transporter to minimize the time spent on-site when making deliveries. Therefore, it is required that the driver is familiar with the layout of the site, informed about safety requirements and that the interaction between workers and drivers is frictionless. This can potentially become a problem at large sites where it is impossible to have a personal relation

with every actor. Construction sites are normally very fragmented when it comes to the actors involved (Behera et al., 2016) and by introducing one more actor would not be a solution to this problem. One way around this, which the Transporter and Developer agreed upon, is to only use a small party of drivers that frequently visit the site.

#### 5.2.2 Construction consolidation centres

A second alternative to improve construction logistics is to adopt a CCC which share the same basic principles of consolidation centres in freight distribution. There are several case studies in the literature, of which some describe temporary CCC that are co-operated by several project actors during the construction phase, while some are permanently active (Allen et al., 2014), albeit, it is important to note that far from all construction projects use terminals. CCC are generally operated by a TPL provider or any other logistics specialist, and therefore share some of the results that were discussed in the previous section.

One important feature of effective construction is, according to the Developer, the ability to pause the construction process. This means that when problems inevitably occur at the site, the project management team can easily pause all work, including material deliveries, until the problem has been identified and fixed. The ability to pause material deliveries is a key strength of CCC because goods are stored at the offsite terminal until it is called to the site, which also make up an effective way to avoid the loose couplings between supply chain actors, that was found by Dubois and Gadde (2002). Not only can shipments be delivered JIT but the quality of shipments is improved because defective or incomplete shipments can be detected while undergoing visual inspection at the terminal. Replacement orders can be placed at the terminal and the site do not have to pay attention to shipments that are incomplete. By allocating storage at an offsite facility it prevents the additional costs of damaged, theft or lost materials that was discovered by Josephson and Saukkoriipi (2007).

Consolidation of shipments is the central idea of using a terminal in construction. Consolidated shipments increase the load factor and prevents sending half full trucks to the site, which minimizes the amount of material handling. Less time is spent on unloading deliveries, because fewer deliveries are made, which in turn means that workers can spend more time on construction work and less time on handling materials. One the Developer's project proved to be very successful in that regard, and the number of deliveries were greatly reduced. And because suppliers deliver to the terminal, there is less need for storage on site, which in urban areas can be hard to find since available land is usually a scarce. An important point was made by the Developer, who explained how suppliers also benefit from a CCC. This is because the suppliers no longer have to worry about having appropriate vehicles to make deliveries at the construction site. In a CCC-setup, the supplier can deliver to the terminal with standard vehicles and unload at the loading platform. The operator takes care of the final leg of delivery with special-equipped vehicles to complete the unloading at the construction site. Thus, the only difference for the supplier is that shipments are bound for the terminal and not the construction site.

While there are many gains from adopting the use of CCC, results also point at several barriers that need to be solved. As most construction projects are run by an appointed production manager who have the final saying in any decision regarding the project.



According to the Developer, this means that it is up to the production manager to make the decision to use the CCC. Therefore, the production manager must acknowledge the potential benefits and assess them in relation to the cost. The Developer pointed out that it can sometimes be hard to estimate the cost of using CCC or other logistics solutions, which in some cases makes it hard for the production manager to justify the use of efficient logistics. The total project cost is an important measure for evaluating, not only the performance of the project, but the performance of the project management team. What is far more difficult to estimate is the potential cost savings from using a CCC. Damaged material, incorrect shipments, excessive material handling, accidents due to on-site storage all comes with a cost. Finding a way to visualize the total benefit of efficient logistics would help justify the use of CCC.

Goods stored at the CCC undergoes an additional unloading and loading. This extra movement increases the risk of damaging the goods, which was brought up by the Developer. However, how much of a problem this is can be questioned, as terminals are operated by experienced professionals who spend entire days using proper equipment to process shipments. The risk of damaging shipments at the CCC is still considered to be far less compared to the cost of damaged material that are stored at the site.

A potential threat to consolidated shipments is the weight restriction (enforced by the local authority) that may apply so heavy vehicles do not damage weak roads. It is common to find weight restriction in urban areas because the road network is usually based on historical roads which lack proper foundations. This does not only impair the benefits of consolidation in areas where it is needed, but it makes planning harder for the Transporter, who is responsible to make sure that shipments meet the restrictions that applies on the route to the site.

### 5.2.3 Construction logistics plans

CLP should in theory be an effective way of sharing information that concern the logistics to all participants in the project. However, it is still unclear to what extent CLP's are practiced in the industry. Even the Specialist (active in the U.K. construction industry with several years of experience) was unable to account for all the details of the CLP. Starting as an initiative by the Transport for London (2013), the framework works as a complete guide to all project participants, explaining internal and external flows of material, information and people. Also, the requirement of presenting a CLP document appears to vary depending on the location of the construction site. The strength of the CLP is the sharing of information and how it helps to improve coordination between actors involved in the project.

How much logistics that is discussed within the project management varies depending on the people involved and the type of project. In most projects, logistics is discussed early in the planning, albeit, at an informal level. Any of the suggested logistics solutions are certainly not discussed in all projects, but the Developer mentioned basic drawings of temporary storage areas as well as potential areas for loading zones early in almost all projects. In projects where construction logistics has been discussed at an early stage tends to be more successful, which suggest the importance of having some kind of discussion regarding construction logistics. If problems can be identified at an early stage it is easier to mitigate or work around them later on. Major projects might even have something that resembles of a CLP in the project health

and safety document. Therefore, it already exists a good opportunity to publish what has been discussed, and make it accessible to other participants.

#### 5.2.4 Flexible organization

The complexity of construction projects (Gidado, 1996) is one of the key reasons why supply chain optimization is difficult to achieve (Vrijhoef & Koskela, 2000). Having a flexible organization is an important factor for construction companies to deal with the complexity of construction projects. It became clear that much of the problems that occur at construction sites (and to some extent further upstream the supply chain) can be solved quickly with an agile organization. This was particularly true for the Developer, who has a dedicated logistics division that, in the event of emergencies, can support all current construction projects by using the logistics network of the partnered TPL provider. By having logistics resources at standby mode, the logistics team can intervene and support projects on a very short notice, which include projects where logistics has not even been discussed before. The logistics team is also important in the early stage of construction projects and provide excellent discussion support for production managers. With this flexible organization, the Developer has created an organization that allows logistics to be more involved in the planning of construction projects without interfering with production managers.

#### 5.2.5 Collaboration with suppliers

Due to the project-based environment, the construction supply chain has often been described as temporary by nature (Baccarini, 1996; Vrijhoef & Koskela (2000)). The industry has further been characterized by low innovation diffusion (Bygballe & Ingemansson, 2014), and both the Developer and Specialist witnesses of practically no incentives to collaborate with construction site participants. Still, the Developer's willingness to co-develop a new label standard goes against this fact. It witnesses of an aspiration to collaborate with key suppliers to form long-term relationships that would make the material handling process more efficient. A label standard would force the Developer to use the same suppliers continuously in projects to a greater extent than what current practice does, where the opposite was pointed out to be a problem in the planning phases of projects. Like any industry relationships should be based on trust, the construction industry should not be an exception.

### 5.3 Construction consolidation centres and stakeholders

As urbanization continues, more people are moving to densely populated areas which increases the demand for residential buildings. Urban construction without adequate logistics have a considerable negative impact on the people that live and work in the urban areas where construction is happening. This section will address RQ2 (*How can construction consolidations centres (CCC) contribute to a more sustainable environment for urban stakeholders?*). The question has deliberately been narrowed down to only include a discussion around how urban stakeholders are affected by CCC. In addition to the benefits associated to using CCC, this thesis has also discussed TPL providers and CLP as effective solutions to inefficient construction logistics. However, the most important factor to improve the environment for urban stakeholder is the reduction of trucks to or from the construction site.

Following the work of Winch (2002), this study has identified several stakeholders of urban construction projects, which are grouped into internal and external, where internal have contractual agreements within the project, whereas external have other stakes involved. The body of literature identified several issues that affected both internal and external stakeholders that could be resolved by using CCC. Issues can be categorized into economic, environmental and social issues (Elkington & Burke, 1989), to provide a holistic framework to assess the sustainable contribution of CCC. This section analyses the empirical findings in relation to the findings of the literature and follows up with a discussion with an intent to answer the second research question. Each sustainability measure will be presented separately.

**Table 5.3** The economic effects of CCC on urban stakeholders based on findings.

Possible effect of using CCC	Verified in the study	Results from the study	Stakeholders expected to be affected	Results from the study
Increased labour productivity	Yes	Save time by focusing on core competencies (the Developer) Less workflow disruptions (the Transporter) Higher productivity (the Specialist)	Mostly Internal	Mostly Internal
Lower cost	Yes	Projects that used CCC showed better financial result than expected (the Developer)		
Competitive advantage	Yes	Construction logistics as a competitive advantage (the Developer)		
Innovation	Yes	New business ideas presented (the City) New ways of transporting goods (the City)		

Table 5.3 illustrates that more efficient construction logistics generates economic benefits, which was verified across the case studies with effects on foremost internal stakeholders. The respondents shared the view that costs related to logistics are difficult to calculate, nevertheless they all found positive economic effects. Increased labor productivity is a highly welcomed benefit, that was found to be a consequence of efficient logistics by the Developer, the Transporter and the Specialist respectively. The Developer found productivity gains since the workers could focus solely on managing their own tasks, thus time efficiency is increased since there is no need to stop working to offload goods or look for goods etc. which follow the findings from Lindén and Josephsson (2013). In addition, the Developer and the Specialist argued that a higher quality of building is achieved by a more focused mindset and less risk of damaged material. Together this results in higher value of output in relation to input. Furthermore, the Transporter explained how a more efficient goods reception on the site improved productivity amongst the truck drivers as well as they could to a larger extent

follow the plan and make use of the existing capacity, which supports the findings of the literature review found in section 2.3.2 that CCC can overcome supply chain problems. Altogether, these results show that internal stakeholders are to a high degree affected positively by increased productivity, both on demand and supply side. No one mentioned if higher productivity benefits external stakeholders, which theoretically is a valid statement when looking at the long term, as the industry has a large influence on the economy and is a large employer (Sveriges Byggindustrier, 2015).

Despite the difficulties of measuring cost savings connected to logistics, the Developer is sure about that the unexpectedly positive results from the previous projects had improved logistics very much to thank for that. Following the arguments from Lundesjö (2009), Sveriges Byggindustrier (2010) and Josephson & Saukkoriipi (2007), the costs of logistics are often hidden within waste of different kinds, such as damaged materials or waiting time, which by being addressed, increases productivity and lowers cost consequently. These findings indicate that the internal stakeholders are winners of lowered cost. Either it is the supply side that can gain by higher profit margins, or it is the actors on the demand side that benefit from lower prices.

The Developer believes they would have a competitive advantage if construction logistics was demanded from the clients or a public organ, since they have such flexible organization that can provide a high-class logistics solution containing CCC in short time. Such demand/requirements do not exist in the city of Gothenburg at this moment, but as the building boom expected within the upcoming years will force contractors to rethink logistics, it is strongly suggested that those companies that can manage it most efficiently will have better financial results or a better offer in competitive tender than the others, thus gain from a competitive advantage in managing logistics. The competitive advantage is highly desired from the internal stakeholders.

There are a few companies and organizations that have acknowledged business potential in construction logistics where some of them have even contacted the City to discuss different scenarios and possible solutions. That the river is considered to be used to transport construction supplies is a sign that a need to upgrade construction logistics foster and requires innovation, which leads to new business opportunities and actors in the market. This is considered to have internal stakeholder benefits in the short run, as the initiatives that the City explained usually starts from the actors that have contractual agreements to each other. In the long run, external stakeholders could benefit from an increase of innovation in the city which could facilitate new jobs and investments.

There are several economic benefits from using CCC, which affect internal, and to some extent external stakeholders as well. Despite, the overall assessment is that the internal stakeholders are gaining mostly from the productivity increase from using CCC.

**Table 5.4** The environmental effects of CCC on urban stakeholders based on findings.

Possible effect of using CCC	Verified in the study	Results from the study	Stakeholders expected to be affected	Results from the study
Less pollution	Yes	Less transportation reduces air and noise pollution (the developer; the Transporter) Less air pollution (the Specialist) Noise and vibration (the City)	Mostly External	Mostly External
Less congestion	Yes	Less vehicles queuing at the site (the Transporter) Less vehicles in the city (the Developer)		
Waste reduction	Yes	Reverse logistics (the Specialist)		

The effect on the environment are summarized in table 5.4, and as all four actors acknowledges reduced transportation a consequence of using consolidation centres, reduced pollution is a natural environmental gain that foremost affect external stakeholders. By reduced transportation, various pollution in form of emissions, noise and vibration is reduced (Spillane et al. 2013). The Developer explains how CCC contribute to a great reduction in deliveries to the site, which have a huge impact on congestion in the area surrounding the project. The Transporter identifies the possibility to reduce congestion on sites by better planning which would improve the environmental quality as less congestion on sites decreases the amount of idling trucks.

Construction projects generate lots of waste that can be reduced by more efficient construction logistics (Stubbs, 2008; Lindhe, 1996), which is verified by the Specialist. In the consolidation service package offered by the Specialist, reverse logistics is provided as well. This means that reusable equipment is efficiently returned to its owners thus reduces the amount of waste that goes to landfill which also reduces the negative environmental impact. This is an example of when waste is treated as a resource, which is recommended by Cherret et al. (2015), also to increase profit.

Altogether, the reduced negative impact that CCC have on the environment mainly benefits external stakeholders, because it does not directly affect the project.

**Table 5.5** The social effects of CCC on urban stakeholders based on findings.

Possible effect of using CCC	Verified in the study	Results from the study	Stakeholders expected to be affected	Results from the study
Improved health and safety	Yes	Less heavy lifting (The Developer) Ability to pause increases safety for surrounding environment (the Developer) Increased safety on site (the Specialist)	Internal and External	Internal and External
Higher comfort of living	Yes	People complain when the city logistics is poorly planned (the City)		

Table 5.5 illustrates how the social benefits of more efficient construction logistics found in the literature by using consolidation centres were verified by the Developer, the Specialist and the City. The Developer noticed appreciation from the construction workers when they did not need to worry about incoming material, and they could spare their backs by letting professionals with the right equipment carry heavy material, results supported by Behm (2005). The Specialist pushed the benefit of creating a safer environment by reducing the amount of material on the site that was unsafely stored which could lead to accidents. Besides the health and safety benefits for the internal stakeholders, the external stakeholders also benefit from more efficient construction logistics. When the Developer could easily pause deliveries to the sites by only one dial to the CCC, it could more easily adapt to surrounding activities and dangers. Thus if a crowd of people is expected to pass by the site at a certain time, the Developer can choose to not have any deliveries at that time which improves the safety for external stakeholders considerably.

The City was well aware of the challenge in getting approval from the citizens for construction work and the impact it has on the daily life. Thus, they know that managing city logistics efficiently makes the comfort of living in the city better (Spillane et al. 2013). The findings of the literature review and the empirical findings together points out that both internal and external stakeholders gain from the social benefits of using CCC.

#### 5.4 Requirements on construction logistics

This section will discuss around RQ3 (*How can more demanding requirements on logistics ensure efficient construction logistics?*). Because the literature review revealed few signs of internal or external requirements being posed on or within construction companies to use more efficient logistics practices, it was interesting to find out how such a requirement is perceived from the different perspectives. Due to the lack of theoretical framework, the following discussion of the empirical findings, which are summarized in Table 5.6, is based on the fellow authors reflections.

**Table 5.6** How a requirement on construction logistics is perceived by the four roles based on findings.

<b>Perspective</b>	<b>Positive to a requirement</b>	<b>Main argument</b>
The Developer	Yes	Could give them a competitive advantage
The Transporter	Yes	Good for the stakeholders, but needs improved communication
The Specialist	Yes	The only way to prioritize logistics, but needs to be clearly formulated
The City	Yes	Possible to implement, and good for the stakeholders, but too late now

Currently, few requirements on how to manage construction logistics exist. The City requires a project traffic plan that describes how the regular traffic around the construction site is going to be redirected during the construction time. However, this plan does not contain any practical information about how the construction material will be transported, or any other project-specific information, e.g. where construction workers and subcontractors will park their cars. Thus, the traffic plan reveal nothing about how the construction logistics may disrupt the local surroundings. Logistics requirements are scarce independent of whether the client is public or private. The Developer has only encountered external requirement of construction logistics when tendering for large and complicated projects that had a specific need for free passage of emergency vehicles. Likewise, the Specialist has some experience of projects in urban areas that contained such high complexity that it was required from the client that the logistics was managed in a highly controlled way, and sometimes, the government also required a CLP to be produced. The Transporter on the other hand, reports that there are a lot of restrictions regarding transportation of material in urban areas. These restrictions are a direct threat to any requirement scheme concerning logistics, because of how it restricts the physical attributes of vehicles, e.g. weight, and therefore, prevent shipments to be consolidated.

As all of the actors in this study acknowledges the mutual benefits of construction logistics for both internal and external stakeholders, it is interesting that the initiatives are so few. It is required by the client only when there is no other way, e.g. hospital or university and initiated by the Developer only when the site manager finds it convenient. This also indicates that the industry can adapt to these sort of requirements, and that the clients have the possibility to add this requirement to the tendering process without major interventions.

The Developer described how the ability to pause material deliveries due to unforeseeable external activities could better ensure safety, however it seems quite irresponsible by the City, as a public authority, to leave this sort of issues to the Developer alone. The City has facilitated for extended communication between different projects within the city, which is a good start, but without clear directions on what is allowed and not, they will not be able to ensure a safe environment for all stakeholders. The Transporter explained how fuzzy requirements regarding transportation leads to a vast variety of measures and methods, and

the Specialist also stressed the importance of a clear framework for managing logistics if a requirement was posed, as it otherwise will be adapted in multiple different ways. This implies that a requirement to ensure more efficient construction logistics should be process-oriented rather than outcome specific.

The Developer and the Specialist were both positive to the idea of an external requirement on construction logistics. It would remove the barrier caused by the competitive tender process which rewards the lowest bidder. If all participants in the tender needed to account for the costs of logistics, which otherwise tend to be hidden, there would be an equal playfield, where those who have a well-developed logistics system, would have a competitive advantage. The Specialist shared this view, but further elaborated that an external requirement was perhaps the only way to implement the use of efficient construction logistics across the industry. The Transporter thought a requirement in general was a potentially good idea, as it would benefit all stakeholders. However, it would require a much more extensive communication between actors on the site. The Specialist believes that a requirement would help to facilitate that communication. If the contractors were mandated to produce a CLP to meet this requirement, the Specialist thinks that the communication within the supply chain would open, and the subcontractors and suppliers would know exactly what was expected from them, and they would have time to plan for that. Furthermore, the City, who would have direct access to these plans, would notice potential risk zones well in advance.

Despite the rising interest from the local authorities considering stakeholder impact of construction, the City does not have any upcoming plans to implement any requirements regarding construction logistics, although, it would be feasible to incorporate a logistics plan as part of the competitive tender process. The most extensive projects that will occur in Gothenburg during the next few years have already been approved and assigned, which suggests that the timing is wrong to make any substantial changes to the tender process. This shows how the view on construction projects as being temporary is shared outside the construction industry. The city of Gothenburg is currently in an expansive development which is expected to continue, which would make a perfect start to focus attention to construction logistics.

Based on the results from this study a requirement appears to be the most effective way of changing the industry's view on logistics. The suggested requirement should come from an external partner (e.g. the client or local authority), because an internal requirement simply does not work. Making the requirement a part of the competitive tender process means that main contractors must adapt to the new industry norm and production managers will be more motivated to use construction logistics as a tool to improve the entire construction process. The benefits associated with more efficient construction logistics will reach internal and external stakeholders of the projects. The concept of CLP provides a useful start to the contents of the requirement, and the results favors a process-oriented requirement, which would help to mitigate the impact that current transportation restrictions may impair the performance.



## 6. Conclusion

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*Before providing a brief version of the answers to the research questions, this chapter starts by summarizing the key findings of this research with the inherent limitations. After that, the practical implications of this research are presented, by recommendations for actors in the construction industry, and for future research.*

### 6.1 Main findings and answers to research questions

The purpose of this thesis was to identify how more efficient urban construction logistics could be adopted by the industry and if that would benefit both the companies within the construction supply chain, and the stakeholders of the projects.

The first key finding is the power of the production manager. The production manager in construction projects has a great deal of power, and will decide if logistics will be a priority in the project. Being responsible for employees, health and safety, environmental requirements, customer satisfaction and external stakeholder satisfaction, and to complete the project within budget means a heavy workload, thus, the incentives for adopting more construction logistics must be clear.

One of the main incentives of construction logistics is that the savings must outway the costs. This is because today's competitive tender processes are based on the principles of lowest-cost-wins. This relates to the second main finding which is the difficulty in assessing the cost of logistics in construction projects. For instance, freight is often included in the price of construction materials, hence, the main contractor does not know the actual cost of freight, and thus, does not know the potential savings if logistics is handled differently.

The third main finding relates to the introduction of a potential requirement regarding the logistics activities of construction projects. All four actors that took part in this study were positive to the idea of a requirement, more specifically it was important that this requirement came from the client. This is also perceived to be the only way forward in making logistics more prioritized in the construction industry.

Three research questions were posed to fulfil the purpose of this thesis. The first question is on a company level, the second question moves outside of the company to the stakeholders of urban construction projects and the third question goes even further, to an industry level.

**RQ1:** *What are the barriers and incentives for construction companies to implement more efficient construction logistics?*

The most persuasive barrier for construction companies to implement more efficient logistics practices, such as using a TPL provider, CCC or CLP, is the power of the production manager. The production manager decides how logistics will be managed in the project, and while some production managers are more interested in optimizing the logistics activities of the project, others prefer 'business as usual' and manage logistics related problems as they arise. A second barrier is that costs related to logistics are difficult to assess, mainly because these costs often are included in the total price of the goods. Nevertheless, there are several production managers that focus on managing construction logistics more efficiently and the

greatest incentive for this is found to be that it allows construction workers to focus on their core competencies when material and information flows smoothly without disrupting the work.

**RQ2:** *How can construction consolidations centres (CCC) contribute to a more sustainable environment for urban stakeholders?*

There are economic, environmental and social benefits of using CCC which affect internal and external stakeholders of urban construction projects. The economic benefits are mainly perceived to derive from better resource allocation, since construction workers can focus on their core work which adds value to the final product, and logistics is managed in a much more cost-efficient manner. The environmental benefits derive mainly from the reduction of vehicles entering the city centre, which diminishes pollution and congestion both on and off site substantially. Connected to this lies the social benefits which are dominated by health and safety gains, by better working conditions at the construction site and a safer environment both on and off site.

**RQ3:** *How can more demanding requirements on logistics ensure efficient construction logistics?*

A requirement on how the logistics will be managed during the construction project should come from the client and be a part of the competitive tender process. This way, the main barriers found in RQ1 can be eliminated, because there will be higher motivation for the production manager to prioritize the logistics of the project. In addition, competing companies will have to submit similar tender proposals, thus, making construction logistics a bigger part of the industry. However, the client requirements must be clearly formulated, either in outcome or process. The results of this study favors a process-oriented requirement, since it would create less confusion about how to conform to it.

To reach these conclusions, in-depth interviews with four different actors in the construction supply chain have been performed. The people interviewed had much experience, and could reflect on a variety of construction projects from their different perspectives. Nevertheless, the experiences are limited to four actors and were mainly qualitative.

## 6.2 Implications and future recommendations

Construction logistics will be increasingly important as urbanization continues. To promote more efficient construction logistics, that creates a more sustainable environment for urban stakeholders, the following recommendations are made:

- Actors in the construction industry should cooperate to identify and break down the cost of logistics and make the benefits of efficient construction logistics visible.
- Construction industry actors should avoid managing construction supply chains as temporary phenomena, and instead focus on the similarities between construction projects to achieve greater resource allocation.

- Clients should demand more efficient construction logistics by incorporating a plan of how the main contractor intends to execute the logistics of the project in the competitive tender.

Including the logistics activities of a project in the competitive tender will require a comprehensive framework that goes beyond the sole focus on lowest cost and should include methods of how to account for the savings related to efficient construction logistics. A possible future study can investigate how this framework can be developed and how it can be adopted by the construction industry.

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## Appendices

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### Appendix 1 - List of top 10 construction companies in Sweden

<b>Placing 2015 (2014)</b>	<b>Company</b>	<b>Net sales (m SEK)</b>	<b>Number of employees<sup>2</sup></b>
1 (1)	Peab	36.780	11.036
2 (2)	Skanska	34.124	10.300
3 (3)	NCC	32.104	9.718
4 (4)	JM	10.880	1.919
5 (6)	Veidekke Sverige	7.121	1.378
6 (5)	SVEVIA	6.961	1.868
7 (7)	INFRANORD	3.947	1.891
8 (12)	SERNEKE GROUP AB	3.107	618
9 (8)	Strukton Rail AB	2.531	859
10 (10)	Erlandsson Bygg	2.529	771
Total of top 10		140.084	40.358
Total of 11-50		38.170	7.307

Adapted from Sveriges Byggindustrier (2016, p. 3)

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<sup>2</sup> From operations in Sweden.

## Appendix 2 - Interview guide themes

- Company description
- Services offered within the construction industry
- Characteristics of the construction industry
- Construction logistics historically and presently
- Construction Consolidation Centres
- Construction Logistics Plans
- Third-party logistics providers
- Stakeholders of construction projects
- Benefits of efficient construction logistics
- Requirements on construction logistics
- Future challenges in construction logistics