CHALMERS
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Logistics in dense cities

A study on large infrastructure projects

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

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Master's Thesis BOMX02-17-36
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ABSTRACT

The densification of cities makes construction logistics in urban areas increasingly complicated. Construction sites are cramped, roads are congested, and restrictions in terms of delivery times and environmental zones create severe challenges regarding transport and logistics. Such problems regarding construction logistics are often overlooked, especially for infrastructure projects. The aim of the thesis is to examine how infrastructure projects can handle logistical challenges while constructing within increasingly dense cities.

A qualitative study is suitable for in-depth scrutinising of the prerequisites and challenges with regard to construction logistics. This is done through a literature study and interviews with a selection of managers at Skanska. Two case studies are performed on infrastructure projects at Skanska, one at Hisingsbron, a project that has a traditional approach towards logistics, and one at Slussen, a project that uses innovative logistical solutions.

The results show that project-based organisations tend to have few standardised solutions for logistics, and it is therefore a matter for each site manager to address logistics. Few resources are spent on improving construction logistics, a topic where competitive advantage can be gained. Additionally, the construction industry needs to stop blaming the uniqueness of each project, and instead focus on the similarities to create logistical solutions that can be used across many projects and involve many actors in the supply chain. The client - often a public actor - has a great opportunity and responsibility to influence contractors to adhere to logistical solutions, as there is potential to decrease rush hour traffic and the environmental impact when the number of trucks are reduced due to the more efficient transports. Finally, it is easier to convince site managers of the benefits of well-planned logistical solutions if the benefits are easy to visualise. It is therefore a suggestion to investigate the economical outcome of implementing various logistical solutions in the construction industry.

Keywords: construction logistics, dense city, infrastructure, urban, consolidation centre, electronic scheduling, material handling

Contents

Preface

This master's thesis is the pinnacle of our Master of Science in Civil Engineering education at Chalmers University of Technology in Gothenburg. The thesis has been written mostly at Skanska's office in Gothenburg, a place where we immediately felt welcome and appreciated.

We would like to extend our gratitude towards our supervisor and examiner at Chalmers, Viktoria Sundquist, for your positivity, your knowledge, and your ability to encourage us. Your feedback has always been of great quality and contributed to improve our research. We cannot imagine a better supervisor. Great thanks also to our supervisor at Skanska, Henrik Nilsson, for the feedback and time you have provided for this thesis and for all tricky questions that made us rethink and improve our work. We would also like to thank the interviewees for your time and interest, our opponents for your feedback, and all others that contributed to this thesis.

Lastly, Chalmers University of Technology deserves its thanks. It is with mixed feelings that we say goodbye to the life as students. On one hand, we look forward to the working-life and to use our knowledge professionally, but on the other, we will miss the wonderful time we have had as students.

Thank you all!

Gothenburg, June 2017

Anna Jansson and Anton Fredriksson

1 Introduction

This chapter explains the background related to construction logistics within dense cities and why it is an area of interest. It also introduces the case studies Hisingsbron and Slussen and ends with the aim, research questions, limitations, and structure of the thesis.

1.1 Construction logistics in dense cities

Urbanisation is an ongoing trend all over the world, including Sweden (Ljungberg et al., 2012). The densification makes construction and construction logistics increasingly complicated (Lindholm and Browne, 2015). The construction sites are becoming more compact and the roads nearby more congested and with restrictions. The immediate vicinity to third party requires planning for mobility and safety (Sullivan et al., 2010). Thus, challenges regarding construction logistics are increasing and becoming even more important. Logistics in the construction industry entail transports to and from site, material handling, transformation of materials, and waste management (ibid). Many actors are involved, from manufacturing of materials to finished products, through distributors and carriers. Insufficient logistics can make an otherwise successful project fail, in regard to delays and cost overruns. The challenge is to coordinate and streamline the activities at the same time as uncertainties and the uniqueness of the project are taken into consideration.

Research on logistics has been separated from the reality in the construction industry for a long time (Sullivan et al., 2010). It has been difficult for the construction industry to relate to theory that emerged from the manufacturing industry and its clean factories. The reality in construction is another, it includes variability and uncertainty that needs to be handled. There is a need for knowledge of how to combine the two worlds in a way that streamlines outdated methods and thoughts, and create sustainable improvement for construction logistics and the construction industry as a whole. Insufficient logistics can delay an entire project and be costly. Research on what is called construction supply chain management has become more common lately and new actors, like logistics managers and logistics consultants, have appeared on the market. However, there is still not much research on logistics for infrastructure projects, as current construction logistics research is focused on housing construction. Furthermore, the research of logistics in urban environments have been very limited especially for infrastructure projects (Lindholm and Browne, 2015).

1.2 Background to the case studies

The empirical part of the thesis includes two case studies of Skanska projects relevant for the research. The cases are Hisingsbron in Gothenburg and Slussen in Stockholm, two relatively similar projects. Both projects are large infrastructure projects built centrally within cities that are considered as dense. Both projects are situated near water and has a lot of other projects and actors nearby, which leads to both challenges and opportunities.

Hisingsbron is a new bridge that will be built over Göta älv in the middle of Gothenburg. The project is a consortium between Skanska and the Danish company MT Højgaard and will take six years to accomplish. Responsible for the logistics are the two section managers as part of their overall responsibility of their geographical area. The Slussen project in Stockholm on the other hand consists of about 25 sub projects of which Skanska is responsible for five. The project is planned to be finished in seven years and has a designated logistics manager to plan and control the logistics processes throughout the project. The cases make an interesting base for comparison and reflection about how logistics can be planned and handled for large infrastructure project within dense cities and what difference a logistics manager can make.

1.3 Aim and research questions

The aim of the thesis is to examine how infrastructure projects handle logistical prerequisites and challenges while constructing within increasingly dense cities. The thesis focuses on the contractor's perspective and how a single project copes with logistics to handle the impact of densification. Based on this aim, the following research questions are identified:

1. What activities does logistics planning and execution for large infrastructure projects within dense cities entail?
2. What type of technical and organisational resources are needed to plan for and carry out logistics for large infrastructure projects within dense cities?
3. Which actors are involved in the planning and execution of logistics in infrastructure projects within dense cities?

1.4 Limitations

This thesis addresses logistics for large infrastructure projects within dense cities. The starting point is the contractor's perspective and how a single infrastructure project is affected by and can cope with logistics in an urban environment. Gothenburg and Stockholm will serve as examples of large, dense cities and urban areas. This thesis investigates infrastructure projects but takes housing construction in consideration to increase the learning basis as research on infrastructure projects logistics are scant. The thesis focuses on how supply logistics can be streamlined to minimise storage on site, rather than how to handle already existing materials on site.

1.5 Structure of the thesis

The thesis consists of six chapters structured as follows:

Chapter 1 - 'Introduction' introduces the aim and research questions of the thesis. It also contains some background to the subject and an introduction to the selected case studies.

Chapter 2 - 'Method' describes the approach and research process used carrying out the thesis. The execution of the literature study is described and empirical data collection methods are presented and justified for.

Chapter 3 - 'Theory' presents an outline of existing research on the field of construction logistics. This provides a framework for the analysis to lean on.

Chapter 4 - 'Empirical findings' presents the two case studies with empirical observations.

Chapter 5 - 'Analysis' applies the theoretical framework on the empirical findings to analyse and reflect on the case studies.

Chapter 6 - 'Conclusions' summarises the analysis, answers the research questions, and proposes further researches.

2 Methodology

This chapter describes the methods and approaches used conducting the thesis. It starts with the approach of the research and then describes the process. After that, the literature review and the data collection method used in the thesis are described. The chapter ends with a discussing subchapter regarding the quality of the study and the ethical conduct.

2.1 Research approach

This thesis has an abductive approach. According to Dubois and Gadde (2002a), in an abductive study, the original question can change due to new theoretical insights and empirical findings. An abductive approach starts with a real-life observation and is thereafter an iteration between theoretical research and empirical findings, to develop new understanding and apply knowledge in different ways (Kovács and Spence, 2005). The approach creates a:

"fruitful cross-fertilization where new combinations are developed through a mixture of established theoretical models and new concepts derived from the confrontation with reality"

Dubois and Gadde (2002a, p. 559)

The abductive approach suits this thesis well as it started with a real-life observation of an increasingly growing challenge for large infrastructure projects. The iteration between theoretical and empirical findings are suitable as new empirical findings create a need for further theoretical studies and vice versa. This to develop the research towards the essence of the challenge as the understanding of the subject developed.

A qualitative study starts with words and observations rather than something measurable like numbers (Bryman and Bell, 2011). It is advantageous for case studies to use a qualitative approach since it allows detailed analysis compared to more general comparison of large amounts of data. Näslund (2002) argues that researchers in the field of logistics gain more relevance if they spend time in organisations, for example by doing a case study. Also, the problems an organisation faces in logistics are often not easily defined. Interviews are a typical data collection method used in qualitative research.

The research of this thesis matches the characteristics described above and it was therefore chosen to be a qualitative study. The thesis focuses on observations and thoughts and is based mainly on interviews instead of measurable parameters. The limitations in time resulted in relatively few interviews which creates a need for more detailed analysis compared to if a large amount of collected data already existed. If a large amount of easy comparable data had existed, a quantitative method may have suited better.

2.2 Research process

The subject of the thesis emerged from a real-life observation of how complicated the traffic situation in the area around Gothenburg Central Station will be in the near future, and how complex the logistics will be for the contractors who are constructing large infrastructure projects in that area. The idea of investigating construction logistics was developed together with Skanska. This subject is of interest for Skanska since they are building multiple large infrastructure projects in cities which are becoming increasingly dense. Hisingsbron and Slussen are two examples of that. Together with supervisors at

Skanska and Chalmers, it was decided to focus on logistical challenges for large infrastructure projects within dense cities from a contractor's and a single project's perspective. Figure 1 illustrates the research process.

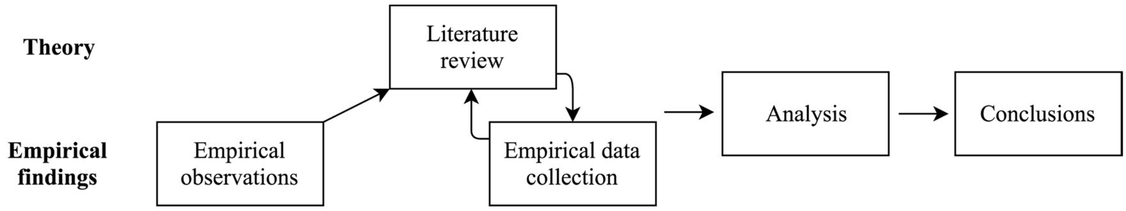

Figure 1 - The research process

The preliminary topic was registered in the beginning of December 2016 and the actual work started in the middle of January 2017. During the first weeks, the topic was developed further, and the aim and research questions of the thesis were developed and rewritten with guidance from the supervisors and due to increased knowledge from reading literature on the topic. A general literature review on the subject and on research methods was carried out early in 2017. This was an attempt to understand the area of research and in combination with writing the thesis proposal it was a good start for the project.

After finishing the thesis proposal, the efforts were focused on performing a literature review. In parallel to this literature review, two initial and overviewing interviews were carried out to help determine which parts of the literature were relevant to focus on. The rest of the interviews were held simultaneously to both writing of the literature review and later the empirical findings. In the early planning of the project, a survey was planned to complement the interviews as empirical research. However, later it was decided to not perform the survey, as the intended basis for the survey was too small to gain any general and comparable information. Two case studies were carried out to both make a deeper analysis and still manage to compare the projects.

When the first draft of the literature review was finished, in the middle of March 2017 the writing of the empirical findings started. In April 2017, the work with analysing the findings and comparing them to the theoretical framework started. As new observations and insights were made, complementary and summarising parts were added to the theoretical chapter and the empirical findings. The need for further interviews and literature research was evaluated and supplemented in April and May 2017. In the end of May, the research and the suggestions for further research was concluded.

2.3 Literature review

The literature review is an essential part of the thesis' foundation to create a theoretical framework for the study, and for the authors to gain general insight and knowledge about the topic. To reflect on the quality of the research, the checklist for literature reviews created by Flick (2014) was used both during and after the process. The checklist contains reflecting questions on, for example, how well the chosen literature covers the issue of the topic, how systematic the research process has been, and how carefully the sources have been treated.

The academic search engines that were used was SUMMON at Chalmers' Library and Google Scholar. The keywords that were used were; *construction, logistics, infrastructure, dense city, urban, transport, consolidation centres, electronic scheduling,* and *ARA-model.* The search results were chosen primarily on the title's relevance to the aim of the thesis. To further evaluate the relevance of the papers, the abstract was read and thereafter the introduction, conclusion, and the eventually of the text, if it was relevant. New sources were also found through extended search among references of relevant articles. The publication year and number of citations were also considered. Besides the digital sources, books about research methods and strategies from Chalmers' Library and Gothenburg's University Library were used. Both literature in Swedish and English were considered. The literature review contained approximately 50 articles and 5 books and was conducted between January and April 2017.

2.4 Interviews

"Interviewing is an active process where interviewer and interviewee through their relationship produce knowledge"

Brinkmann and Kvale (2015, p. 21)

According to Brinkmann and Kvale (2015) the qualitative research interview tries to explain the world in a subjective way. The idea is to understand the world from experiences and thoughts rather than theory. As described before, the research approach of this thesis is qualitative. For a qualitative approach, the suitable question is 'how' rather than 'how much' (Brinkmann and Kvale, 2015). The interviews were organised in a semi-structured way. This means that the questions were described relatively open to make the interviewees freer and more reflecting. In this way, the answers can contain aspects on the subject that the interviewer did not think of while writing the question, and that could have been missed with a more structured interview form. The interviewer does however still have a framework of general questions to lean on to lead the interview in the right direction.

According to Brinkmann and Kvale (2015) research interviews can be divided into seven steps: thematising, designing, interviewing, transcribing, analysing, verifying and reporting. The thematising part are answering the 'why' and 'what' and formulate the purpose of why the interviews are done. The designing is about designing the interviews with current knowledge in mind. Then the interview is conducted and the transcribing part prepares the material for analysis. The analysing part includes choosing a suitable method for analysing. The verifying part reflects on the reliability and validity of the interview. The last step, reporting, is about communicating the results.

The interviewing part of this thesis is divided into four more general steps, which are based on the seven steps by Brinkmann and Kvale (2015) but merged and simplified to suit the process of the thesis.

1. **Interview template:** The first step includes the thematising and designing parts by Brinkmann and Kvale (2015). The interview is planned and templates written to guide and structure the interviews.
2. **Finding and selecting interviewees:** With assistance from the supervisors of the thesis, suitable interviewees are chosen and asked to participate.
3. **Conducting interviews:** The interviews are conducted. Notes are taken during the interviews which also are recorded.
4. **Analysing and concluding the interviews:** Includes the transcribing, analysing, verifying and reporting part. The notes from the interviews are

supplemented by the transcribed recording to not miss anything of importance. Later, the interview is analysed and verified.

The interviewing process was divided into two levels with the same structure as described above, one overviewing part and one specific part. The overviewing part consisted of interviews with persons with general knowledge about construction logistics. The interviewees for this part were a logistics manager from Skanska's logistics group (hereby called logistics manager A), and a consultant for Gothenburg's local road administration, Trafikkontoret. The more specific interviews were held with managers at each case study project and were focused on thoughts and experiences from the projects. This was done to gain understanding of how the projects handled construction logistics, what challenges they had, what they thought was critical in dense cities. The interview also tried to investigate what resources and actors involved the interviewees thought were important to handle these challenges efficiently. The questions used for the interviews is presented in Appendix.

The interviews (see Table 1) were a major part of the empirical study. Most the interviews were about an hour long. After the interviews were done, they were transcribed and summarised to facilitate a comparison of the empirical part to the theoretical framework. As a complement to the interviews, internal documents like tendering documents and information from Skanska's intranet were used.

Title	Name	Company	Date
Logistics manager A	Jon Svensson	Skanska	2017-02-09
Consultant at Trafikkontoret	Johanna Rödström	Trafikkontoret	2017-02-14
Section manager A	Mattias Liewendahl	Skanska	2017-03-16
Section manager B	Per Salfjord	Skanska	2017-03-16
Logistics manager B	Kristina Eliasson	Skanska	2017-03-20
Project manager	Jens Dahlberg	Skanska	2017-03-20
Logistics Manager C	Erik Råsberg	Skanska	2017-05-08

Table 1- Interviews

2.5 Analysis

The analysis emerged from knowledge gained during the writing of the thesis. Some observations were made during the creation of the theoretical framework but most were developed in parallel to the empirical findings as many reflections emerged by comparing literature to empirical results. Reflections made by the interviewees were also noted. The reflections were written down in bullet points and were thereafter restructured and arranged in a suitable order. When the theory and empirical findings were almost finished, the focus shifted to processing the analysis to find recurrent issues and observations. These recurring observations became the foundation for the conclusion of the thesis and suggestions for further researches.

2.6 Quality of the study

A qualitative study requires attention to the issue of trustworthiness and authenticity (Bryman and Bell, 2015). The authenticity comprises, among other things, the fairness of how the research is presented, the sensitivity towards the context and the transparency of used methods. Regarding the authenticity of this thesis, the methods and results are described in the most honest and fair way managed.

Trustworthiness can be analysed through four criteria for evaluation mentioned by Bryman and Bell (2015).

- Credibility - How trustworthy the results are
- Transferability - How replicable the results are in a different environment
- Dependability - How reliable the results are
- Confirmability - If the researchers have acted objectively

The credibility of the results includes many aspects as the trustworthiness of the research and the results are dependent on many things. The data collection method used are primarily interviews related to the two case studies. Brinkmann and Kvale (2015) discusses whether interviews are the best way to conduct a study. Critics against interviews refers to that interviews are subjective and easy to influence, but also that interviews are difficult to analyse and compare. Dubois and Gadde (2002) analyses advantages and disadvantages of dealing with case studies. Arguments against case studies claim that it provides a weak base for generalisation. However, there are also arguments to instead see the specificity of the case study as an opportunity to get fewer but more specific results. In this thesis, the lack of time resulted in that the number of interviewees and studied projects were limited to relatively few. The intention was not to be able to make extensive generalisations, but to gain a better understanding of the subject through applying theory on two different cases. Therefore, the transferability is not considered important and the method chosen is considered to suit the thesis.

The dependability of the thesis is assumed to be quite high as the thesis have received feedback from both supervisors and a peer-review during the process. Regarding the size of the work, relatively much feedback has been received, and facts checked by both supervisors who are familiar with the subject, and other students who are familiar with writing a master thesis in the field of construction.

At last the confirmability can be discussed. The authors entered the research without any particular knowledge of the subject and therefore with a relatively objective approach, not affected by a special company's or professionals view on the subject. As more knowledge about the subject were gained, an ability of questioning the answers of the interviewees developed, but effort on staying objective was made through the whole project.

2.7 Ethical conduct

To ensure that the thesis is written ethically correct, several steps are taken. The interviewees are informed that participation is entirely voluntary. The interviewees are not pressed in any way, and every participant is asked if they are okay with being recorded. Further, the interviewees are informed on the subject of the thesis and that their knowledge will be cited. An example of interviewing questions in Swedish can be seen in the Appendix. Confidentiality is protected, as no classified information is used in this thesis. Material from Skanska's intranet is used with permission from responsible actors.

3 Theory

The chapter aims to provide theory related to the field of construction logistics. The theory is needed to create a theoretical framework to be used for analysis. The chapter starts with general introduction to logistics and supply chain management. Then, logistics and supply processes in construction are described, followed by theory about construction transports, dense cities, and logistical tools. The last subchapter concludes the theory in a theoretical framework for the thesis.

3.1 Logistics and supply chain management

After the industrial revolution, logistics became closely related to the manufacturing industry (Agapiou, 1998). In manufacturing, effective logistics is an important competitive factor and has a large influence on success or failure (Sullivan et al., 2010). Early manufacturers kept large stocks of both raw materials and finished goods to have a safety stock and to be prepared for fluctuations on the market. Having large stocks was, and still is, an inefficient and expensive way to deal with resources, both material, labour, and space. Strategies like Just In Time, JIT, created a new era for manufacturing logistics. When JIT matches perfectly, there is no waiting for the material and no storage is needed, as materials will be used directly upon arrival. This strategic way to work with logistics and to try to include a control over the whole supply process is also known as Supply Chain Management, SCM. There are many ways to describe the relation between SCM and logistics. In this thesis, logistics is considered as the physical flow of materials while SCM is considered as the governing and managing principles and processes behind this physical flow.

3.2 Characteristics of the construction industry

The construction industry is an old industry (Koskela, 1992). Construction is, compared to manufacturing, more uncertain and more complicated (Ballard and Howell, 1998). Sullivan et al. (2010) argue that the construction industry has much more similarities with the military than with the manufacturing industry. Sullivan et al. (2010) explain that the construction industry and the military are both dealing with the messy real-life world in a different way than manufacturing which works within clean structured factories. For them it is about giving the personnel the best possible resources and environment to perform the demanded task. A common way to look at construction is through an activity view, to see construction as a combination of activities that lead to a certain output. This view contributes to the traditional problems of construction, for example a lack of interactions between activities, a lack of feedback, and lack of work with improving quality. According to Koskela (1992) the industry has two kinds of problems. Firstly, the traditional way of working has become outdated and inefficient. Secondly, the special traits of construction have not been sufficiently handled. These special traits are the uniqueness of products, site based production, and the temporary organisation with multiple actors.

It can be argued that every construction project is unique, since every project have its own prerequisites, demands from the client, and environmental conditions (Koskela, 1992). The site production settings create a need for coordination to avoid congestions when everything needs to happen at the same time and place. There is also a need to reduce wastes like waiting and movement of materials. Furthermore, the site production creates a rootedness-in-place which add uncertainties. An example of this is the soil conditions and other environmental peculiarities for the area.

However, it is also easy to dismiss standardisation and to blame the uniqueness and traits of the construction industry to avoid change, which the industry in many ways has a resistance towards (Sullivan et al., 2010). The problems and challenges for the construction industry mentioned above are in many ways related. Ballard and Howell (1998) argue that the construction industry needs to be less fragmented and take control over the entire process to streamline production, minimise wastes, and maximise value. This can be handled in two steps: at first, map and define which part of construction that are similar for every project. Those parts need standardised processes with a lean thinking to create efficient processes with a minimum of waste. Second, techniques for being able to handle single project's need for flexibility and dynamic solutions in a structured way must be developed.

3.3 Construction logistics and SCM

There is no single definition of Construction Supply Chain Management much due to the variation of definitions and approaches to general SCM (O'Brien et al., 2008). The construction industry has special traits that needs to be handled and taken into consideration. As the world gets more urbanised and the demands of efficiency get higher, logistics and SCM gets increasingly complex and important. Traditionally in construction, little consideration is put into the supply system (Arbulu and Ballard, 2004). The supply is rarely designed or seen as a real activity. Many important decisions that affects the SCM are taken early in the project. It is therefore important to also include strategic logistics early to be able to influence those decisions. Sobotka and Czarnigowska (2005) agrees with Arbulu and Ballard (2004) and have identified several logistical activities that are important during the construction process. Hansson and Hedberg (2015) visualises these activities in a table (see Table 2).

Planning	Production
• Preparing schedules and charts of labour and equipment utilisation, subcontractor's work, and material consumption • Preparing logistics concept of the building site • Planning and placing orders, scheduling deliveries • Waste management planning • Planning information flows management and methods	• Work progress monitoring • Schedules and plans update • Adjusting orders to current demand for resources • Planning and coordinating horizontal and vertical transport to site • Planning and coordinating deliveries, loading, unloading and warehousing, distributing deliveries to contractors • Managing waste

Table 2 – Logistical activities (adapted by Hansson and Hedberg, 2015 from Sobotka and Czarnigowska, 2005)

3.3.1 Logistics manager

The need for coordination and increased efficiency in logistics has pushed the industry to realise the value of logistic competences and the importance involving it early in the project (Brown, 2013). The logistics manager should be an extra link in the supply chain, have an overview, and coordinate all actors regarding logistics (Olsson, 1998). The logistics manager can through mutual understanding between different actors create an environment of collaboration in logistics and prevent for example hoarding by individuals in favour for the whole project.

The construction logistics manager's responsibility are all aspects of the logistics supply chain, storing management, and optimisation of site logistics (Brown, 2013). Brown (2013) also states many responsibilities that a logistics manager can have. A selection of them are listed below:

- Planning the site set-up to move labour, plant, and materials around the site efficiently – for example hoarding, cranes, material delivery, and waste management strategy.
- Planning internal and external logistics routes through the project phases, focusing on separation of vehicles, machinery and people, lay-down areas, and off-loading points.
- Create a schedule of logistics meetings and ensure logistics occurrence at site meetings.
- Control material flow in and out of the site.
- Manage subcontractors to deliver their goods or services.

3.4 The construction supply process

As stated above, every project has their own level of uniqueness. Every project does, however, have the same challenge of trying to match the supply and demand (Arbulu and Ballard, 2004). Variability of both supply and demand can have a large impact on, and cause large problems for, the project regarding quality, cost, and time. Olsson (2000) discusses the matching and coordination of the supply chain in the construction process and studies the different actors that are involved through the different phases. The actors involved are architects, clients, and subcontractors in the construction process, and material producers and carriers in the supply process. The end user of a construction project is only interested in the result and the overall efficiency, not the individual activities. This causes a natural focus on the final product and sometimes not enough attention to single activities and how they are linked.

To bridge the gap between the construction process and the supply chain, it is necessary to improve communication and coordination between the different phases (Olsson, 2000). Expectations are often insufficiently communicated or misunderstood. It is important for the project to keep in mind that the material supplier may not be so familiar with the construction environment or the uniqueness of the project. Sharing information between all phases creates new possibilities for improving the total process and the final result.

Reliability and variability can be seen as opposites, and it is the variability that prevents the production system from being perfect (Arbulu and Ballard, 2004). Through reduction of variability, the production line approaches perfection. Arbulu and Ballard (2004) discusses three scenarios when matching supply and demand. The first scenario discussed is the 'Utopia' which represent the perfect match between supply and demand. The supply and demand are both 100 % and there is a reliable work flow to trust. This perfect world does not exist since it would mean no validity or changes at all. The second scenario is with a 100 % reliable supply but a variable demand. As an example, suppose only 90 % of the planned activities one day was carried out but 100 % of the ordered supplies was delivered. Hence, a material inventory emerges. The last and most likely scenario for the construction industry has both a variable supply and demand. The unreliability of demand creates material inventories while the unreliability of supply creates delays for the project. This may also impact other activities and create a vicious cycle. More supply systems lead to lower probability of a total success with on-time deliveries, as it leads to a higher risk for a component to be missing, and in a critical chain of activities that can cause a bottleneck and delay the whole project. This unreliability has caused a tradition of ordering material weeks before they are needed, which sometimes saves the project from being delayed, but also indirectly slows down the project, as the buffer of materials create waste (Akintoye, 1995). The materials will likely need to be moved around on site (Arbulu and Ballard, 2004).

Olsson (2000) highlights the importance of a holistic approach to the material inflow. The material inflow is critical since it cannot be seen as homogenous. They do often have varying characteristics and are often not coordinated. In the construction industry, materials are often ordered differently. Wegelius-Lehtonen and Pahkala (1998) divide the orders into customised materials, standard materials, and small purchases. Through categorising the materials, general improvement can be made in the supply process as the problems often have similar solutions in the respective categories.

3.4.1 Construction transports

The Swedish Construction Federation, Sveriges Byggindustrier (2010), suggests several propositions that will help reduce the amount of trucks on the way to construction sites. The proposals are not forced, but rather a draft that demonstrates that better planning processes will make transports more efficient. Fully loaded trucks could drastically reduce the amount of construction transports, and if the trucks also could bring waste from the construction site, the effects would be even greater. If it is possible to ship materials by train or boat, that should be preferred. IT-tools are also suggested, as delivery planning systems can reduce queues on site.

Another plausible solution to urban transports, according to Muñuzuri et al. (2005), is to increase transports during night-time and thus lower the amount of transports during the day and especially during peak rush hours. It is the peak rush hours that are the most devastating for traffic flow, and since it is not easy to shift the peak of morning commuters, although some municipalities try to, it might be easier to change the time during which transports take place. Muñuzuri et al. (2005) admits that this might cause problems with residents in central areas, as these deliveries may cause some noise, for example from trucks and off-loading of materials. Furthermore, labour may be needed to receive the deliveries, which would mean a work shift during night.

When a business relies on JIT transports, like when concrete is delivered to a construction site, congestion on urban roads can make it difficult for a construction to be productive. The congestion issues will increasingly get worse as the densification in cities progresses further (Ponnuswamy and Victor, 2012).

3.4.2 Relations with suppliers

Dubois and Gadde (2002b) identifies the construction industry as a loosely coupled system. Networks and the concept of "couplings" creates the different dimensions a project need to coordinate and have relationships with. It can be divided into four categories; within the own project, to companies in the supply chain, with other projects, and with other organisations. Within the own project the couplings are often tight but towards all the three other categories the couplings are loose. This is a result of the characteristics of the construction industry. Projects are seen as separate units and individuals are recombined in every project, which makes the continuity and knowledge transferring within the company hard. This also makes it hard to organise joint agreements towards suppliers or joint efforts to improve overall logistics. The loose relationships with suppliers have both positive and negative aspects. The positive aspect is that the project is not locked to one single supplier or a technical solution provided by one supplier (Gadde and Dubois, 2010). Instead it is a competition between suppliers that can reduce the cost and improve the quality. However, there are consequences for keeping a distance to suppliers. It can result in low trust and a lack of interest for adaption, collaboration, and improvement caused by the uncertainty. The loose coupling with suppliers also complicates attempts to improve the general logistics for a specific project.

What complicates the logistics flow and relation to suppliers even more is that construction projects usually have a lot of subcontractors, which in turn often have their own suppliers and material flow (O'Brien et al., 2008). It is important to involve the subcontractors in the general logistic plan to be successful with it, but it can be challenging to coordinate them as they work with their own tasks independently and parallel to each other (Tommelein and Ballard, 1997). They might also compete for the same resources on site, for example space, and do generally not see the whole picture. Sobotka et al. (2005) discusses the value of including subcontractors in a comprehensive solution to make them cooperate with each other and the main contractor. This can reduce time and improve the quality, and consequently save money. A lack of coordination can result in large disturbance of both material and information flow which can lead to a decreased quality.

3.5 Dense cities

Densification of cities is currently a trend in city planning, according to Mattsson (2015). More people are moving to cities all over the world, and Sweden is no exception. Mattsson (2015) states that there are many advantages with dense cities, and that these advantages are getting more appreciated by the local authorities. More efficient public transport is one argument that is often used when denser cities are discussed. The fact that more public services are located in a smaller area makes it easier for the public to access them (ibid).

Sullivan et al. (2010) consider construction sites in larger cities to be restricted by their lack of storage area and that it is important for a project to overcome constraints, to function properly. Sullivan et al. (2010) suggest that these problems should be addressed early in the planning process to minimize disturbances. Furthermore, Sobotka et al. (2005) states that it is in dense city projects the advantages of using logistic systems become the most apparent. When both space and transport possibilities are limited, it is even more important to have full control over larger transports.

3.5.1 Logistical challenges in a dense city housing project

Boverket (2009), discusses different logistical challenges and solutions for a larger housing project in central Malmö. The settings are similar to those of Hisingsbron and Slussen, with dense surroundings and several other contractors in the immediate vicinity. Certain challenges, such as limited space and many deliveries, are the same for the three projects. In the Malmö housing case, they had a few areas designated to off-loading deliveries as the site was too cramped to receive materials at suitable locations. Boverket (2009), suggests the use of electronic delivery schedules as a tool to get an overview of all deliveries and their corresponding off-loading site. By using this tool, middle managers, subcontractors, and transport companies could easily book a time for off-loading and to use the construction crane. When the transport later arrives, it is expected, the material is needed and the off-loading is done quickly, and few logistical collisions occurs on site.

There was also a problem with the common ground between the several contractors that constructed in the area (Boverket, 2009). In the beginning of the construction, there was no regulation of the common ground, and the lack of coordination caused the different contractors to place material as they pleased. This lead to delays when transports could not reach their offloading sites. As a solution to this problem, a common worksite disposition plan was implemented. The common worksite disposition plan had clear boundaries of the respective construction site and roads were clearly marked.

Additionally, it is possible to rely on prefabricated walls and framework, repeatable work, and ready-to-install modules in a housing project (Boverket, 2009). These characteristics make it somewhat easier to streamline the construction process.

3.6 Logistical tools

Several tools and methods can be used to support better and more efficient logistics. The tools presented here are consolidation centres, electronic scheduling, and material handling.

3.6.1 Consolidation centres

Consolidation centres, are a way to increase the efficiency of transports to construction sites (Sullivan et al., 2010). Transports and deliveries from several suppliers are shipped to a consolidation centre, from where the construction sites can have materials delivered on short notice. At consolidation centres, materials are co-loaded and delivered to the construction site when it is needed, thus preventing material to end up in heaps under tarp on the site. The consolidation centre provides a short storage possibility, but the aim is to only have materials stored at the consolidation centre when known when it is needed, and not to provide storage indefinitely. Sullivan et al. (2010) states that the maximum storage time in a consolidation centre should be around 10-14 days. Even if the goal is that most deliveries should be co-loaded at a consolidation centre, some deliveries can enter the site directly. This is preferable for materials that will be used immediately, like concrete or prefabricated structures. These deliveries already adhere to the JIT philosophy and a detour to a consolidation centre is therefore pointless (ibid).

The advantages with consolidation centres are many. More efficient deliveries reduce both waiting time on site and traffic congestion off site (Sullivan et al., 2010). Traditional transports are uncoordinated and therefore prone to congestion at the construction site. Environmental benefits are apparent with the use of consolidation centres, as fewer transports lead to both a reduction in fuel consumption, and a reduction of traffic in cities, thus reducing fuel consumption even more (Lundesjo, 2011). According to Lundesjo (2011), a reduction in transports to the construction site of up to seventy percent can be achieved with a proper use of consolidation centres. Muñuzuri et al. (2005) claims that the municipality has a large influence over traffic within its city's border, and thereby also a large responsibility. Muñuzuri et al. (2005) further states that from a municipal perspective it is safe to say that consolidation centres are a good solution, as the freight traffic would decrease in city centres. Sullivan et al. (2010) claims that consolidation centres are the most beneficial when used in inner-city projects, as these projects are often lacking the space for on-site storage, thus having the need for JIT deliveries. Sullivan et al. (2010) proposes yet another situation where consolidation centres are beneficial, namely when the surrounding is sensitive for transports that may cause disturbances, such as airports and railway stations or hospitals and schools. These are examples of construction sites where business must be kept running with minimal disruptions. According to Salvén (2013), actors are positive to the advantages of consolidation centres, as it will improve the construction efficiency, but there is also a scepticism that the cost for the consolidation centre will be too high compared to the potential savings. The costs for consolidation centres are among others; staff costs, warehouse costs, and administrative costs (ibid).

The location of consolidation centres is of high importance. According to Lundesjo (2011), consolidation centres should be located near highways and larger roads, both due to fact that it will keep transports from having a big impact on smaller roads and to keep transports quick and efficient. The consolidation centre should also be close to surrounding construction sites, preferably not further than 30 minutes away (Sullivan et al., 2010).

3.6.2 Electronic scheduling

The idea of electronic scheduling tools is to easily get an overview of all the deliveries and transports to the construction site, and by doing that, make it easier to discover collisions and manage them before they occur on site (see Figure 2). This by specifying unloading for each transport, including if a construction crane is required (Hagenbjörk, 2014). By using a common system, contractors, suppliers, and shippers are all able to book deliveries and see other deliveries. However, Hagenbjörk (2014) states that it takes time to fully understand a new software, and it may cause problems in the beginning of the project, therefore electronic scheduling is beneficial for larger construction projects. This because the overall costs with material handling has a potential to be considerably reduced, but only if the attitudes and acting of the site management is changed and that is not an enhancement that happens automatically (ibid).

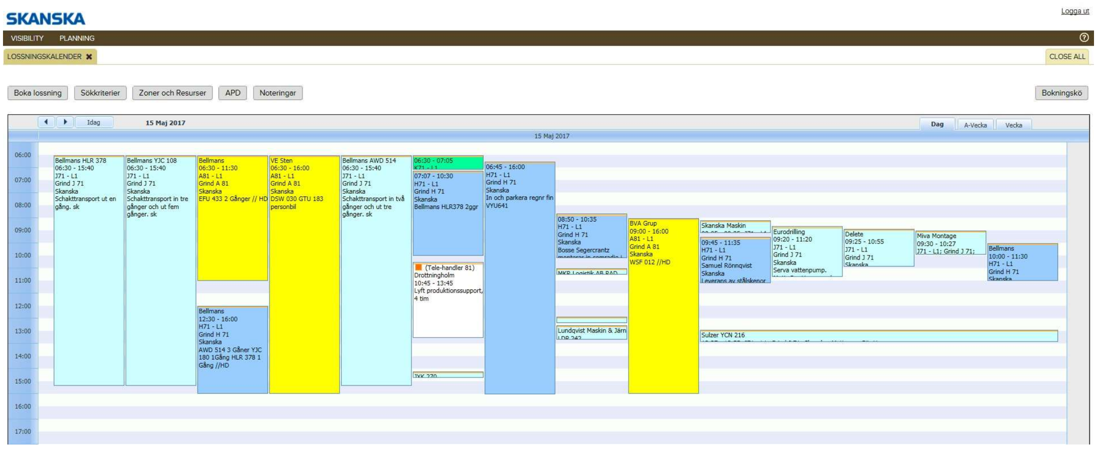

Figure 2 - Example of electronic scheduling at the Slussen project (Skanska, 2017)

3.6.3 Material handling

Materials handling entails when materials on the site are moved from the off-loading location to the place where it is to be used (Sullivan et al., 2010). Often construction workers undertake materials handling, but in recent years, companies focused on logistics have taken a larger role in on-site logistics including materials handling. The idea is that construction workers shall construct, and not be disrupted by handling materials. By adhering to this philosophy, the construction industry becomes more streamlined like a manufacturing industry, which is an industry that is often praised for being highly efficient. Lindén and Josephsson (2013), discuss whether the use of out-sourced material handling is preferable over in-house handling. The paper states that it is more favourable to out-source material handling as it is more cost-efficient and simultaneously time saving. It is stated that indirect costs and waste of handling materials on site are often overlooked and an unknown cost.

3.7 The ARA-model

The ARA-model is part of the industrial network approach, where companies are studied from their connections to other companies. ARA is abbreviated from Activities, Resources and Actors which are the layers involved in the model (Håkansson et al., 2009). The ARA-model can be used to analyse business interactions, both within an organisation, and between organisations. According to the model, the different layers are connected to each other like visualised in Figure 3. Activities are performed by actors who use resources in the process. Håkansson (1987) states that actors and activities are heavily co-dependent, as actors learn to perform activities more efficiently, as their experience of the activity develops. Resources can be both tangible and immaterial. Resources can be tools and machines, financial assets, and human assets, like knowledge. Håkansson (1987) argues that new knowledge can emerge by using resources in a new way, and thus increase the performance of the resource. Actors are those who perform activities and control resources (ibid). Actors are among others: suppliers, customers, construction workers, managers, and consultants. Each of these actors has specific resources at hand, and they perform activities. The actors create relationships with other layers as they try to perform activities and resources creating the most efficient process possible.

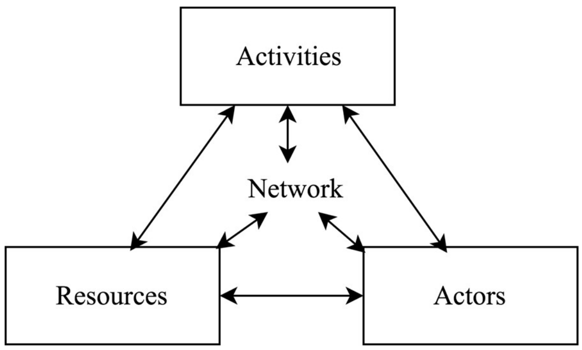

Figure 3 – The ARA-model (adapted from Sundquist, 2014)

The ARA-model also suggests that each layer is connected within a larger network (Håkansson, 1987). The network does not only exist on an individual level but also as a part of many relationships, expanding into other companies. The three layers are not isolated but connected in different ways. Interactions are created over time, gain content from multiple parties, and are developed without full control from either of them. Furthermore, the network that combines activities, resources, and actors, stretches out into a fourth dimension where more relationships are located, each with more activities, resources, and actors.

When a specific layer is analysed, it is easier to understand the complexity that this layer operates in (Gadde et al. 2010). When each of these three analyses are studied together as a whole picture, it is possible to draw conclusions of the reality (Gadde et al. 2010).

3.8 Theoretical framework

The theoretical framework of this thesis is based on the theoretical topics presented. The discussed topics have couplings to, and can be organised in relation to the research questions of the thesis. Research question 1, what activities logistics planning and execution entail, is treated by subchapter 3.1, logistics and SCM, and 3.3, construction logistics and SCM. Research question 2, about resources needed to carry out logistics are processed by 3.3 as well but also by 3.6, logistical tools. The last research question addresses actors involved in logistics planning and execution which are treated by 3.3.1, logistics manager and by 3.4 about the construction supply process. The setting of a dense city and the characteristics of the construction industry, common for all the research questions are processed by subchapter 3.5, dense city, and 3.2 characteristics of the construction industry, respectively.

A way to summarise and connect the research questions to each other is by using the ARA-model described in 3.7. The ARA-model combines research question 1, 2 and 3, activities, resources and actors and shows their relation to each other as a network (see Figure 4). The setting of a dense city included in the questions and the characteristics of the construction industry can be seen as prerequisites that affects the network.

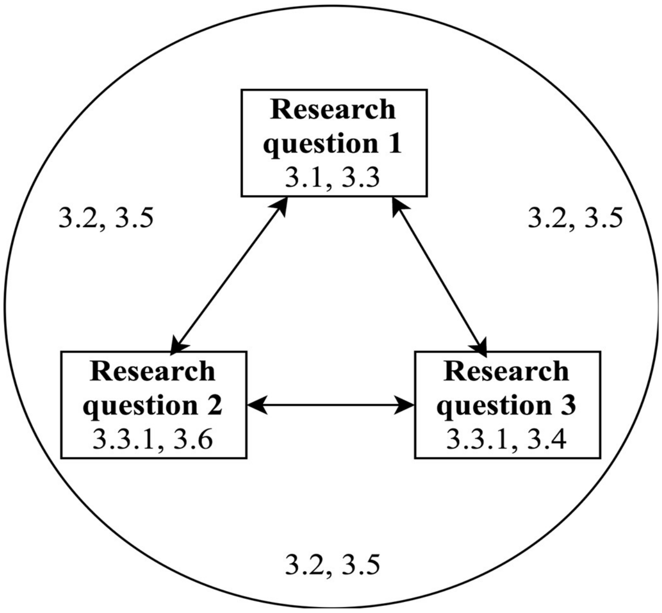

Figure 4 – Visualisation of the theoretical framework

4 Empirical findings

This chapter contains the empirical findings of the project. It starts with an introduction to Skanska's logistics group and the services they provide. After that two case studies and how the site management plan to handle their logistical challenges are described. The case studies contain some background about the projects, what their logistical organisation looks like, what logistical prerequisites and challenges that exists, and how these are planned to be handled.

4.1 Logistics at Skanska

Skanska claims to be the leading contractor working towards a more logistics effective construction industry in Sweden. They have a logistics group located in the purchasing unit, which has the goal to implement a 'logistical thinking' in all construction projects. The benefits of implementing this logistical thinking, according to the logistics group, are reduced costs and shorter construction times. The services provided and recommended by the logistics group are tools like the delivery planning system 'Leveranskalendern', consolidation centres and material handling, but also to contribute with knowledge by offering a logistics manager.

However, it can be an investment to adhere to this logistical thinking, and logistics manager A claims that is sometimes daunting for a production manager who might feel that the value is hard to perceive and the effort is too big compared to old and proven methods. This is a problem that occurs quite frequently at Skanska, according to logistics manager A, and especially when it comes to infrastructure projects. The logistics group at Skanska has had difficulties reaching out to infrastructure projects, and it is not very common that their competence is being used in such projects. They are, however, more frequently hired during housing projects, but not to the same extent that logistics manager A would like. Logistics manager A claims that the logistics group can provide a solution to all logistical problems a construction site could meet.

Skanska has consolidation centres that can be used by several projects at once. This consolidation centre is the result of a contract with DHL, one of the larger carriers in Sweden. By encouraging projects to use this consolidation centre, Skanska aims to minimize transports to the construction sites. This is a goal that is based on Skanska's housing project 'Trollhättan', in Stockholm, where transports were reduced by 80%, according to logistics manager C. To make the effect more prominent, the goal is to purchase goods and materials without the transport, and transports the material themselves in collaboration with DHL. This is a way to save money, as the price of transports often is a way for producers to make a better profit. According to logistics manager A, separating transports costs from the purchasing price has taken a lot of effort from the purchasing unit to accomplish. Material providers gladly charge for transports, and without it, revenues might go down. Logistics manager A stresses that it is important to early put demands on material providers in the procurement phase to achieve satisfying agreements.

The logistics group of Skanska also suggest the use of material handling during evenings and nights when the construction site is empty. They have agreements with companies specialised in bringing material into the site during off hours. This is a way to further strengthen the idea that construction workers should work with construction and not material handling, which is one of the logistics group's philosophies. Material handling is however a seemingly controversial subject for infrastructure projects. While logistics manager A and C claim that material handling is suitable for any project, the site management of Hisingsbron and logistics manager B do not see how this could be implemented in infrastructure projects.

The logistics group has developed a delivery planning system that aids in the planning of receiving transports. This tool is called Leveranskalendern and it is free for Skanska's projects to use. Subcontractors and carriers can log in and fill in when their transports are scheduled. Thereby all deliveries are scheduled in the same system in order to avoid clashes.

4.2 The Hisingsbron project

The following part describes the first case study of the thesis, the Hisingsbron project. It starts with some background and information about the logistical prerequisites of the project and ends with how the organisation, that is responsible for the logistics, is structured and how the logistical challenges have been handled so far in the project.

4.2.1 Background

The area surrounding Gothenburg's central station is planned to undergo a major transformation the coming years. In the area is a new train tunnel, a lot of new buildings, and a new bridge over the river going to be built (Göteborgs stad, 2017). In addition to this, the highway in the area will be lowered underground. The new bridge is called Hisingsbron, and is one of the larger infrastructural investment in Gothenburg for the near future. Hisingsbron will replace the current bridge, Götaälvbron, connecting Hisingen to the mainland over the river Göta älv (see Figure 5). The current bridge has been in place since 1939 and is in the very end of its life time. The demolition of which is included as the last part of the project Hisingsbron and will be done 2021-2022 when the new bridge has opened.

Figure 5 – Aerial view on Hisingsbron (Göteborgs stad, 2017)

When the current bridge was built in 1939 it was still partly adapted to horse transport. The current bridge is made of steel which now is aged and fragile. Technical investigations show that the lifespan expires in 2020 and cannot be repaired, therefore a new bridge is necessary. Since a few years back the only heavy traffic that is allowed to use the bridge is public transports and they are only allowed to use the middle lanes of the bridge. The vision is that the new Hisingsbron will connect both sides of the city in a better way than today, free space to densify the city, and create more places for meetings. The construction time for Hisingsbron is between 2017 and 2022. In 2020, it will be opened for road traffic and in 2021 for tramlines. Skanska and the Danish company, MT Højgaard, in a consortium will construct Hisingsbron. These companies have worked together in the same constellation before. Both when Öresundsbron was built in the 1990s and more recently at Södra Marieholmsbron in Gothenburg.

4.2.2 Logistical organisation and responsibilities

At Hisingsbron there is no general logistics manager. Instead the two section managers are responsible for the logistics within their own area. The project is divided in geographical areas, the main bridge is one part and the ramps and all connections to existing roads is the other. The section managers are also responsible for the production within their area. Above them hierarchically is the site manager and the project manager who are responsible for the whole project in different ways. Thus, the section managers are responsible for a lot of different things, of which logistics is only one. Generally, it is a lot about coordinating people and information, claims the section managers. That is also the case when it comes to logistics. The foremen working on site are usually responsible for the logistics and resources their activities entail. The section managers coordinate the foremen and are responsible for that nothing is overlooked.

Skanska's logistics group is not a part of the organisation at Hisingsbron, since the section managers feel like they possess the experience to solve the logistical challenges themselves. Section manager A knows that the logistics group exist, as they were considered in another project, but has never worked with them. Section manager B has, at the time of the interview, not heard of them.

Considering that Hisingsbron does not have a designated logistics manager, the section managers admits that this solution will probably not be the most optimal, and that they have a lot to learn from housing construction, where logistics managers are more commonly hired. However, they claim that infrastructure projects do not have the same settings as a housing project. "They have smaller materials, like bathtubs or windows that can be stored in a consolidation centre. That is not the case in an infrastructure project like this. We have more concrete and steel piles, those are not suited for a consolidation centre".

4.2.3 Logistical prerequisites and challenges

The immediate area of Hisingsbron, especially the south side, is very central and dense with lots of buildings and roads. This means a lot of traffic nearby and congestions during rush hours. Transportation to the construction site will contribute to, and be affected by, the congestions. The dense environment on the south side, also result in a lack of work space and storage areas. The lack of space puts additional strains on the project and its management. Due to the lack of space it is more important to get deliveries when they are needed and not create a large storing area on the construction site. The everyday life and traffic in the vicinity need to work out without major disruptions. Like described in 4.2.1 Hisingsbron is only one of many projects in the area close to Gothenburg's central station. The client, Trafikkontoret, has together with the client for some of the other projects, tried to coordinate the different actors in the area to decrease their total impact. However, they had no specific requirements on logistical solutions in the contract documents, instead their focus was soft values. Trafikkontoret and Trafikverket has made proposals for coordination meetings between contractors in the area and have also coordinated the construction of a new roundabout to improve the traffic situation.

The lack of space at the construction site cause a challenge in storing materials. The conditions on the north side of the river are quite good, but on the south side it is more difficult. Another issue is the fact that the current bridge, Götaälvbron, cannot support heavy traffic, such as freight transports. This means that these transports must go through Tingstadstunneln three kilometres away, which during rush hours are prone to congestion. During rush hours, the travel time is twice as long as compared to low traffic flows.

The area is also geotechnical challenging as there are up to 110 meters of clay above the bedrock. This results in a large need for long piles to be delivered to the construction site. Even more challenging are the 25-meter-long sheet piling which will need special transports to be transported to site.

4.2.4 Logistical solutions and handling

Since the duration of the project is relatively long, about six years, and still in such an early stage, there are a lot of logistical implementations that are not yet decided. According to the section managers they continuously work on improving the logistics situation as new information appears. More critical steps, like temporary stops for the tram traffic, are however planned early in the process. A large part of the section manager's work consists of trying to coordinate information, activities, resources, and people, so also with respect to logistics. A tool to coordinate the foremen to well-planned logistics is to use a worksite disposition plan to visualise where current work is performed and where storage areas and transport routes are placed. There are however no plans to use the tool Leveranskalendern to get a comprehensive view of the deliveries. A challenge with the coordination is that the foremen naturally become very focused on their own work and can have difficulties seeing the big picture. The coordination towards other projects in the area of the southern ramp is, like mentioned, partly organised by the client, but in addition to this, the contractors also arranges similar meetings themselves. Hisingsbron has the most interactions with Peab, the contractor who is lowering the highway nearby, as their work sites overlap. The coordination between the two projects is made by a common work site disposition plan.

As the storage space at site is limited, especially on the south side, a solution for this can be to have more storage on the north side and almost nothing on the south. That will however create a need for more transportations. Treating more deliveries according to JIT is also a way to handle the situation. Furthermore, some materials are planned to be stored at an intermediate storage in Gothenburg's harbour. The pilings are most likely to be bought and shipped from China by boat. This procurement may be less expensive, but as it leads to long delivery times and uncertainties, the material is ordered well in advance. As a result, the material needs to be stored nearby in the harbour until they are needed on site. Barges will be used for transporting the piles to site. This intermediate storage is not in collaboration with DHL, who Skanska's logistics group have an agreement with, this is simply because DHL does not have storage space for barges.

Transporting the sheet piling is complicated as they are 25 meters long. They will therefore be transported by train to Marieholm, north of Gothenburg, where they will be loaded onto trucks and transported to site. Since the sheet piling are so long they need special transport. The special transport will need restrictions for other traffic while transported centrally in the city. Transports and work during night-time is a good option as it is more efficient with less traffic on the roads. The cost is however an important factor to consider for work during nights. A positive aspect on night transports for the project is that the buildings near the construction site are mainly offices and therefore not that sensitive towards noise during night-time.

4.3 The Slussen project

The second case is on the reconstruction of Slussen in Stockholm, which is a project that in many ways are similar to Hisingsbron. The similarities are that both projects are large infrastructure projects built in a dense city environment with water and has a lot of different projects and actors nearby.

4.3.1 Background

Slussen is located in central Stockholm and is an important junction for traffic of all kind. The first version of Slussen was built in 1642 and after that it has been rebuilt about every hundred years. The current Slussen was built in 1935 and is after 80 years in very bad condition. The foundation has subsided about 25 centimetres and during a quality examination in 2010, 178 serious structural damages were found. This is both due to a failure with the foundation when Slussen was constructed, and concrete degradation.

Stockholm is growing and will by 2030 have over one million inhabitants (Stockholms stad, 2016). When the current Slussen was built in the 1930s it was designed to handle more cars than what passes today. At its peak in the 1960s, around 90,000 cars per day used Slussen, but after other new large roads like Essingeleden was built, the traffic was reduced to 30,000 cars per day as of today. The new Slussen will suite a growing Stockholm better. It will be less adapted for car transports and have more space for pedestrians, cyclists, and public transport. The vision is that it will be a place for meetings with more open areas and a connection to the water (see Figure 6). The project is also important for the area of Mälardalen since it today is exposed to a large flood risk. Mälaren provides the water supply for the whole area of Mälardalen. The new Slussen will decrease the flood risk by increasing the capacity to release water by five times and thereby lower the flood risk and the risk for pollutants. The client of the project is the city of Stockholm, but SL, Stockholm's public transport, is financing some parts of developing the public transport. The Slussen project contains around 25 sub-projects. Skanska is responsible for the two largest sub-projects and three smaller projects. One of the larger project is the sluice facility with quays. The construction work started in 2016 and is planned to be finished in 2022.

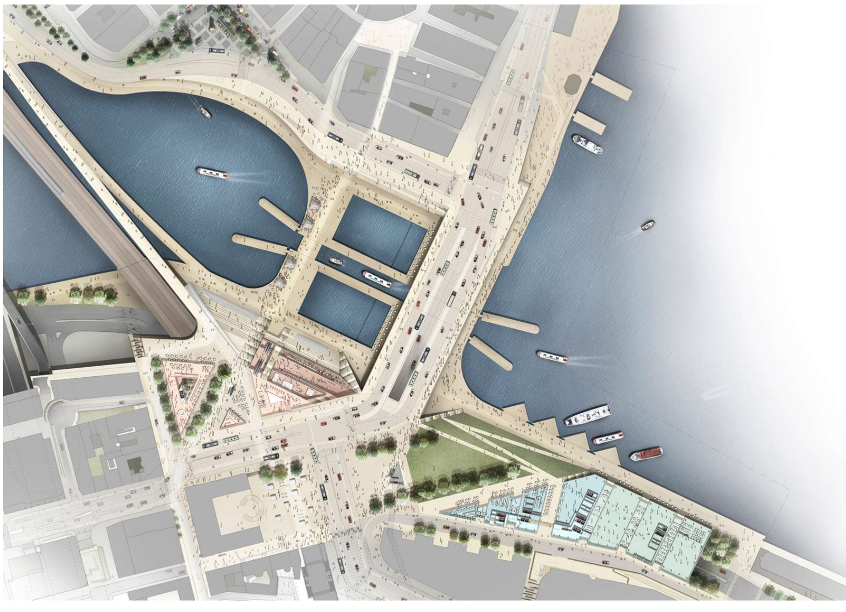

Figure 6 - Aerial view of Slussen (Stockholms stad, 2016)

4.3.2 Logistical organisation and responsibilities

At Slussen a logistic manager that normally work at Skanska's logistics group has been hired to organise and take care of the logistics. This logistics manager will hereby be called 'logistics manager B'. Logistics manager B's responsibilities includes logistics in all forms, like finding new logistical solutions, coordinate logistics, setting up guidelines, and a logistics plan. It also involves temporary work, such as traffic signs, safety for third parties, and provisional solutions like electricity and water. Logistics manager B is head of a unit supporting the production-focused part of the organisation. This to provide expertise in the area of logistics, and in that way support foremen and site managers.

The logistics manager was involved in the project early in the procurement phase. This made it easier to influence the logistics of the project from the start, and to create a well elaborated logistics plan. The reason to why a logistics manager was involved is due to many aspects. The client had a high focus on how to solve the logistical challenges in the tender request documents. Logistics manager B possesses experiences from a similar role at the large housing project, the hospital New Karolinska Solna. These reasons all contributed to the decision of having a designated logistics manager.

4.3.3 Logistical prerequisites and challenges

The project is challenging in many ways and has many similarities with Hisingsbron. Since the project is located in central Stockholm there is a lot of large and complicated work to be done in tight areas. There is also a lack of space for material storage and logistics which contributes to the need for coordination and planning. To have a good logistics plan is also important as the everyday life of Slussen should work as usual, and to be able to manage that it also put high demands on safety. The contract documents had high focus on how to solve these logistical challenges which puts extra importance to the issue. Slussen also contains many different projects in which, like described above, Skanska is responsible for five of them. This creates a need for coordination both within Skanska and between the projects and other actors in the area. The client thinks that cooperation is important, and to solve challenges with for example logistics, it is necessary to have good contact with contractors nearby. The client arranges some of the meetings, but some need to be coordinated by the different contractors.

The setting for this area includes many challenges. In addition to the obvious problem with lack of space and storage on site, the central location has other constraints. A lot of roads nearby in Gamla Stan and on Södermalm cannot be used for freight transports since the municipality prohibits it. The freight transports are all limited to one road, Stadsgårdsleden, south of Stockholm. According to logistics manager B, the road recently got recertified to bearing capacity one, the highest capacity, which makes the transportations a lot easier as the project does not need to consider the weight of the truck as much. Transports and work at nights are however limited as there are a lot of people living in the area who do not want to be disturbed during night time. The proximity to water causes difficulties in reaching the areas for piling.

4.3.4 Logistical solutions and handling

Slussen has a designated logistics manager that is working towards streamlining the organisation in respect to logistics. This person has a holistic responsibility and makes sure that there is not an area that gets overlooked. Logistics manager B has been involved in the Slussen project since the planning phase, and several solutions has been implemented. Of the three solutions that the logistics group of Skanska suggests, two are currently used, namely, Leveranskalendern and a solution similar to consolidation centres. Furthermore, a waiting area for trucks has been developed, and far-reaching worksite disposition plans and traffic redirection plans has been planned to ensure transports and relations to third party.

Leveranskalendern is very suitable for this project, according to logistics manager B. The reason is that the construction site has around ten gates, each leading to certain areas of the site. In Leveranskalendern, it is possible to see where each transport is going, and detect if any collisions are at risk, and possibly change the arrival gate. It is otherwise plausible that a truck arrives to the wrong gate when there are so many, according to logistics manager B.

Slussen uses two storage areas that provide the construction site with materials. One in Södertälje harbour, and one in Bro, 40 kilometres north of Stockholm. The centre in Södertälje has a storage for sheet pilings and steel tubes that arrives from Belgium. The material is transported by train to Södertälje harbour, and by barge from the harbour to Slussen. The other centre located in Bro is a storage facility for material that can be delivered by trucks. The storage centre in Bro is made in collaboration with a smaller carrier called Bellmans, not the DHL, who Skanska has an agreement with. These centres are important to reduce the need for storage areas on site, as the construction site is lacking the space for such endeavours. Logistics manager B highlights that these centres are not consolidation centres as such, but rather a short-term storage facility. The purpose of the centres is not that the material will be loaded and transported together, but rather to minimize the need for storage on site.

The only suggestion from Skanska’s logistics group that is not used in the Slussen project is material handling. Logistics manager B of Slussen says that material handling is not suitable for infrastructure projects, as there is not much material that is easy to handle by hand. The material in an infrastructure project is often too bulky to handle without machine equipment.

5 Analysis

This chapter analyses the empirical findings compared to the theoretical framework to discuss and evaluate different aspects of construction logistics within dense cities in relation to the chosen research questions of the thesis. The first subchapter discusses the setting of a dense city. The second to fourth subchapter analyses the research questions and the three layers of the ARA-model, logistical activities, resources, and actors, which in chapter 5.5 is combined in the ARA-model. Subchapter 5.6 concludes the analysis with discussing the importance of construction logistics.

5.1 Dense cities

There is an ongoing process towards constructing denser cities and construction projects have a lot of various challenges during construction. Many of the challenges affects logistics in some way, like lack of space, restriction on roads, and intense traffic. The limitations in both space and transports create a large need for planning and coordination, and many of the decisions need to be taken early in the project for them to make a difference and prevent bottlenecks.

Both Hisingsbron and Slussen have similar prerequisites and challenges to the ones mentioned above, with respect to construction in dense cities. Both projects have a lack of space on site, restrictions on roads nearby and dense areas surrounding the site. Planning and coordination become extra important in a dense city. Because of the challenging conditions and that the everyday life around the site should work properly, the client of Slussen had very high demands on the logistics handling, which resulted in that a logistics manager was needed. At Hisingsbron congested surroundings is mainly a problem at the south side, which resulted in some special solutions, like shipping large elements, for example long sheet piling, by night. There is a need for more innovative solutions when building in dense cities, as older, more commonly used solutions might not work within these compact settings. These solutions may also be able to improve the logistics for more ordinary projects where the need for developed logistics is not as apparent.

5.2 Logistical activities

To be able to carry out as good and efficient logistics as possible, it is an important factor to consider logistics activities as real activities throughout the construction process. Logistical activities need to get the attention they deserve to develop into opportunities for the projects instead of being a ‘necessary evil’. If logistics is made visible as an important activity in the process, it also enables more strategic work. This is a key aspect as many of the decisions that affects logistics are taken early in projects. With more strategic work, there is also a better opportunity to transfer experiences between projects and adjust general logistical solutions to suit a specific project. Through this adaption and subsequent evaluation, logistics can continuously improve.

Strategic work and logistics is mainly treated by the project management and the planning team. It is however important to create awareness of the strategic work through the whole organisation, even to the subcontractors. If the organisation is not involved in the idea of streamlining logistics nothing will change. Clarifying responsibilities is a good start. In the planning phase of the project, logistics can be visualised by charts and schedules. A worksite disposition plan is another tool to use to plan logistics, which is done in the theoretical case and the two empirical cases to manage offloading sites, for example. To focus on planning and information flow through the organisation is a prerequisite to manage good logistics, and move away from the ad-hoc nature of solving these problems.

As the project progresses there is a need for adjusting, updating, and monitoring what has been planned otherwise the planning will become outdated. For the responsible manager, it comes down to coordination. Coordination needs to be between all actors involved, all production activities, and all resources.

5.3 Logistical resources

Logistical resources can be divided into technical and organisational resources. This thesis treats consolidation centre, electronic scheduling, and material handling as technical resources, or tools, to use to carry out activities. Knowledge, experience, and specialist skills are considered organisational resources.

5.3.1 Consolidation centres

Consolidation centres are an efficient resource to reduce storage of material on-site and the number of trucks coming to site and thereby congestions. However, it might not always be suitable for all infrastructure projects, where materials such as concrete are delivered already JIT. Traditionally for infrastructure projects, it is common to have large areas near the site to store bulky materials, but when construction of infrastructure projects takes place in city centres, storage space is often rare, which is the case in the Slussen project and partly at Hisingsbron. Slussen uses extra storage areas in the vicinity of Stockholm with the purpose of reducing the material stored on site, as well as trucks to the site. The outcome is meant to be the same as if consolidation centres were used, but without the service of material handling. At Hisingsbron the construction site on the north side is spacey and provides a possibility to store material without it getting in the way of construction. The south side however, is denser and will thereby be exposed to the same lack of space as the Slussen project. Delivery times are important in any project, but due to a wider timeframe at Hisingsbron the situation is rather flexible. Because of that the site management of Hisingsbron does not chase time savings to the same extent as the Slussen project.

Consolidation centres are costly, both the facility and the personnel costs money. This cost is however saved due to the more efficient deliveries and less waiting time for the project. To reduce the cost for the consolidation centre, and therefore further increase profitability, it is possible to share a consolidation centre and its costs between multiple projects, like what was done in the Malmö housing case. One alternative, used by the both case studies, is to only use the storing part of the centre, and not load together. This storage area needs to be close to the construction site to make a difference and fulfil its purpose. Renting a storage area is cheaper than using a consolidation centre, and will, according to the interviewees, suit the infrastructure projects better due to the characteristics of the materials to be stored there.

5.3.2 Electronic scheduling

Electronic scheduling makes it easier to get a comprehensive overview of transports to and from a construction site. This tool is useful when the construction site is large and/or has many entrances, or different zones for receiving and unloading materials. However, it is necessary for all actors on site, even subcontractors, to have access to this tool and possess the knowledge of how to use it, as it loses its value if it is not fully implemented. Electronic scheduling has a potential to reduce delivery collisions, long waiting times for trucks and eventually congestions around the construction site.

Skanska has developed their own electronic scheduling program ‘Leveranskalendern’ which has the necessary characteristics of a reliable planning tool. Leveranskalendern is used at Slussen. The tool is relatively new, but has been used in housing projects for a while. Electronic scheduling is possibly going to keep increasing in usage as more actors understand the benefits of this tool. However, electronic scheduling does not erase the human factor from the transport process. Deliveries can still end up on the wrong off-loading site, despite it being clear in Leveranskalendern where the transport is going.

5.3.3 Material handling

Material handling is one of the solutions suggested by the logistics group at Skanska. This solution is however more commonly implemented in housing projects where the materials are of smaller sizes that needs to be in a specific place for it to be useful. The project managers for Hisingsbron and Slussen agreed that this is not a solution to increase logistic efficiency for their projects. This solution is deemed unlikely to function well in an infrastructure project, although the basic idea of placing material where it is needed is appealing. However, it is a controversial subject, as some logistics managers claim that it is indeed possible to implement in an infrastructure project.

5.3.4 Knowledge and experience

In addition to the technical logistical resources mentioned above, organisational resources are just as important. The organisational resources treated by this thesis are knowledge, experience, and skills without focusing on other organisational resources like assets and machines. Experiences and knowledge on how logistics has been handled by other projects in the past and what the outcome has been are useful for choosing a logistical solution for project. A knowledge of potential logistical solutions makes it easier to choose a solution that fits the specific project. Experience of, and interest for, logistics also helps turning the local prerequisites and challenges into opportunities. One example of that is the use of water to facilitate logistics which both Hisingsbron and Slussen utilises. They both use the water to transport large components instead of seeing it as an obstacle. The experience of challenging logistics can be found at logistical specialists like in Skanska’s logistics group but also in ordinary site managers. There is however a greater risk for logistics to drown among all other tasks if a site manager has the logistics responsibility.

5.4 Logistical actors

The logistical process for construction projects involves many different actors throughout the production chain. Some are involved in the planning, some in monitoring and adjusting the plans, and some in carrying out the work.

It is the organisational structure of the project that influences the ability to handle logistics for the project. One of the projects, Slussen, chose to lay the logistics responsibility on a logistics manager, while the other project, Hisingsbron, distributed the responsibility between the two section managers. These are two different ways to handle logistics management. The advantage of having a designated logistics manager is, regardless of whether it is a logistics specialist or just a person assigned for the task, the clarity it creates for the organisation. If questions about logistics arises somewhere in the organisation, or outside it, finding the answer is easier as there are no uncertainties of whom to ask. Having a person assigned to the task also enables a holistic view on logistics and thereby opportunities to improve and streamline logistics for the whole project. If the person in charge is also a logistics specialist, like from

Skanska's logistics group, much general knowledge and experience of logistics is gained. A risk with having one person assigned to logistics is that this person can become blind for the big picture of the project, and only seeing the importance of logistics. It is therefore important to be part of a site management team that can provide a holistic view of the project. Another alternative is having logistics as one of the many general responsibilities of a site manager or a section manager. This solution is implemented in Hisingsbron, and creates a better general understanding on logistics as part of the whole construction process, but also creates a risk for logistics to drown among other tasks.

Choosing to have a designated logistics manager seems to be an active and informed choice based on positive experiences. Deciding to not have a designated logistics manager is presumably based on a lack of knowledge of what such a role would contribute with. If the site management does not even know of the logistics group, it is no surprise that they are not hired to work on their projects. However, if logistics is one of many tasks a manager is responsible for, the attention logistics gets is dependent on the interest of the manager and the demands of the management or the client. As Skanska have their own logistics group, it is remarkable that the knowledge of them is not sufficiently established in the whole company, and that they only just started with focusing on infrastructure. To make good, active, and informed decisions, it is important to understand the options and what consequences they entail.

5.4.1 Suppliers, subcontractors, and adjacent projects

As stated in the theory chapter, contractors generally have a loose relationship towards its suppliers. This leads to fewer strategic agreements that has potential to increase logistical focus. With this traditional way of thinking, it is easy to see why fewer resources are spent on improving logistics. The short-sightedness of a loose relationship has worked fine in the past, but with more demanding situations comes more to gain from more effective supply system. By getting suppliers involved in the construction process, site-related settings, and demands set by the client, it is more likely that all parties will work closer to each other and increase efficiency.

In the case of Slussen there is a more coupled relationship with the shipper Bellmans, who will deliver material to the construction site from their storage site. This is an example of how different actors can work together and increase efficiency and awareness of logistics. The storage site outside Stockholm leads to less material stored on the already dense construction site of Slussen.

The housing case from Malmö had other contractors in the vicinity and needed to share the common space in between their construction sites. As a tool to handle this conflict, a common worksite disposition plan was implemented. A similar solution should be implemented in any construction project where there are other contractors nearby. Coordination between the adjacent project, like on both Hisingsbron and Slussen, is also an important part of cooperating and making the most of the situation.

5.4.2 The client

The client can have a large impact on how logistics is handled. One way to influence the project is with requirements in the tender documents, which was the case at Slussen. Requirements and demands addresses the subject as extra important and may also attract contractors with special competence or encourage existing contractors to improve their knowledge in the area. The fact that the client's requirements matter is the case for Hisingsbron as well, but at Hisingsbron it is not logistics, but soft values, that is in focus. The client has therefore an opportunity to decrease the impact on the environment and the everyday life of the city. For infrastructure projects the client is exclusively public sector with a holistic view on the infrastructural network and strategies for developing the city. With improved logistics and fewer trucks to construction sites, the air quality, traffic noise, and congestions can be improved, which is of interest in terms of environment and sustainability. Encouraging and arranging coordination between projects nearby, like in the case of Hisingsbron, can also be an efficient way for clients to influence the general situation for the city.

5.5 The application of the ARA-model

The purpose of introducing the ARA-model in this thesis is to describe the different relationships that connects activities, resources, and actors together in the setting of a dense city infrastructure construction project. It is possible to view organisations through the lens of the ARA-model and thus easier see the connections between the different layers of the organisation. The idea of the model is that actors use resources to perform activities. In this thesis, the three research questions correspond to each ingoing layer of the ARA-model, and the idea is to use it to clarify the connection between these questions. All the research questions have the prerequisites of a dense city, which can be seen as the playfield of the model.

During the thesis, there has been a distinction between infrastructure and housing. Housing projects has appeared more progressive with the use of logistics managers, compared to infrastructure projects. It was clear during the literature study phase that it was an apparent difference in the amount of research done in each respective area. Most existing research on construction logistics were aimed towards housing projects, and the case studies were almost exclusively made with a housing perspective. This leads to a curiosity to find out what the differences are between housing and infrastructure, and what their similarities are.

When activities, resources, and actors of construction logistics are studied in this thesis, the setting differentiates between infrastructure and housing. As the setting changes, so does the activities, actors, and resources. The actual activities of housing and infrastructure projects have many similarities like for example casting and piling. The activities in infrastructure project are however more comprehensive and homogenous which also lead to more homogenous transports. Housing construction on the other hand has a greater variety of minor jobs, like different installations, which lead to many different small transports. The actors in a housing project are partly different, with often more subcontractors and suppliers than in an infrastructure project. This is due to the varying work of constructing a house, where electrics, ventilation, and sanitation makes a large part of the finished house. Furthermore, is the client in infrastructure projects almost exclusively public, while it in housing projects often are private clients, although public clients are common as well. The logistical resources are mainly the same, regardless of housing or infrastructure, but, as stated earlier, material handling is one resource that is possibly not suitable for infrastructure projects. However, it is not the differences that should be studied, but rather the similarities, to develop efficient logistical processes for the whole construction industry.

5.6 The importance of construction logistics

Construction logistics is an upcoming subject for the construction industry. This is true for especially infrastructure projects which nowadays need to build large constructions centrally in order to develop the cities. There is however a lack of research on logistics related to infrastructure projects in published papers and a lack of established and standardised working methods in the industry. Scientific papers on construction logistics is oftentimes regarding housing construction. This trend in academia seems to match the situation in production, where logistical managers are more often involved in housing projects. The two case studies of this thesis handle logistics in separate ways; Hisingsbron in a more traditional way, and Slussen in a more innovative way. The thesis does not try to judge which is the best solution, but to reflect on how different choices and mind sets affect logistics.

Both theory and interviewees discusses the fact that every project has their own level of uniqueness and that this is the reason for the difficulties with implement permanent changes in the construction industry. This also leads to why the construction industry is considered old-fashioned. That it exists differences between infrastructure projects and housing construction is a fact, but how large the differences actually are can be questioned like discussed in chapter 5.5. When trying to find general logistical solutions that streamlines the industry, the focus needs to be on the similarities and what can be learned from each other. Theory teaches that all projects have the same desire to control flows of material to and from the construction site, which is reasonable as this variability is difficult to handle. It should be possible to start with this as the common ground and from there work towards the more unique parts of each project. The differences should be taken into consideration and a well-planned logistical thinking should be flexible enough to handle them. Compared to the car manufacturing industry, the construction industry is a long way behind in streamlining their production and logistics. JIT is far more developed in industries like manufacturing. Infrastructure projects blame their uniqueness and their lack of repetitive work compared to the housing construction in the same way the whole construction industry does compared to manufacturing. However, infrastructure projects have repetitive work as well, although maybe not to the same extent as housing. Bridge pylons, for example, are often built with little to none variation. Activities like constructing these pylons can therefore be seen as a repetitive activity. As Ballard and Howell (1998) stated, the process of streamlining the construction industry can be handled in two steps. Step one is to find what parts of construction are similar for every project to create an efficient process. The second step is to create techniques for taking care of the need for flexibility and thereby the adaptability towards the unique parts of a project. Relating this to infrastructure and housing projects, the process could be divided into three steps instead. The first with the most general processes used by all projects, both infrastructure and housing, the second with standardised processes for infrastructure or housing separately, and the third step as the flexibility towards the individual project.

That Skanska has an own logistics group indicates that the organisation considers logistics important. Whether a project uses their services is however dependent on individuals' attitude towards logistics and logistical solutions. The logistics group wants to reach out to more projects and is convinced of the value they can supply, but they do not have the resources to market themselves. It is possible they need help with reaching out, or focusing resources on how to do that in a more strategic and efficient way. Convincing projects of the value of logistics in a tête-à-tête may be the most successful but not the most efficient way. If Skanska as a company believes logistics to be an important area to improve, it needs to be communicated in the company.

It seems as the current focus on logistics in infrastructure projects is good for the industry. The solutions and actions that are taken in the logistically difficult projects can provide a basis for smaller projects with a seemingly smaller need for logistical solutions. To convince the management of a project to invest in logistical solutions there is a need to make better measurements on how well the logistical solutions work regarding, for example, saving time and money. I can be argued that, infrastructure projects have been carried out for a long time without the use of logistics managers, so it can be questioned why they suddenly are so important. It can be the new norm to efficiently trim organisations towards making them fine-tuned economically, and this has led to a chase for even the smallest gain. This measurement is something Skanska's logistics group does but the result is only communicated while discussing the use of their services with projects. If logistics gets easier to measure it will be easier for project to choose the right solutions. Projects would benefit from considering logistics as an activity. An activity that is part of a network represented by the ARA-model. Whether the project management chooses to work with logistics managers or not, is still dependent on the project and its prerequisites.

6 Conclusion

This chapter is the concluding remarks of the thesis. It answers the research questions and discusses additional conclusions that emerged through the research.

6.1 Aim and research questions

The aim of the thesis is to examine how infrastructure projects handle logistical prerequisites and challenges while constructing within increasingly dense cities. This is investigated based on three aspects, activities, resources and actors, which provides the foundation for the research questions. Various logistical actors use logistical resources to perform activities in different ways.

What activities does logistics planning and execution for large infrastructure projects within dense cities entail?

Planning logistics for a project includes, among others, deciding what type of logistical solution is needed, planning where and how deliveries will take place, planning storage on site and potential external storage. When the execution of the project begins, the focus is shifted to adjusting and monitoring logistics. Communication and knowledge transferring are important activities to continually improve and extend the process to other actors inside and outside the organisation.

The research highlights the value of considering logistics as important activities early in the project, as many decisions affecting logistics are taken early. When construction logistics is well scrutinised in terms of its importance, logistics can become an important competitive factor within the industry.

What type of technical and organisational resources are needed to plan for and carry out logistics for large infrastructure projects within dense cities?

Technical logistical resources can be electronic tools, like electronic scheduling program, or services, like material handling and external storage. This kind of resource is used when projects are executed. Organisational resources are mainly knowledge and experience which are important resources to plan for, and carry out all logistical activities and to interact and collaborate with other actors.

One characteristic of the construction industry is the project-based organisation. For such organisations, it is a challenge to implement common structures and transfer knowledge. The logistics group at Skanska is a way to tackle this challenge, both providing knowledge, experience, and interest in the area, but also recommending and providing technical resources to the projects.

Which actors are involved in the planning and execution of logistics in large infrastructure projects within dense cities?

Actors involved in logistics vary between projects. This thesis identifies the actor responsible for logistics as either a logistics manager or a designated person within the site management. Involved actors in the supply process are suppliers and carriers, and at site, construction workers, subcontractors, and the site management. Additionally, the client and adjacent projects are also seen as actors that can influence the planning of logistics.

Comparing the case studies, it is clear that individual thoughts, and experiences, but also demands from other actors, like the client, has major impact on how logistics are handled. To prevent logistics from being dependent on the interest of individuals it is important for a company to actively consider logistics and communicate its importance to all involved actors.

6.2 Prerequisites and challenges of logistics in dense cities

Uniqueness of each project is a perception that dominates the construction industry. Unfortunately, the uniqueness easily becomes an excuse to avoid standardisation. This attitude must be changed to focus on the similarities instead of blaming the differences, and thus efficient, standardised logistical processes can be developed.

The challenge of constructing in increasingly dense cities highlights the importance of logistics and can be used as a springboard for streamlining construction logistics. The lessons learned can contribute to streamlining more ordinary projects with a seemingly smaller need for advanced logistics. To make the site management realise the value of investing in logistics there is a need for good measurements of the savings they contribute to. Good measurements can visualise indirect and hidden costs of not having logistical solutions and thereby contribute to a fair comparison. Regardless of whether actions are taken to improve logistics or not, the decision should always be informed and actively taken. Otherwise logistics can become “forgotten activities” and unnecessarily large costs that are not even noticed.

In conclusion, construction logistics is an upcoming subject of both research and practice, and this is especially true for infrastructure projects, where currently few resources are spent on creating well-planned logistical solutions. The densification of cities creates a need for a more developed logistical solution especially for infrastructure projects. To streamline logistics, it is essential that logistics primarily needs to be noticed as an important activity early in the planning of the project. Furthermore, the similarities rather than the differences between projects need to be embraced. This will lead to knowledge and routines being used more consequently. Good economical measurements on how well different logistical solutions work need to be developed. This is because it ultimately is a question of economy. To fully implement well-planned logistics is only possible if it is economically defendable.

6.3 Suggestions for further research

During the research of this thesis, a few areas have been discovered where research could benefit from further investigations. One suggestion is to develop measurements on how efficient and well-functioning logistical solutions or resources are. This would be a key in evaluating and choosing the proper solution for a specific project. Future studies should focus on creating a template for measuring costs and efficiency with regard to resource utilisation. Another interesting area of research is to study and map the standardisation of logistics in the construction industry. It would be preferable to have guidelines of what to do and when regarding logistics on a construction site. Whether material handling is applicable on infrastructure projects could be a part in that research as the opinion differs.

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Appendix

Questions to the consultant at Trafikkontoret

- Vad är din bild av området kring Centralen de kommande åren?
- Vilka logistiska utmaningar finns det för projek i området tex. Hisingsbroprojektet?
- Vilka åtgärder tas för att både trafiken och leveranser ska flyta på bra under byggtiden?
- Finns det några krav med avseende på logistik som sätts på entreprenörerna i området från Trafikkontorets sida?
- Ges entreprenörerna några speciella förutsättningar för att underlätta/klara av dessa?
- Finns det någon samordning entreprenörer emellan?
- Finns det några externa aktörer som är med och planerar trafiken i området?
- *Något annat du vill tillägga?*
- *Någon annan som vi borde prata med?*
- *Tips?*

Questions to the site management for Slussen and Hisingsbron

- Berätta kort om projektet, Skanskas del
- Varför togs initiativet till att ha/inte ha en logistikansvarig (förmodligen pga. förutsättningar)
    - Komplicerad situation?
    - Inte kompetensen bland folk ute?
    - Erfarenheter om att det är jättebra att ha?
    - Kostnadsbesparande?
    - Annat?
- Hur märks närvaron av en logistikansvarig ute i produktionen?
    - Hur fungerar det?
    - Hur går det till när logistikavdelningen kommer in?
    - Vem har ansvar för vad?
    - Vilka förbättringar märks?
    - Vad kostar en logistiker från Skanska?
- Lösningar
    - Vilka lösningar har implementerats?
    - Hur har utfallet varit?
- Förutsättningar
    - Unikt med projektet?
    - Huvudutmaningar
    - Beställarens roll i projektet?
    - Projekt i närheten?
    - Platsbrist?
    - Trafik?
    - Vatten?
    - Stort projekt?

Questions to Logistics Manager A

- Hur ser din avdelning och dina arbetsuppgifter ut?
- Vilka logistiska utmaningar jobbar du främst med och hur? (lösningar)
  - Vad finns det för utmaningar när man bygger centralt?
  - På vilket sätt tas hänsyn till trafikflöden under rusningstrafik kontra lågtrafik? (JIT, SCM, Timeslots, Consolidation centres)
- Vad krävs det för aktiviteter vid planering och utförande av logistisk för stora infrastrukturprojekt?
- Hur ser du på logistikens betydelse för ett projekt?
- Du nämnde att det oftast var Skanska Hus som använde sig av dina tjänster, varför tror du att det är så?
  - Skulle dina tjänster kunna tillämpas på anläggningssidan också? Isåfall, hur?
  - (Vad är det för skillnader på infra och hus, om det är några?)
- Vad krävs för att ett projekt (i täta städer) ska fungera bra logistiskt (Organisatoriskt och resursmässigt)?
- Digitala hjälpmedel, Leveranskalendern
- Vilka personer är involverade i planering och utförande av logistik? Hur samarbetar dessa?
- Om du hade jobbat med Hisingsbron, vad skulle du tänkt på för att underlätta logistiken?
- Är samarbete vanligt entreprenörer och projekt emellan?
- Något du vill tillägga
- Någon annan vi bör prata med?
- Något intressant projekt du rekommenderar att titta på?