Improving Transport Efficiency in the Construction Supply Chain

Farah Naz
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Farah Naz

Linköping Studies in Science and Technology. Dissertation No. 2396

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Abstract

Construction is responsible for a large part of carbon dioxide (CO2) emissions worldwide (39%) and environmental concerns in construction are growing. Construction is transport intensive since the final construction products like buildings are built directly at the site of use and all resources need to be transported to and from the construction site. The environmental impact of construction transport is significant and requires attention since 90% of the transport within construction is road transport. However, historically both regulatory bodies and the construction companies have overlooked construction transport causing transport to remain unnoticed as a separate activity. Construction transport efficiency (CTE) is low, but CTE can be improved using solutions such as logistics services, digital tools, and information sharing which in turn add value to the involved actors and reduce CO2 emissions. However, there is a need to better understand how to improve CTE.

The purpose of the thesis is "to investigate how to improve construction transport efficiency by using logistics services, digital tools and information sharing to add value for the involved actors".

Three research questions (RQs) have been developed to achieve the purpose of the thesis:

**RQ1a**: What activities constitute construction transport?

**RQ1b**: What are the challenges in improving construction transport efficiency?

**RQ2**: How can logistics services, digital tools and information sharing improve construction transport efficiency?

**RQ3**: How does improving construction transport efficiency add value for the involved actors?

To answer the RQs, a case study has been used as a primary research approach to develop an in-depth and detailed understanding of construction transport. The thesis comprises five studies over the period of five years. Data has been collected mainly through observations, interviews, and company’s internal statistical data. Furthermore, construction transport flows have been studied from different actor’s perspective such as transporter, main contractor, material supplier, and waste collector.
The thesis highlights the lack of efficiency within construction transport by identifying value adding, non-value adding, and necessary but non-value adding activities. The underlying reasons for the low CTE are lack of planning, poor communication, and lack of standard operating procedures (SOPs). Lack of planning leads to poor routing, empty travelling, and an increased number of transport. Likewise, poor communication results in outdated plans, last-minute changes, delayed deliveries whereas lack of SOPs results in non-standardized processes, lack of proper loading and unloading zones and improper material handling leading to damages. Due to poor transport planning, poor communication and lack of SOPs, construction transport uses more resources (such as time, fuel, vehicle, energy, and effort) than needed, adding less value to the involved actors (i.e. transporter, main contractor, material supplier and waste collector) as well as impacting the environment negatively.

The thesis emphasizes the value of logistics services (such as material management, on-site vendor management inventory (VMI), waste management) for the involved actors in terms of improving CTE and how CTE can be improved using logistics services, digital tools and information sharing. Given the critical importance of delivery reliability within construction transport, the thesis provides value by detailing the time taken by each activity within construction transport flow via value stream mapping approach. Moreover, the thesis broadly adds knowledge to Logistics and Construction Management research areas whereby focusing specifically on construction transport—so far unnoticed as a distinct activity.

Keywords: construction transport efficiency, actors perspective (transporter, main contractor, material supplier and waste collector), logistics services, digitalization, information sharing, sustainability
I would like to express my deepest gratitude to everyone who has supported and helped me throughout my PhD journey. I extend my heartfelt thanks to my managers, supervisors, and colleagues at both Linköping University (LiU) and the Swedish National Road and Transport Research Institute (VTI). Your guidance and encouragement have been invaluable. I am immensely grateful to my family and friends for their 24/7 availability. Your belief in me has been a constant source of strength. I would also like to thank Triple F for their continuous support and assistance throughout this journey.

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My PhD experience has been an interesting journey, filled with significant learning and both professional and personal development. I have greatly enjoyed my time at both LiU and VTI, and I am deeply thankful for the opportunities and experiences I have had here.

Thank you all for being a part of this journey.

Farah Naz
Norrköping, May 2024
Thesis Outline

The doctoral thesis “Improving Transport Efficiency in the Construction Supply Chain” is documented as a requirement for the completion of Doctor of Philosophy (PhD) degree. The thesis, being composite in nature, is divided into two parts:

1. **Kappa** - an extensive summary of research conducted over a period of five years.

2. **Five research papers** - acting as the basis for Kappa.

Below is the list of research papers included in this thesis along with their titles, conferences where the papers are presented, and author’s contribution. The research papers have been arranged in the order of studies conducted during the doctoral research.

**List of research papers included in the thesis:**

**Paper I**  
**Title:** Construction Transport (In)Efficiency – An Effect of Information Asymmetry Among Construction Actors.  
**Authors:** Farah Naz, Mats Janne and Anna Fredriksson.  
**Status:** Submitted to the journal “Construction Innovation: Information, Process, Management” on April 29, 2024.  
**Conference:** An earlier version was presented by Naz at the LRN Conference, Cardiff Business School 2020, online.  
**Author’s Contribution:** Naz did the data collection and writing key sections of the paper such as the introduction, frame of reference, methodology, analysis, and discussion. However, the writing was shared equally between Naz and Janne. The earlier versions of the paper were primarily authored by Naz. Whereas in this version, Janne played a major role in organizing and structuring the content, along with finalizing the analysis section. Fredriksson provided guidance as well as insightful feedback throughout the writing process.

**Paper II**  
**Title:** The Potential of Improving Construction Transport Time Efficiency – A Freight Forwarder Perspective.  
**Authors:** Farah Naz, Anna Fredriksson and Linea Kjellsdotter Ivert.  
**Status:** Published (Year 2022)
Available at: MDPI Journal Sustainability Special Issue, 14(17), p.10491. https://doi.org/10.3390/su141710491

Conference: Presented by Naz at the NOFOMA Conference (2021) online.

Author’s Contribution: The paper is primarily authored by Naz. Naz did the data collection and data analysis, as well as writing key sections of the paper including the introduction, frame of reference, methodology and analysis. However, the discussion section of the paper was written with input from Fredriksson. Furthermore, Fredriksson and Kjellsdotter Ivert provided insightful feedback throughout the writing process.

Paper III

Title: Creating Logistics Service Value in Construction – A quest of coordinating modules in a loosely coupled system.

Authors: Anna Fredriksson, Linea Kjellsdotter Ivert and Farah Naz.

Status: Submitted to the journal “Construction Management and Economics” on May 9, 2024

Conference: Presented by Fredriksson at the NOFOMA Conference (2021) online.

Author’s Contribution: Fredriksson and Kjellsdotter Ivert took the lead role in conceptualizing, writing and performing analysis. Naz conducted the literature search, identified relevant concepts that could be used in the analytical framework of the paper and compiled a reference list. Data gathering was a joint act between Naz, Fredriksson and Kjellsdotter Ivert. Additionally, Naz performed the language editing, final formatting, and paper submission to the journal.

Paper IV

Title: Clarifying the interface between construction supply chain and site – A key to improved delivery efficiency.

Authors: Farah Naz and Anna Fredriksson.

Status: Published as Springer conference proceedings (Year 2023)

Available at: https://link.springer.com/chapter/10.1007/978-3-031-43670-3_10


Author’s Contribution: The paper was primarily authored by Naz. Naz did the data collection and data analysis, and wrote key sections of the paper including the introduction, frame of reference, methodology, analysis, and discussion. Insightful comments and constructive feedback were consistently provided throughout the writing process by Fredriksson.
Paper V  Title: Improving construction transport efficiency by digitalization.

Authors: Farah Naz and Linea Kjellsdotter Ivert.

Status: Conference Paper

Conference: Presented by Naz at the NOFOMA Conference (2023) in Helsinki – Espoo, Finland.

Author’s Contribution: Naz collected and analyzed the data, as well as wrote key sections of the paper including the introduction, frame of reference, methodology, analysis, and discussion. Insightful comments and constructive feedback were consistently provided throughout the writing process by Kjellsdotter Ivert.

Research paper not included in the thesis:

Paper VI  Title: Electrification of construction – A multi actor challenge scaling up with transport efficiency.

Authors: Müge Tetik, Anna Fredriksson and Farah Naz.

Status: Conference Paper


Author’s Contribution: Naz collected, analyzed and presented the data in the workshop and to the other authors. Tetik collected additional data and wrote key sections of the paper including the introduction, frame of reference, methodology, analysis, and discussion. Fredriksson provided guidance in the planning of the study as well as insightful feedback throughout the writing process.
The only way to make sense out of change is to plunge into it, move with it, and join the dance.

ALAN WILSON WATTS
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List of Terminologies

Construction logistics setup (CLS): CLS is defined as "a governance structure for construction that has been agreed on to control, manage and follow up the flow of materials, waste, machinery and personnel to, from and at the construction site" (Janne, 2020).

Construction supply chain (CSC): CSC refers to the planning, coordination and optimization of the flow of materials, information and finances across construction. It involves managing the sourcing, procurement, logistics and delivery of construction materials and services required for the construction.

Contingency plans: Contingency plans are predefined strategies and actions that companies implement to respond to potential unexpected events or emergencies that could disrupt normal operations e.g. alternative delivery routes, backup material suppliers, additional labor etc.

Developer: A developer is a company responsible for overseeing the planning, financing, and execution of construction.

Freight forwarder: Freight forwarder is a company that arranges shipments for individuals or companies, coordinating the transportation of goods from the material supplier to a market, customer, or final distribution point.

Information asymmetry: Information asymmetry refers to a situation in which one actor has access to more or better information than another actor (Clarkson et al., 2007), or that no actor has access to all the information needed to carry out their tasks efficiently (Aben et al., 2021).

Involved actors: Involved actors is a term used in this thesis to refer to the actors involved in the construction transport such as transporter, main contractor, material supplier and waste collector.

Logistics service provider (LSP): LSP, commonly referred as third party logistics provider (TPL), is a company that specializes in offering
logistics services as its primary business e.g. storage, transportation, material management, waste management etc.

Main contractor: The main contractor is a company who oversees the building process according to the terms and conditions outlined in the construction contract. This role involves engaging personnel to carry out different construction activities. In Sweden, it falls upon the main contractor to handle on-site logistics and oversee daily operations on the construction site.

Main contractor subsystem: The main contractor subsystem includes suppliers, subcontractors, transporters, and construction LSPs, all of whom either possess the materials or influence the transport processes at some stage of delivery.

Material supplier: A material supplier is a company that provides the necessary materials required for various projects. In the context of construction, e.g. a material supplier would provide items such as scaffolding, steel, insulation, glass, and other building materials needed to complete construction.

On-site vs off-site logistics: On-site logistics is the management of logistics activities directly on the construction site, whereas off-site logistics involves the management of logistics activities related to the transport of resources to and from the construction site (Ghanem et al., 2018).

Slack resources: Slack resources refer to the extra resources, such as time, personnel, equipment, or materials, that a company maintains beyond its immediate operational needs. For example, additional delivery vehicles, excess inventory etc.

Subcontractor: A subcontractor is a company hired by the main contractor to perform specific tasks or provide specialized services e.g. electrical work, plumbing, etc. within construction.

Transporter: A transporter refers to a company responsible for moving items from one location to another. Ownership of vehicles by the transporter is optional.

Vendor Managed Inventory (VMI): VMI is an inventory management approach where the material supplier is responsible for maintaining the inventory levels of their products. The customer shares usage data with the material supplier, who then takes on the responsibility of replenishing stock as needed, typically directly at the point of consumption.

Waste collector: A waste collector is a company that deals with the collection of waste, transporting, sorting and recycling.
1 Introduction

This thesis begins with an introduction that sets out the background of the conducted research. It further outlines the purpose and the research questions, in addition to presenting the problematization and the scope of the thesis.

1.1 Background

Environmental concerns are rising for construction (Eriksson, 2019) given that construction accounts for 39% of all energy and process-related carbon dioxide (CO2) emissions worldwide (IEA, 2019; World Green Building Council, 2020). In parallel to this, an ongoing urbanization trend has intensified construction globally (The World Bank, 2021). Cities have been growing in terms of both population and economic activity (Statista, 2024). Transport plays a pivotal role in construction, mainly due to the need to move materials to, from and at the construction site (Ekeskar & Rudberg, 2016). Construction is unique in that it uses a wide variety of materials which are often both heavy and voluminous (Colangelo et al., 2018). One of the most critical factors in construction is the timely delivery of materials (Shehu et al., 2023). Late deliveries can lead to significant delays in construction and increased costs due to idle labor and machinery (Shehu et al., 2023). Therefore, transport efficiency is essential as it directly impacts the construction timeline, cost, and CO2 emissions. Construction transport efficiency (CTE) is defined as “performing
all construction transport activities from the point of loading to the point of unloading materials either from or to the construction site while utilizing the minimum number of resources including, but not limited to, fuel consumption and time taken, while ensuring minimum environmental impact” (Naz, 2022).

From an environmental perspective, according to Hong et al. (2015) material transport to and from the site accounts for 3.6% of CO2 emissions at project level. As per Sezer and Fredriksson (2020), construction transport involves delivering materials, machinery, and equipment to construction site, as well as removing waste from construction site. According to Guerlain et al. (2019), transport related to construction accounts for 30% of the total freight transport in urban regions. Furthermore, 90% of the transport within construction is road transport (Cederstav et al., 2023). Given these insights, it is clear that the environmental impact of construction transport is significant and requires attention (Sezer & Fredriksson, 2020; Xu et al., 2020).

Historically, both regulatory bodies and construction companies have overlooked construction transport as a contributing element to the environmental impact from construction (Sezer & Fredriksson, 2021). One reason for this can be that transport costs are typically included in the material price. This means that transport remain unnoticed as a separate activity (Dubois et al., 2019; Eriksson, 2019), thus resulting in a lack of knowledge of the organization of transport in construction. Additionally, since actors such as transporter, main contractor, material supplier and waste collector interact among themselves through transport, hence this highlights the need to better understand construction transport and improve CTE. Furthermore, understanding construction transport and improving CTE is crucial because the way material is transported not only impacts productivity at the construction site but also affects the efficiency of involved actors (Backstrand & Fredriksson, 2022; Sezer & Fredriksson, 2020). Recently, there has been a shift in the attention given to transport as a significant factor in environmental impact, aligning with the Paris Agreement, a climate change treaty established in 2015 (UNFCCC, 2022). In response to this, Sweden has set an objective to achieve net-zero CO2 emissions by the year 2045 (Swedish Climate Policy Council, 2023). Lately, Swedish Climate Policy Council has put high demands on reporting transport emissions, due to the need to accelerate the transition towards climate neutrality (Swedish Climate Policy Council, 2023). Given this, there is a considerable potential in improving transport efficiency within construction in order to cut CO2 emissions and realize the objective of net-zero CO2 emissions (Cederstav et al., 2023).

Existing research in construction logistics and construction supply chain has primarily focused on describing logistics activities that occur at construction sites. For instance, Thunberg and Fredriksson (2017) explored the managerial challenges present on-site and strategies for addressing them.
Similarly, studies by Lindén and Josephson (2013), Ekeskar et al. (2022), and Bortolini et al. (2015) have proposed efficient management of materials on-site. However, the aspect of construction transport, particularly off-site, has received limited attention, with notable exceptions being the work of Sezer and Fredriksson (2020), Eriksson (2019), and Babak (2017), despite its significance as highlighted by Dubois et al. (2019) and Sundquist et al. (2017). However, while efforts have been made to examine construction supply chains – for example, Thunberg (2016) developed a framework for planning within construction supply chains, and Dubois et al. (2019) investigated coordination within supply chain – the focus on the transport component of construction logistics remains relatively underexplored. This highlights the need to better understand construction transport in order to improve its efficiency. Thus, this thesis focuses on enhancing the understanding of construction transport and improving CTE.

1.2 Problematization

Since the final construction products are built directly at the site of use (Ekeskar, 2016), all necessary materials and resources are transported to the site (Josephson & Saukkoriipi, 2007). Additionally, waste generated during construction is transported away from the site throughout the duration of construction (Gangolells et al., 2014) making construction very transport intensive. Currently, construction transport is managed non-systematically, lacking structured planning and organization. Although improving CTE is necessary, the construction faces a substantial knowledge gap in relation to the benefits and implementation of transport efficiency. Consequently, this lack of knowledge calls for investigation that not only look deep into the solutions but also study their role in improving CTE which ultimately add value to the involved actors. However, improving CTE is challenging. This is because of the complicated nature of construction, for example in terms of temporariness (Bakker, 2010; Lundin & Söderholm, 1995), involvement of multiple actors (Ekeskar, 2016), uniqueness (Jonsson & Rudberg, 2013), arm’s length relationships (Bankvall et al., 2010; Briscoe & Dainty, 2005), goal conflicts (Ejohwomu et al., 2016), lack of trust and commitment (Gad & Shane, 2014; Gadde & Dubois, 2010) etc.

Solutions such as logistics services (Chisuwa et al., 2019; Gremyr et al., 2023), digital tools (Duarte-Vidal et al., 2021; Sepasgozar et al., 2022), and information sharing (Ibrahim, 2014; Nezami et al., 2022) are commonly considered for driving improvements. Logistics services are defined as activities that organize and manage the movement of goods (Mentzer et al., 1999). Digital tools offer real-time tracking and allow greater visibility and control (Duarte-Vidal et al., 2021; Sepasgozar et al., 2022). Likewise, another
1. Introduction

The proposed solution, information sharing aims at bridging the communication gap among involved actors (Ibrahim, 2014; Nezami et al., 2022).

However, the implementation of these solutions in improving CTE has not been thoroughly studied. Furthermore, there is a limited understanding of how logistics services, digital tools and information sharing can be integrated into construction transport. The benefits these solutions provide are yet to be explored within construction transport. For example, these solutions might lead to timely construction and reduced costs, however how transport efficiency is improved and how this improved efficiency adds value individually to involved actors — transporter, main contractor, material supplier and waste collector, requires deeper investigation. Generally, value is defined as the ratio between perceived benefits and total costs (Kilibarda et al., 2013). Likewise, in this thesis, adding “value” refers to significant time and cost savings (Gronroos & Voima, 2013).

To improve CTE, it is important to shift towards a more systematic approach in managing construction transport. Adopting solutions like logistics services, digital tools, and information sharing can facilitate this shift, leading to more systematic transport management. Such improvements in CTE are expected to significantly add value for all involved actors in construction.

1.3 Purpose and research questions (RQs)

The purpose of the thesis is “to investigate how to improve construction transport efficiency by using logistics services, digital tools and information sharing to add value for the involved actors”.

Three research questions (RQs) have been developed to achieve the purpose of the thesis:

Research Question 1a (RQ1a): What activities constitute construction transport?

Research Question 1b (RQ1b): What are the challenges in improving construction transport efficiency?

To improve CTE, it is essential to begin with a comprehensive understanding of construction transport. This involves studying the activities that constitute construction transport and understanding the challenges associated within construction transport. Gaining this deep insight is a critical first step, as it lays the groundwork for identifying areas of improvement.

Research Question 2 (RQ2): How can logistics services, digital tools and information sharing improve construction transport efficiency?
Once a detailed understanding of construction transport and the challenges within construction transport are established, the next step is to study solutions such as logistics services, digital tools and information sharing and the role these solutions play in improving CTE. There are various logistics services, however in this thesis logistics services – material management, on-site VMI and waste management are considered. Furthermore, the use of digital scanners is studied as a digital tool in this thesis.

**Research Question 3 (RQ3):** How does improving construction transport efficiency add value for the involved actors?

From a monetary perspective, adding value is seen in terms of significant time and cost savings (Gronroos, 2017). However, adding value extends beyond the financial gains, into areas such as technical and perceived gains. By improving CTE, resources will be used efficiently, thus resulting in adding the monetary value of time and cost savings. In addition to this, improving CTE might create technical and perceived value for all the involved actors.

Figure 1.1 provides a pictorial depiction of the RQs. RQ1 identifies the challenges within construction transport. RQ2 presents the role of solutions such as logistics services, digital tools, and information sharing in improving CTE. RQ3 discusses how improvements in CTE provide value to the involved actors.

1.4 Scope

The scope of the thesis is illustrated in Figure 1.2:
The thesis studies house building construction in Sweden. House building construction includes the construction of both residential and commercial properties, such as single and multi-family homes (Lessing, 2019).

The thesis primarily focuses on construction transport to and from the construction site. The scope of the thesis is limited to the final segment of transport, focusing solely on the movement of material from the material supplier to the construction site and the movement of waste material from the construction site to the waste collector. Furthermore, the thesis studies two transport flows mainly i.e. material flow and waste flow. Material flow includes transport of material from the material supplier to the point where the material is unloaded at the construction site and is depicted in Figure 1.2 using arrow between the material supplier and the main contractor. The waste flow includes transport from the waste collector collecting the waste from the construction site, emptying the waste container at the sorting facility, and returning the empty container to the collection point. Pictorially, the waste flow is represented by the arrow between the waste collector and the main contractor in Figure 1.2.

The focus of the thesis is on improving CTE and adding value for the involved actors. The unit of observation (UoO) is transport, including both material and waste flow, whereas the unit of analysis (UoA) is adding value by improving CTE. The thesis focuses on the following actors: transporter, main contractor, material supplier and waste collector.
1.5 Thesis outline

The introductory chapter 1 outlines the thesis’s background, motivation, purpose, and research questions concerning the problems studied. Chapter 2 presents frame of reference to address research questions and the purpose of the thesis. The method and design of the thesis are detailed in Chapter 3, which also explains the research process comprehensively and illustrates the interconnection between the different studies within the thesis. Summaries of the five papers that make up the thesis are provided in Chapter 4, while Chapter 5 offers answers to the research questions (RQs). The discussion is articulated in Chapter 6, with the study’s contributions and conclusion. Finally, Chapter 7 concludes the thesis by discussing further research possibilities and delineating the limitations of the research.
This chapter lays the theoretical foundation for the thesis by exploring the concepts upon which the thesis is based on. It begins with construction logistics and transport, followed by a section on transport efficiency. Subsequently, the proposed solutions, including logistics services, digital tools, and information sharing will be presented. The chapter concludes with an elaboration on the added value these solutions bring to construction.

2.1 Construction logistics and transport

The primary aim of construction logistics, as outlined by Ying et al. (2018), is to ensure the adequacy and availability of materials for construction. “Construction logistics” is the process of planning, coordinating and executing the transport, storage and distribution of materials and equipment needed for construction (Sullivan et al., 2010). Simply put, it includes organizing and moving materials and resources to, from and at the construction site (Janne & Fredriksson, 2020). Construction logistics can be divided into two primary areas: 1) on-site logistics, which involves managing logistics activities directly at the construction site, and 2) off-site logistics, which involves the management of logistics activities related to the transport of resources to and from the construction site (Ghanem et al., 2018). On-site logistics focuses on planning the physical flow and handling of materials directly at the construction site, while off-site logistics involves...
tasks such as specifying, procuring, transporting and delivering materials to and from the construction site (Fadiya et al., 2015). Fadiya et al. (2015) highlight that the productivity within construction depends on the efficient integration of both on-site and off-site logistics activities.

Lundesjö (2015) notes that over 80% of the activities in construction can be classified as logistics related. Lundesjö (2015) further states that construction logistics involves managing and scheduling truck deliveries to the construction sites, providing and managing resources such as hoists and cranes, including scheduling crane hook times, as well as the on-site storage and handling of materials. Additionally, construction logistics encompasses a range of activities, including packaging, moving materials to storage, loading material onto trucks or other vehicles, transporting material to the site, unloading and storing material on-site, moving the material to the point of use, and finally, the return of waste and recyclable materials from the construction sites (Lundesjö, 2015).

The term logistics is much broader than the term transport (Topolsek et al., 2018). Transport refers to the movement of goods from one location to another (Ramstedt & Woxenius, 2006), while logistics considers managing the entire “flow”. This means that logistics includes not only transport but also storage, handling, inventory, packaging, order fulfilment, fleet management, and various other activities. Basically, transport is a function within logistics and can be carried out through different modes such as sea, road and air (Skrucany et al., 2018). Furthermore, construction transport involves various transport ranges, including long distance - moving frame elements over long distances, medium distance - transporting soil and rock masses over medium distances, short distance - delivering material supplies and removing waste over short distances (Sezer & Fredriksson, 2020). The transport of these materials to various construction sites, varies depending on the construction type and size, requiring different vehicles and load carriers (Sezer & Fredriksson, 2020).

Moreover, various actors such as transporter, main contractor, subcontractor, and material supplier are involved within these material flows (Gustavsson & Hallin, 2015). For example, a construction site mainly consists of actors such as main contractor, subcontractor, site manager, installation company and alike (Brusselaers et al., 2021). However, the main contractor is responsible for managing the construction site, including making decisions about on-site logistics and transport (Fredriksson et al., 2021). Furthermore, main contractor also oversees daily operations, working closely with subcontractors (Fredriksson et al., 2021). Likewise, the construction supply chain primarily involves transporter, material supplier and LSP (Fredriksson et al., 2021). The actors at the construction site and within the supply chain are dependent through construction transport, which typically
involves a two-way flow: materials are either transported from material supplier to the construction site or from the site to sorting facility, waste management facility or mass storage area (Lundesjö, 2015).

2.2 Transport efficiency

Efficiency, as described by Markovits-Somogyi (2011), is the ability to perform an activity using the least possible resources while avoiding waste. The concept of transport efficiency, however, lacks a clear, universally accepted definition and varies based on the perspective of the individual (Arvidsson, 2011; Sanchez-Diaz et al., 2020). Arvidsson et al. (2013) view transport efficiency as the ability to provide a service with minimized resource consumption, while maintaining delivery performance in terms of costs and quality. Moen (2016) suggests that transport efficiency depends on resource utilization, which includes factors like business models, vehicles, drivers, information technology, and infrastructure. Furthermore, Arvidsson et al. (2013) emphasize that improving transport efficiency involves not only technical and behavioral improvements but also significant operational improvements.

Transport efficiency aims to achieve economic, environmental, and societal advantages. Economically, it focuses on lowering fuel expenses, labor costs, and vehicle maintenance outlays (Janne, 2018; Janne & Fredriksson, 2020), while also aiming to minimize resource wastage (Sternberg, 2011). From an environmental perspective, the aim is to enhance air quality by cutting CO2 emissions (Aronsson & Brodin, 2006). From a societal perspective, the benefits include easing traffic congestion and promoting safe driving practices (McKinnon, 2018). These objectives align with the broader goals of sustainable development by integrating economic savings, environmental control, and societal well-being.

The reduction of environmental impact through improved transport efficiency is a critical goal, as emphasized by McKinnon (2018). In pursuit of this aim, various researchers have developed frameworks that serve as guidelines for simultaneously improving transport efficiency and reducing environmental impact. Notable examples of these frameworks include those proposed by McKinnon (2018), ALICE (2019), and Arvidsson et al. (2013). These frameworks offer structured approaches to address the dual challenge of improving transport efficiency as well as minimizing environmental impact.

Table 2.1 summarizes the parameters to improve transport efficiency identified by McKinnon (2018), ALICE (2019) and Arvidsson et al. (2013) framework along with presenting the most relevant parameters for this
thesis. The symbol ‘×’ represents a check mark representing ‘yes’ for the identification of a parameter by the respective framework.

<table>
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<tbody>
<tr>
<td>Delivery efficiency</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Empty running</td>
<td>×</td>
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<td>Driver behavior</td>
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<td>Load factor</td>
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<td>Vehicle efficiency</td>
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<td>Length of haul</td>
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<td>Modal split</td>
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<td>Packaging in terms of material and design</td>
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Table 2.1: Parameters to improve transport efficiency by different frameworks (Adapted from Naz (2022)).

All three frameworks emphasize key parameters such as load factor, vehicle efficiency, driver behavior, and empty running as critical factors in improving transport efficiency. The load factor is concerned with how efficiently a vehicle’s capacity is used, typically measured in weight terms, though volume measures are considered for lower-density products (McKinnon, 2018). Vehicle efficiency refers to the distance covered per unit of energy used (Mamala et al., 2021). Additionally, vehicle efficiency is affected by factors including the type of vehicle (e.g., hybrid or electric) and traffic conditions (ALICE, 2019; McKinnon, 2018). Driver behavior focuses on driving techniques that lower fuel consumption and maximize efficiency. This includes practices such as maintaining optimal tire pressure, appropriate speed, and reducing vehicle idling, which can be improved through training in eco-driving (Arvidsson et al., 2013). Empty running, which refers to vehicles travelling without load, is measured as the percentage of total vehicle-kilometers travelled empty. (McKinnon, 2018). Improvements in these areas can lead to more efficient use of resources such as time, fuel, labor, vehicles, energy, and effort.
McKinnon (2018) and Arvidsson et al. (2013) also recognize the length of haul and the modal split as critical factors in transport efficiency. The length of haul pertains to the distance of each trip within the supply chain (McKinnon, 2018). Proper planning and the use of information and communication technology (ICT) tools are key in optimizing these haul lengths, as suggested by Arvidsson et al. (2013). The concept of modal split refers to the choice of transport modes (such as road, rail, sea, or air) and their impact on transport efficiency. While road and air transport are often more time-efficient (McKinnon, 2018), rail and sea are preferable for energy efficiency (Arvidsson et al., 2013). Furthermore, both Arvidsson et al. (2013) and ALICE (2019) highlight delivery efficiency as another vital aspect in improving overall transport efficiency.

Delivery efficiency is defined by Arvidsson et al. (2013) as the ability to stick to delivery schedules. Garza-Reyes et al. (2017) support this view, emphasizing that optimizing transport and delivery schedules is key to improving transport efficiency. Additionally, Arvidsson et al. (2013) propose that optimizing packaging in terms of materials and design, known as packaging efficiency, can also contribute to transport efficiency. This is achieved by reducing the frequency of transport and preventing damage to goods, thereby streamlining the overall logistics process.

In the context of transport efficiency, factors like load factor, driver behavior, empty running, length of haul, modal split, and delivery efficiency are associated with behavioral and operational aspects. On the other hand, vehicle efficiency and packaging efficiency are related to technical improvements. This thesis mainly focuses on the operational aspects of transport efficiency.

2.3 Role of coordination and collaboration within construction

Bankvall et al. (2010) highlight that construction supply chains are characterized by sequential and pooled interdependencies, necessitating enhanced planning and coordination. Sequential interdependencies are interdependencies where output of one task act as the input for the next task whereas pooled interdependencies occur when tasks are independent of each other however, contributing to the common output (Bankvall et al., 2010). These interdependencies contribute to the challenges in managing supply chains and achieving efficiency within construction, which is known for its complexity due to factors such as temporariness, uniqueness, and the involvement of multiple interdependent actors maintaining arm’s length relationships (Ekeskar & Rudberg, 2020; Janne, 2018; Thumberg & Fredriksson, 2017) as mentioned earlier.
Construction is distinctive because it operates in an external environment, making it vulnerable to weather disruptions such as rain and snow, as noted by Ekeskar (2016). Additionally, the geographical and ground conditions of construction site differ significantly, further adding to the complexity (Ekeskar et al., 2022; Jonsson & Rudberg, 2013). The temporary nature of construction leads to the formation of temporary organizations (Bygballe & Ingemansson, 2014) as groups of organizational actors collaborating on a complex task for a limited time.

Construction engages a wide array of participants, including main contractors, subcontractors, material suppliers, logistics providers, developers, designers, consultants, clients, and governmental bodies, each playing roles in different construction phases (Brusselaers et al., 2021; Fredriksson et al., 2021; Janne & Fredriksson, 2020). For example, designers and consultants are active during the design phase, while the construction and procurement phases see the involvement of material suppliers and main contractors (Osipova, 2007; Sears et al., 2015; Vrijhoef & Koskela, 2000).

Poor supply chain performance in construction is often attributed to inadequate coordination and communication among different actors (Bankvall et al., 2010). Bengtsson (2019) emphasizes the necessity for coordinated construction logistics to improve efficiency and minimize material waste, proposing that such coordination can lead to improved productivity and cost reduction.

Coordination, as discussed by Vanagas and Stankevic (2014), is about aligning various components of an organization or multiple organizations to achieve common goals efficiently, which involves goal alignment, information sharing, and managing task interdependencies. Effective coordination can streamline resource use, minimize redundancies, and improve performance (Vanagas & Stankevic, 2014).

While formal structures such as contracts and organizational hierarchies are traditional coordination mechanisms, informal elements like trust and shared norms also play critical roles (Donato et al., 2015; Elsner et al., 2010). However, in construction, there is often a tension between main contractors, subcontractors and material suppliers, where the former views the latter as key to cost savings, leading to potentially unfair practices and undermining trust (Donato et al., 2015).

To mitigate these issues, it is suggested that fostering “collaborative partnerships” can improve construction supply chain (Bygballe et al., 2010; Crespin-Mazet et al., 2015; Donato et al., 2015). Furthermore, Ekeskar et al. (2022) propose that construction supply chain performance can be improved through construction logistics setups (CLS) that facilitate coordination of
actors, resources, and activities, ranging from checkpoint-based systems managed by third-party logistics to terminal-based setups allowing material storage. Yet, the dynamics between contractors and third-party logistics providers require more attention to optimize these arrangements (Ekeskar et al., 2022).

2.4 Adding value through logistics

Successful enterprises focus on adding value efficiently, which in turn provides benefits for both the company and its customers (Porter & Kramer, 2011). Traditionally, the value has been assessed in monetary terms, emphasizing the production of goods or services in response to consumer demands (Vargo & Lusch, 2017). More recently, the notion of adding value has emerged as a significant area of interest. According to Ramaswamy (2011), value is a collaborative process that results in mutual benefits.

Value emerges from interactions within dyadic relationships between participating entities (Liu & Huang, 2020). Gronroos and Helle (2010) identify three dimensions of value in these interactions: technical, monetary, and perceived. Technical value refers to the functionality provided by one party and how well it integrates into the processes of the other. Monetary value relates to the financial impact, including pricing effects and control for one entity, and sales volumes for the other. Perceived value is about one party’s appreciation of the other’s efforts (Gronroos & Helle, 2010). Perceived value involves the quality of the relationship, marked by trust and ease of interaction (Gronroos & Helle, 2010). The intertwined nature of roles in service delivery introduces several challenges, including understanding what is valued (Yazdanparast et al., 2010). Other challenges include understanding delivering services that generate true value, and continually adapting the service offerings to meet current and anticipated value drivers among participants (Yazdanparast et al., 2010).

Historically, logistics is primarily perceived as a cost to be minimized (Kilibarda et al., 2013). Logistics has evolved to become a strategic tool for gaining competitive advantage in today’s era of shortened product life cycles and increased globalization. There are two common ways to examine value within logistics: activity-based and resource-based, as identified by Wang et al. (2016). Activity-based approach focuses on identifying and assessing the value added by each activity performed in an organization whereas resource-based approach focuses on the rare and inimitable resources as a primary source of adding value (Wang et al., 2016). These approaches are further categorized into firm-level and organizational-level analyses. Firm-level research emphasizes adding value through differentiation strategies,
while organizational-level research focuses on the role of interaction and collaboration in adding value (Wang et al., 2016).

2.4.1 Logistics services

Kilibarda et al. (2013) suggest that logistics can add value through a combination of standard logistics services, additional services, and tailored logistics solutions. Standard logistics services, encompassing transport, storage, reloading, and delivery, are fundamental in adding both spatial and time value. Spatial value emerges from changing a product’s location, as its worth varies depending on whether it is in a factory, warehouse, store, or at consumer’s place. This value is improved by strategically placing products where they are most needed or used by customers. Additionally, time value is added by ensuring product availability at the right time and place. For instance, a product’s value increases when it is delivered precisely when a customer needs it (Kilibarda et al., 2013). In the context of construction transport, improving efficiency can lead to reduced transport costs (Halldorsson & Skjott-Larsen, 2004), thereby adding value not just for the transport buyer, such as the main contractor, but also for the transport provider, such as transporter.

Logistics services play a crucial role in modern supply chain management, involving a broad spectrum of activities essential for the efficient movement and storage of goods from their origin to the point of consumption (Mentzer et al., 2001). A key component of logistics services is transport, which involves moving goods via various modes such as road, rail, air, and sea (Jaafar, 2021). Efficient transport management is vital for ensuring timely and cost-efficient deliveries, crucial for customer satisfaction and maintaining the integrity of products (Jaafar, 2021). Beyond transport, logistics also includes warehousing and storage, where goods are safely stored, managed, and prepared for distribution (Bhatnagar et al., 1999). Inventory management is another critical aspect, involving the tracking and control of goods to balance supply and demand efficiently (Bhatnagar et al., 1999). Additionally, logistics services extend to order fulfilment, ensuring that customer orders are processed accurately and efficiently (Mentzer et al., 2001). Logistics services include picking, packing, shipping, and sometimes handling returns (Jaafar, 2021). Importantly, logistics services also encompass value-added services such as packaging, assembly, and product customization, which enhance the value of the product for the consumer (Franceschini & Rafele, 2000). In today’s globalized market, logistics services are not just about moving and storing products; they are integral to the overall strategy of businesses, directly impacting customer satisfaction, operational efficiency, and the bottom line (Mena et al., 2007).
2.5 Value adding and non-value adding activities

Value-added services, often referred as additional logistics services, play a crucial role in enhancing the utility value of products. These services involve activities like packaging, repackaging, marking, adding final touches, assembling, installation, refining, transforming, and improving quality. These activities improve the product’s utility, making it more valuable or useful to the customer (Kilibarda et al., 2013).

According to Sternberg (2011), activities that are beneficial to customers and positively influence the final product are classified as value adding activities. In contrast, non-value adding activities are those that do not contribute to enhancing the final product’s value and may even impact it negatively. Koskela (1993) suggests that while all activities involve costs and time consumption, it is the value adding activities that actually contribute to process outcomes. Therefore, the lean approach focuses on process redesign with two primary objectives: 1) to eliminate or minimize non-value adding activities, and 2) to allocate more time and resources to value adding activities.

Value adding and non-value adding activities are distinguished based on customer perception, but from a producer’s standpoint, these are often categorized under the broader term of “waste”. According to Bølviken et al. (2014), waste is typically classified into three main types: material waste, time loss, and value loss. Material waste pertains to suboptimal use of resources such as materials, machinery, energy, or labor, and is viewed from a transformation perspective (Bølviken et al., 2014). Time loss, considered from a flow perspective, involves unnecessary movements of people, inefficient work, waiting, underutilized space, unprocessed materials, and needless transport of materials (Bølviken et al., 2014; Kurdve & Bellgran, 2021). Value loss, from a value perspective, includes issues such as poor quality, lack of intended use, harmful emissions, and injuries (Bølviken et al., 2014). This study primarily focuses on time loss, aiming to identify and eliminate non-value adding activities to improve transport efficiency.

According to Sternberg (2011) and Villarreal et al. (2017), by adopting a lean approach, transport efficiency can be improved by eliminating non-value adding activities. Non-value adding activities include waiting during loading and unloading, unnecessary vehicle movements, incorrect routing, incomplete information sharing, redundant administrative tasks and paperwork, excessive travel, using inappropriate equipment, and labor shortages. However, it is important to strike a balance in transport activities, as advised by Pérez and Costa (2018). Over-incorporating transport activities can reduce the time available for productive work, while excessively reducing transport activities can adversely affect the construction transport (Pérez & Costa, 2018).
2.6 Digital tools and information sharing

Digitalization refers to the process of changing from analog to digital form, also known as digital enablement (Richnak, 2022). Where Ageron et al. (2020), Attaran (2020), and Shamout et al. (2022) consider technologies like the internet of things (IoT), blockchain, 3D printing, artificial intelligence, machine learning, and robotics as digitalization, Gray and Rumpe (2015) view digitalization as business analytics and big data. This shows that digitalization’s definition varies based on the context (Kuusisto, 2017). However, digital tools are important for driving digitalization (Drugge & Rezaei, 2020). In construction, digital tools are instrumental in improving planning and information sharing, centralizing communication and increasing transparency in the delivery process (Chen et al., 2022). The use of digital tools helps in ensuring the availability of necessary materials on-site (Chen et al., 2022). Digital tools not only enable the recording of images of delivered items, but also facilitate the search and procurement of various goods and materials from different material suppliers with delivery specifics (Drugge & Rezaei, 2020).

While digital tools offer numerous advantages, some logistics managers still opt for traditional methods such as planning deliveries using whiteboards in their offices (Drugge & Rezaei, 2020). This preference for traditional methods stems from various factors, including the limited functionality of digital tools, a lack of time to learn new technologies, challenges in regularly updating information, and a perceived lack of tangible improvements from using these digital tools. The extent of digitalization in companies varies, with some adopting it partially and others fully (Sezer et al., 2021), leading to different levels of digital integration (Wernicke et al., 2023). OConnor et al. (1999), as modified by Sezer et al. (2021), categorize digitalization into three levels:

- **Level 1** - Analogue and manual, indicating no use of digital tools.
- **Level 2** - Digital and manual, representing partial use of digital tools.
- **Level 3** - Digital and automated, signifying a fully automated system.

The primary advantage of digitalization, as noted by Kuusisto (2017), lies in improving the accessibility and transparency of information. Digital tools have simplified the process of making information available to all actors, as observed by Liu and Chua (2016). This widespread availability of information empowers managers at various organizational levels to make more informed decisions (Kuusisto, 2017). A significant challenge in construction transport today, as identified by Sanchez-Diaz et al. (2020), is the uncertainty surrounding delivery arrival times. The factors contributing to these
2.6. Digital tools and information sharing

delays include poor communication, the involvement of multiple actors, and information loss during the transport process (Hsu et al., 2017; Sanni-Anibire et al., 2022; Tafesse, 2020). Given the numerous actors involved in a delivery, clear communication throughout the transport chain is crucial (Backstrand & Fredriksson, 2022; Thunberg & Fredriksson, 2017). To ensure smooth information flow, there is a need to minimize manual handling of information and reduce the reliance on individuals for information exchange, as this can lead to information loss due to human error (Sezer et al., 2021; Wernicke et al., 2023). Digital tools address this issue by automating the transfer of information across the transport flow (Sezer et al., 2021), thereby reducing human errors and misinterpretations ((Adekunle et al., 2022; Aghimien et al., 2022).

Information sharing within transport, especially in construction transport, presents a notable challenge, impacting the efficiency of logistics operations in the construction. Lack of information sharing refers to the imbalance in the access to and quality of information among various actors (Clarkson et al., 2007) which can significantly affect decision making processes (Clarkson et al., 2007). Transporters without precise delivery details or site conditions might for example face delays or additional costs due to waiting times or rerouting (Gayialis et al., 2022). Furthermore, lack of information sharing can lead to increased costs and environmental impacts, such as through unnecessary trips or idle vehicles, which contribute to higher CO2 emissions (Gayialis et al., 2022). In the construction industry, where project timelines and efficient material flow are critical, information sharing is essential (Brown & Hillegeist, 2007). This can be achieved through improved communication channels, integrated IT systems, and collaborative practices among all parties involved (Mohr et al., 1996). By ensuring that accurate and timely information is shared efficiently (Mohr et al., 1996), it is argued that construction transport can become more efficient, cost-efficient, and environmentally sustainable (Naz, 2022).
This section presents research overview, research process, research approach and describes the methods and tools used for data collection and data analysis in the respective studies. The section concludes with presenting research quality.

3.1 Research overview

The thesis comprises five studies resulting in five research papers. The relation between research questions, studies and research papers is shown in Figure 3.1:
3. Method

Figure 3.1: The relation between research questions, studies and research papers

Table 3.1 outlines studies and respective research papers in terms of the theme, status of research papers and the actor’s perspective.
<table>
<thead>
<tr>
<th>Timeline</th>
<th>Studies</th>
<th>Research Papers</th>
<th>Main theme</th>
<th>Status of research Papers</th>
<th>Actor’s Perspective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct 2019</td>
<td>Study I and Study IV</td>
<td>Paper I</td>
<td>Initially focused on developing transport performance measures, later shifted to exploring information asymmetry within the context of CTE</td>
<td>Submitted to the journal “Construction Innovation: Information, Process, Management” on April 29, 2024</td>
<td>Initially Transporter, later Main contractor</td>
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<tr>
<td></td>
<td>Study II</td>
<td>Paper II</td>
<td>To identify activities within construction transport and classify them as value adding, non-value adding and necessary but non-value adding</td>
<td>Published in MDPI Journal Sustainability Special Issue, 2022</td>
<td>Transporter and Waste collector</td>
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<tr>
<td></td>
<td>Study III</td>
<td>Paper III</td>
<td>To create value through logistics services in construction</td>
<td>Submitted to the journal “Construction Management and Economics” on May 9, 2024</td>
<td>Main contractor</td>
</tr>
<tr>
<td>Apr 2022</td>
<td>Licentiate</td>
<td></td>
<td>To study construction transport efficiency from the perspective of main contractor and transporter</td>
<td>Published on Diva Portal, 2022</td>
<td>Main contractor and Transporter</td>
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<tr>
<td></td>
<td>Study IV</td>
<td>Paper IV</td>
<td>To study transport activities at the interface between construction site and the supply chain to improve delivery efficiency</td>
<td>Published as Springer Conference Proceedings, 2023</td>
<td>Main contractor</td>
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<tr>
<td></td>
<td>Study V</td>
<td>Paper V</td>
<td>To study the use of a digital scanner in construction transport</td>
<td>Conference Paper, NOFOMA, 2023</td>
<td>Material supplier</td>
</tr>
<tr>
<td>Sep 2024</td>
<td>Doctoral defense</td>
<td></td>
<td>To improving transport efficiency in the construction supply chain</td>
<td>To be published on Diva Portal, 2024</td>
<td>Transporter, Main contractor, Material supplier, Waste collector</td>
</tr>
</tbody>
</table>

Table 3.1: Overview of studies and respective research papers
3. Method

3.2 Research process

My research journey began while doing my Master’s degree in Logistics and Supply Chain Management at Linnaeus University, Växjö, Sweden. As part of my Master’s degree, I did my thesis at Linköping University. The title of my Master’s thesis is “Developing Transport Performance Measures for Construction Logistics Solutions: A Case Study.”

After I finished my Master’s degree, I was hired as a Research Assistant at Linköping University, Norrköping Campus, Sweden. During this time, I continued the work I started in my Master’s thesis. This continuation became Study I for my doctoral research. During my time as a Research Assistant, I continued to explore and add more details to the ideas and findings from my thesis. Study I consisted of analyzing five datasets that included data on material deliveries. These datasets were carefully studied with respect to performance measures I had developed in my Master’s thesis. The primary objective of this analysis was to identify what data is available and what data is missing in relation to developing transport performance measures within construction. This helped in identifying which transport performance measures can be calculated with the available data and which cannot, due to the gaps in the data. Based on the insights and findings from Study I, I started writing Paper I, which digs deeper into the data analysis and its implications for construction transport.

After working as a Research Assistant for six months, I started my doctoral research focusing on improving transport efficiency within construction. My doctoral research project is part of Triple F (Fossil Free Freight) and receives funding from the Swedish Transport Administration (Trafikverket). The doctoral research project is a joint effort, split evenly between Linköping University (LiU) and the Swedish National Road and Transport Research Institute (VTI). At the beginning of my doctoral research, I continued to work on Paper I, which was based on research conducted during my time as a Research Assistant and for my Master’s thesis. Simultaneously, I enrolled in various courses to broaden my knowledge and skills in the field.

While working on Paper I, I also began conducting truck visits for a second study, Study II. Given my background in logistics and supply chain management, these visits provided an opportunity to deepen my understanding of operational practices in construction. I conducted two truck visits: one to observe the delivery of materials to construction site, and another to observe how waste materials are collected from these sites. Based on these observations, Study II developed into Paper II. Paper II aims to identify and classify the various activities involved in construction transport into three categories: activities that add value, activities that do not add value, and activities that are necessary but do not add value. During this
period, I was diligently working on both Paper I and Paper II, while also participating in various courses to broaden my understanding and skills.

Study III, which began during the Covid-19 pandemic, focuses on logistics services within construction. Due to the pandemic, initial meetings were conducted online. Furthermore, I could not visit any construction site at the beginning of the study. The blueprints for logistics services were discussed and developed during these online meetings. Several interviews were conducted with various actors involved in the study, including main contractors, subcontractors, material suppliers, and transporters. In the meetings and interviews, my role was to observe. Later in the study, I had the opportunity to visit the construction site, where I observed two logistics services in action: material management and frequent material handling. Unfortunately, by the time of my visit, the third of the logistics services that I studied, on-site vendor managed inventory (VMI) had already been removed as the construction had been completed.

Upon reaching the halfway point in my doctoral research, I completed my Licentiate, which comprised three studies, three papers and earning a total of 60 course credits. Until the completion of my Licentiate, my research involved visits that focused on actors such as transporter and waste collector. After completing my Licentiate, I aimed to broaden my research by including more actors to fully understand how transport works in construction. This led to the beginning of Study IV, focusing on construction transport from the main contractor’s perspective. During this period, I also pursued additional courses to further broaden my knowledge. Additionally, my supervision team expanded with the addition of a new supervisor, complementing the guidance provided by the two existing supervisors.

Study IV was conducted on-site, understanding the perspective of the main contractor. The primary aim was to study the transport at the interface between the construction site and the supply chain. To achieve this, I made several visits to the construction site from September to November 2022, where I observed and analyzed the management and execution of transport at the interface. The insights and data collected during these visits resulted in Paper IV, which presents the findings and conclusions from this extensive field study.

Study V was conducted from the perspective of the material supplier. In this study, I focused on the use of a digital tool, specifically a digital scanner, to assess its impact on transport flow. Study V involved an in-depth understanding of how the digital scanner could improve transport efficiency at the material supplier level. Through careful analysis and observation, I proposed an improved transport flow that could save 20 minutes per transport
flow. The insights from Study V resulted in Paper V, which provides a detailed analysis of how the digital scanner currently improves transport efficiency.

Meanwhile, Paper I underwent a significant shift in focus, changing from studying construction transport performance measures to exploring the concept of information asymmetry within construction transport. Consequently, Paper I was completely rewritten to provide a comprehensive analysis of how information asymmetry impacts construction transport efficiency. This new direction provided a deeper insight into the communication barriers that can impact construction transport.

Furthermore, the final thesis for my doctoral research was finalized, incorporating these revisions. While completing my thesis, I concurrently worked on two papers: the revised Paper I, now focused on information asymmetry, and Paper III, focusing on creating value through logistics services. For Paper VI, an extension of Paper II, I conducted two visits to observe material flow and waste flow with electrified trucks, and then collected and analyzed the data. However, Paper VI is not included in the thesis. At this point, I had earned 94 course credits. Furthermore, I actively participated in teaching and supervising Bachelor’s and Master’s theses throughout my doctoral research. Managing multiple tasks simultaneously was challenging, yet essential for maintaining coherence across the various components of my doctoral research, ensuring that each aspect contributed to a comprehensive understanding of the field.

3.3 Research approach

Research can be categorized into explorative, descriptive, or explanatory types, based on the extent of the problem and the amount of information available at the start of the research (Yin, 2018). Throughout the duration of the research, various studies were conducted with different research approaches, each tailored to the evolving understanding of the research area. Initially, exploratory and descriptive studies (Study I and Study II) were undertaken to grasp the essence of the phenomenon being investigated. As the research progressed and a clearer understanding of the problem emerged, the focus shifted towards studies (Study III and Study IV) that aimed at resolving the identified issues and interpreting the phenomenon. This transition marked a move from merely describing and exploring to actively understanding the complexities of the research area. Since the purpose of the thesis is to investigate improving CTE, some possible cause-and-effect relationships are established. Few propositions are proposed however, no testing has been conducted on these propositions yet. Each study within the thesis follows a strategic research approach, carefully chosen to align with the
specific objectives and stages of the research process. This approach ensured a comprehensive and systematic exploration of the research area.

Usually, research gaps are identified in areas where knowledge is limited, and explorative methods are used to collect extensive information on such areas (Yin, 2018). In general, construction transport has not been given much attention, which is why there is a need for exploration into the activities that make up construction transport (Study I, Study II, Study IV, Study V). Furthermore, it is crucial not only to understand the challenges of improving CTE (Study II, Study III, Study IV) but also to identify which activities are value adding and which activities are non-value adding (Study II), as well as how construction transport is carried out at the interface between the construction supply chain and the construction site (Study IV).

As mentioned, however, the research carried out has also been descriptive. Such research involves describing the historic or present state of particular phenomena within a field or related to a specific issue (Bell & Bryman, 2015). For example, Study II and Study IV sets out to describe how construction transport is carried out at present, how information asymmetry acts as an obstacle to improving CTE (Study I) and how logistics services (Study III) and digital scanner has the potential to improve CTE (Study V).

3.4 Literature review

In this thesis, a traditional literature review has been conducted, following the definition by Jesson et al. (2011): a written summary of existing knowledge. Given the exploratory nature of the thesis and the aim to develop a deep understanding of a relatively less studied phenomenon – construction transport, the traditional literature review approach was chosen. This type of review is instrumental in identifying knowledge gaps by summarizing the current state of understanding on a specific topic (Jeson et al., 2011). Unlike systematic reviews, traditional literature reviews do not adhere to a formal methodology or detailed descriptions of the review process (Jeson et al., 2011).

For the literature review in this thesis, electronic resources were utilized. Google Scholar was the primary search engine, due to its extensive collection of quality sources. Additional sources included One Search, Diva, and Scopus. Peer-reviewed articles were considered. To ensure the use of valid and credible sources, the publication institute and the number of citations were considered important factors.

The search for relevant literature involved keywords such as construction transport, construction transport efficiency, construction logistics setup, logistics services, digitalization, information sharing, information asymmetry,
value, construction industry etc. The initial list of publications identified through each keyword was manually reviewed to select the most recent and pertinent ones. The snowballing technique, as described by Wohlin (2014), which involves using the references of a paper or its citations to find additional papers, was also employed. This method of back tracing proved to be highly efficient in sourcing credible literature. Secondary or tertiary sources such as survey papers, dissertations, and systematic literature reviews were also considered, where relevant.

3.5 Case study

The data for the studies was collected using case studies. This method involves examining real-life situations to understand a current phenomenon, which in this thesis is construction transport. Case study is used to explore how or why things happen, especially when the researcher cannot control what occurs (Yin, 2018). The choice of a case study research design for this thesis is justified by the aim to dig deep into the phenomenon of construction transport and to gather comprehensive insights. The case study approach entails an empirical study of a phenomenon within its real-life context, drawing on multiple sources of evidence (Yin, 2018).

Case-based research can include either single or multiple case studies. According to Yin (2018), a single case study is suitable for conducting an in-depth and detailed study of a phenomenon. Single case study allows the researcher to focus on a specific context and gain a deep understanding. Dubois and Gadde (2002) also support the use of single case studies for achieving depth and richness. On the other hand, a multiple case study is used to draw connections between two or more cases, as stated by Yin (2018). This approach is useful for comparing findings across cases to evaluate generalizability.

Yin (2018) notes that for generalizability purposes, multiple case studies are preferable. However, for an in-depth investigation of the phenomenon, a single case study is more suitable. In this thesis, single case studies have been used in Paper III, Paper IV, and Paper V to facilitate a thorough exploration of the underlying phenomenon. Paper I and Paper II, on the other hand, are based on multiple cases, with a view to understanding any differences or variations related to the subject matter. The case study research design is appropriate for this thesis because it provides detailed, context-rich insights and is well-suited for exploring the nuanced aspects of construction transport, which are crucial for addressing the research questions.

Table 3.2 presents the empirical scope of the thesis.
3.5. Case study

<table>
<thead>
<tr>
<th>Study</th>
<th>Case</th>
<th>Year</th>
<th>Data collection</th>
<th>Case selection criteria</th>
</tr>
</thead>
</table>
| Study I | - Performance Measurement Case  
- School Case  
- Office Case | From 2019 to 2022, followed by a shift in focus from 2022 to 2024 | - Descriptive statistics  
- Observations  
- Structured interviews  
- Unstructured interviews  
- Workshops  
- Project documents | - Relevance  
- Accessibility  
- Data richness |
| Study II | - Material Delivery Case  
- Waste Material Case | From 2020 to 2022, with further development extending from 2023 to 2024 | - Observations  
- Unstructured interviews | - Relevance  
- Accessibility  
- Data richness |
| Study III | - House Case | From 2020 to 2024 | - Interviews  
- Workshops  
- Study visit | - Relevance |
| Study IV | - School Case | From 2022 to 2023 | - Observations  
- Unstructured interviews | - Accessibility  
- Data richness |
| Study V | - Digitalization Case | From 2022 to 2023 | - Observations  
- Unstructured interviews | - Relevance |

Table 3.2: Empirical scope of the thesis

3.5.1 Case selection

Cases were carefully selected based on the specific problems that required investigation and the overall nature of the study. In addition to aligning with the study’s aim, several key criteria were also taken into consideration during the selection process. These criteria included 1) relevance, ensuring that each case would provide significant insights into the research problem; 2) accessibility, which refers to the practical feasibility of conducting research in the chosen locations or environments, including factors such as geographic access, participant willingness, and legal permissions; and 3) data richness, which involves choosing cases that offer substantial and meaningful information. This rich data is crucial as it supports robust analysis, providing detailed, comprehensive insights that enhance the credibility and applicability of the research findings. By following these criteria, the research conducted provides not only methodologically sound but also insightful and actionable conclusions.

In Study I, Performance Measurement Case was selected not only for its relevance and accessibility but also because it aligns with the purpose of
3. Method

the study i.e. to increase the understanding of the data gathered through Construction Logistics Setup (CLS) booking systems to improve CTE. CLS is defined as “a governance structure for construction that has been agreed on to control, manage and follow up the flow of materials, waste, machinery and personnel to, from and at the construction site” (Janne, 2020). The Performance Measurement Case was selected because, given the fragmented nature of the construction, CLS currently serves as the sole source for gathering and recording construction transport data. However, for data richness, the School Case from Study IV and the Office Case were selected.

In Study II, the Material Delivery Case and the Waste Material Case were chosen based on their relevance, accessibility, and data richness. Both the cases served the purpose of understanding activities involved in construction transport and identifying the challenges in improving CTE. These cases were geographically accessible and had participant support, aligning with the mutual interest of improving sustainability and transport efficiency. The selected cases facilitated the collection of detailed data through comprehensive time study.

The House Case was chosen in Study III for its large scale, which facilitated the implementation of logistics services. The case selection was ideally suited to the study’s purpose of exploring logistics services within construction, providing a thorough opportunity to observe logistics services in practice.

The School Case in Study IV was selected because the case provided a unique opportunity to participate in an ongoing project. Furthermore, the proximity of the case to the university facilitated frequent site visits and allowed the author to observe the deliveries and on-site material handling continuously as the project progressed. Due to the mutual interest in improving sustainability and transport efficiency the author was given an opportunity to inquire about the current practices and their underlying reasons.

In Study V, the Digitalization Case was particularly relevant because in this case digitalization occurred at Level 2, meaning tasks were performed both manually and digitally. This blend of manual and digital task execution was ideal for Study V as it facilitates an easier assessment of the advantages and challenges associated with digitalization. Such an analysis would be more challenging in cases where transport flow was either fully manual or fully automated.

3.6 Data collection methods and analysis

The thesis is based on five studies resulting in five research papers. An abductive approach has been used for the collection of data. “Abduction”
is recognized as a form of organized creativity or intuition in research, crucial in the development of new knowledge (Kovács & Spens, 2005). The abductive approach starts with an observation or a set of observations and aims to identify the simplest and most likely explanations for these observations ((Kovács & Spens, 2005). Dubois and Gadde (2002) suggest that the abductive approach is particularly useful when the aim is to discover new insights. Given that this thesis focuses on exploring a relatively under-researched area, construction transport, an abductive approach has been adopted. Throughout all five papers, there has been an iterative process of moving back and forth between theoretical frameworks and empirical data collection. An initial literature review was conducted to gain a deeper understanding of the problem, to identify what has already been explored in this field, and to find out areas that still require investigation. Moreover, during the empirical data collection phase, the author continuously revisited the literature to refine and inform the research process.

This section will detail the data collection methods used in the studies that form the basis of the papers.

3.6.1 Study I: Construction Transport (In)Efficiency – An Effect of Information Asymmetry Among Construction Actors.

Purpose The purpose of the study is to explore the relationship between information asymmetry in the main contractor subsystem and CTE. The focus in this study is the off-site logistics and the management of delivery planning and transport coordination.

Data Collection Data has been collected through observations, interviews, company documents, workshops, transport follow-ups, and descriptive statistics. The interviews evolved from being unstructured in the initial stage of the research, aimed at exploring the cases, to semi-structured later on as the research problem became more defined. Likewise, the observations were initially broad, focusing on building a general understanding of the cases, and then became more focused on transport efficiency and information asymmetry as the research progressed.

Data analysis The analysis of the gathered data was conducted through thematic coding, a method of qualitative analysis used to detect and examine recurring themes or patterns in the data (Flick, 2009). This approach entails systematically organizing the data by pinpointing and tagging recurrent concepts, ideas, or patterns observed within the dataset (Flick, 2009). First, the conceptual model was developed from literature to establish the overarching themes and sub-themes related to information asymmetry and adapt these to construction
3. Method

transport. Next, the data was pre-analyzed through repeated readings to familiarize the authors with its content and to identify initial ideas, concepts, and patterns. Third, potential themes and patterns were identified using open coding, where the data was coded without any preconceived notions (Flick, 2009). Fourth, similar codes were grouped into categories (Flick, 2009). These categories were then refined, combined, and divided into sub-themes, allowing the authors to organize the codes in a hierarchical format, which was used to elaborate on the underlying mechanisms of information asymmetry impacting CTE.

3.6.2 Study II: The Potential of Improving Construction Transport Time Efficiency – A Freight Forwarder Perspective.

**Purpose** The purpose of this study is to contribute to construction transport time efficiency by identifying non-value adding activities and their causes from a freight forwarder perspective.

**Data Collection** Data for this study was gathered using observations and unstructured interviews. The observations involved the main author accompanying a truck driver for a full day on two separate occasions, focusing on material flow and waste flow. During these transport flows, the duration of each activity was meticulously recorded. Pictures were taken of the unloading areas at the construction site and of the materials being loaded and unloaded. Google Map was utilized to determine the routes and delivery locations. Notes were taken during the interview, and the interview was also recorded.

**Data analysis** Value Stream Mapping (VSM) served as a guiding framework for both data collection and analysis in this study. As a key component of the lean methodology, VSM is employed to visually represent activity flows (Abdulmalek & Rajgopal, 2006) and to distinguish between activities that add value and those that do not (Rother & Shook, 2003).

3.6.3 Study III: Creating Logistics Service Value in Construction – A quest of coordinating modules in a loosely coupled system.

**Purpose** The purpose of the study is to increase the understanding of the logistics service value adding process in construction.

**Data Collection** The study uses interviews, workshops, and service blueprinting for data collection. Interviews were conducted with logistics service providers, main contractors and subcontractors
to understand logistics services from different actor’s perspective. Furthermore, four workshops were conducted to develop service blueprints. Service blueprints were developed to understand how the logistics services were designed and used in a selected House Case. Service blueprinting was selected as a tool as it helps to create a joint understanding of the content and interrelationships between services (Bitner et al., 2008).

**Data analysis** The data analysis in this study was conducted in two main steps, following a framework focused on adding value. First, the study used service blueprint to analyze how activities within the logistics services and the interactions among actors were related. This included detailed coding of interviews to find values linked to specific activities, which were then categorized into technical, monetary, and perceived values. Second, these categorized values were studied to understand the value adding process, particularly the interactions between actors and logistics services. This step-by-step analysis helped in understanding how different logistics services improved overall efficiency and added value.

### 3.6.4 Study IV: Clarifying the interface between construction supply chain and site – A key to improved delivery efficiency.

**Purpose** The purpose of the study is to capture non-value-adding activities of the order-to-delivery process at the interface between the construction site and the supply chain in order to identify efficiency improvement potentials.

**Data Collection** Data was collected through observations and unstructured interviews, focusing on activities at the interface between the construction supply chain and the construction site, particularly deliveries and on-site material handling. The author visited the construction site on eight different occasions in the autumn of 2022 (September 2nd, 5th, 7th, 8th, 19th, 20th, November 7th, and 11th) from 6:30 AM to 3:00 PM. These dates were strategically selected based on the delivery schedule to observe variations in daily delivery and material handling processes. The observations aimed to study activities at the interface, including transport delivery operations and on-site tasks such as unloading, the duration of unloading, material handling, material storage, damage assessment, and waste management. Pictures and notes were taken, with particular attention to the timing of each activity, to facilitate the analysis of value-adding and non-value adding durations. Concurrently, unstructured interviews with drivers
and the site manager were conducted, focusing on gaining a deeper understanding of the observed activities and identifying the root causes of non-value adding activities.

**Data analysis** The analysis of the collected data was conducted in three distinct phases. Initially, the data was structured using the process mapping technique. Process mapping involves creating a visual diagram that outlines each step or activity in a process from start to finish, and it serves as a tool to identify, analyze, and enhance the activities within a flow (Conger, 2011). In the second step, activities that did not add value were pinpointed, and the duration of these activities was calculated. Finally, the third step involved extracting the underlying causes of these non-value adding activities from the information gathered during the unstructured interviews.

### 3.6.5 Study V: Improving construction transport efficiency by digitalization

**Purpose** The purpose of the study is to increase the understanding of improving transport efficiency using digital tools in the transport flow of construction material.

**Data Collection** Data collection for this study was primarily conducted through observations, and unstructured interviews. The author accompanied a truck driver for an entire day (from 4:00 am to 2:00 am) to closely observe the digitalized transport flow. This was done on two separate occasions, specifically on September 12th and 13th, 2022. During these observations, all activities carried out by the driver were meticulously monitored. Pictures and notes were taken, particularly of the unloading zones at construction site and the process of loading and unloading materials. Additionally, Google Map was employed to accurately determine the routes and delivery locations.

**Data analysis** The data gathered in this study was systematically structured using the process mapping technique. The human, technological, organizational (HTO) model was employed as the guiding framework for data analysis. The HTO model refers to designing technology and organizational systems by iteratively considering the needs, abilities, and limitations of humans involved in the activity (Paes et al., 2022; Rollenhagen, 2000). The analysis helped in the identification of both the advantages and challenges linked to the utilization of digital tools.
3.7 Research quality

To judge the quality of research, reliability and validity are often considered, as mentioned by Halldorsson and Aastrup (2003) and Bell and Bryman (2015). However, reliability and validity come from quantitative research and might not fully fit with qualitative research, according to Halldorsson and Aastrup (2003). For example, reliability means whether the study can be repeated consistently. In practical terms, it involves detailed steps and documentation to help replicate the study, aiming for consistent results (Yin, 2018). However, this is more applicable to quantitative research. In qualitative research, replicating the exact social environment and context is nearly impossible, making it challenging to achieve the same level of reliability (Bell & Bryman, 2015).

Given this, many logistics researchers suggest using different quality criteria that are better suited to qualitative research, such as case studies, to evaluate research quality (Halldorsson & Aastrup, 2003; Wowak et al., 2022). In this thesis, the research quality is measured by credibility, transferability, dependability, and confirmability, as recommended by Halldorsson and Aastrup (2003) and Wowak et al. (2022).

Credibility is about how well the author’s interpretation of the data matches the actual situation or the participants’ perspectives (Wowak et al., 2022). To maintain credibility in this thesis, detailed notes were taken during interviews and observations, and shared with the participants to guarantee an accurate depiction of the collected data. The findings were presented both internally within a fossil free construction logistics research group and externally within case participants.

The second criterion, transferability, refers to how well the research results can be applied to different situations or settings, as noted by Wowak et al. (2022), and the capacity to make broad statements about the world, according to Halldorsson and Aastrup (2003). In this thesis, transferability was achieved by selecting cases that were alike enough to cross-check different cases, yet diverse in terms of actors, enhancing the broader applicability of the findings.

The third criterion, dependability, means that the research outcomes or interpretations remain reliable and consistent during the study, as explained by Wowak et al. (2022), and involves verifying that data is stable over time, according to Halldorsson and Aastrup (2003). To maintain dependability in this thesis, the two main methods of data collection are used: interviews and observations. In interviews, protocols were developed from the literature, ensuring a solid foundation in established concepts. These protocols were consistently applied in all interviews within each case to cover the same
subjects systematically. For observations, the focus was set from the start on improving CTE for the involved actors.

The final criterion confirmability, questions whether the research findings accurately reflect the data from participants and are free from author’s bias, as described by Halldorsson and Aastrup (2003) and Ejohwomu et al. (2016). To minimize the author’s bias, the collected data was reviewed internally and externally by presenting it to both the research unit and the case participants. Additionally, participants were provided with notes or sometimes transcripts of the collected data to verify the author’s understanding and accuracy of the recorded information. To promote triangulation and further ensuring objectivity, all authors contributed to the data analysis.
4 Summary of appended papers

This chapter provides a summary of the five papers contributing to this thesis. The chapter begins with the title and purpose of each paper, followed by an overview of the key findings and an explanation of how each paper contributes to the thesis.


The purpose of the paper is to explore the relationship between information asymmetry in the main contractor subsystem and CTE. This paper highlights that information asymmetry presents a challenge in improving CTE. However, it is often observed that construction tends to be set in its traditional ways, preferring reactive measures over proactive planning. This tendency makes it difficult to reduce information asymmetry and improve CTE. The paper clearly indicates that inadequate information sharing among involved actors in construction can result in delays and increased costs. The paper emphasizes that improved organization and information sharing are crucial to addressing the challenges of information asymmetry. Construction is frequently criticized for its slow adoption of new technologies and practices in information sharing. To improve CTE, a significant shift is needed in how different actors manage and
exchange information. The traditional approach of maintaining arm’s length relationships is not favorable in improving CTE. Instead, information sharing among transporter, main contractor and material supplier is essential. This will allow the transporter and material supplier to plan their transport more efficiently, enabling the main contractor to plan goods reception more efficiently, reducing the reliance on slack resources and contingency plans. Therefore, there is a pressing need for a change in the construction mindset, moving towards greater interorganizational collaboration where information sharing is recognized as a solution to improve business performance.

The paper has thoroughly examined the impact of information sharing, or frequently its absence, in improving CTE and how this, in turn, influences the overall productivity of construction. It is evident that information asymmetry is a common issue, yet adopting a more current approach to information sharing could significantly mitigate many of the challenges stemming from this asymmetry. However, this necessitates a willingness among the involved actors to embrace change.

4.1.1 Contribution
The paper contributes to improving CTE by highlighting the critical role of information sharing in the construction supply chain. The paper demonstrates how the lack of structured information sharing and low digital maturity among involved actors lead to lack of efficiency, such as increased use of resources and delays. The paper proposes that collaborative planning and the adoption of digital tools can significantly improve information sharing, leading to better coordination and timely deliveries. Furthermore, the paper advocates for standardized data collection and information sharing practices, thereby improving CTE. Overall, the paper offers a framework for improving CTE through improved information sharing and inter-organizational collaboration.

4.2 Paper II: Improving construction transport- A freight forwarder perspective.

The purpose of the paper is to contribute to construction transport time efficiency by identifying non-value adding activities and their causes from a freight forwarder perspective.

This paper studies two transport flows within construction: material flow and waste flow. The activities within these flows are analyzed using Value Stream Mapping (VSM), which serves as an organizational and analytical tool for the collected data. The paper classifies activities into three categories: value adding, non-value adding and necessary but non-value adding. This classification is based on factors such as the importance of an activity within
4.2. Paper II: Improving construction transport- A freight forwarder perspective.

the transport flow, the amount of time loss versus benefit, and potential alternative methods for conducting the activity, drawing on insights from previous literature (Bølviken et al., 2014; Hosseini et al., 2011; Koskela, 1993; McKinnon, 2018; Sternberg, 2011).

In the material flow, value adding activities include loading, transporting, and unloading materials. In contrast, non-value adding activities are searching for the correct address, finding the unloading zone, contacting relevant personnel, and waiting to unload. Activities such as collecting pick lists, documenting unloaded materials, marking deliveries as completed, and returning empty are considered as necessary but non-value adding.

Similarly, in the waste flow, loading filled waste containers, transporting them to sorting and recycling facilities, and unloading waste materials are considered as value adding activities. Non-value adding activities include waiting to lift filled waste containers and returning to the site just to return an empty container. Necessary but non-value adding activities involve securing loaded containers with a net, weighing containers, and handling paper receipts.

The VSM analysis indicates that nearly 43% of the time in both material and waste flows is consumed by non-value adding activities.

4.2.1 Contribution

The paper contributes to the thesis by highlighting that lack of efficiency within construction transport is primarily due to poor planning, information sharing, and coordination among involved actors. The paper suggests that improvements in these areas, supported by digitalization and the use of ICT tools, can significantly improve time efficiency, and reduce environmental impacts. These digital tools, including advanced mapping devices, telematics, GPS technology, and real-time information systems, can streamline operations, reduce waiting times, and optimize routing. The paper also suggests technological innovations, such as smart waste containers and specialized vehicles, to further improve efficiency.

The paper provides a comprehensive framework for identifying non-value adding activities specific to construction transport. Furthermore, the paper also offers practical solutions for improving efficiency, thus contributing valuable insights to transport operations and reduce emissions. The paper emphasizes the importance of better planning, coordination, and communication among involved actors.
4.3 Paper III: Creating Logistics Service Value in Construction – A quest of coordinating modules in a loosely coupled system.

The purpose of the paper is to increase the understanding of the logistics service value adding process in construction. The paper aims to address the complexities of coordinating multiple actors and logistics services within construction, focusing on how value is added and maintained through these interactions.

The paper elaborates on three logistics service modules: material management, on-site VMI, and waste management. A module refers to a distinct, self-contained unit of logistics service that can be combined with other logistics services within a CLS (Eriksson et al., 2021). Each logistics service module is described in terms of its design, implementation, and perceived value from the perspectives of different actors. The material management focuses on transport planning and material storage, the on-site VMI on providing frequently used materials through a mobile shop, and the waste management on efficient waste handling and recycling. The paper shows that these logistics service modules, while beneficial in terms of technical and perceived value, present challenges in terms of monetary value, particularly for subcontractors who are often forced to use these service modules.

The paper emphasizes the critical role of logistics service modules and actor’s involvement in the value adding process within construction logistics. The paper highlights that designing logistics service modules simplify the implementation of logistics solutions, allowing for a more tailored approach to meet the specific needs of construction. However, the paper also highlights that while these service modules can streamline operations, they do not automatically simplify the overall service value adding process. The involvement of multiple actors, including subcontractors who are often mandated to use these logistics service modules, introduces complexities and potential resistance. The paper stresses the importance of early and continuous involvement of all actors in the value adding process to develop trust and commitment, which are essential for the successful adoption and utilization of logistics service modules. Moreover, the use of tools like service blueprinting is highlighted as crucial for visualizing the relationships and value propositions among the various services and actors, thereby improving the overall understanding and effectiveness of CLS. The study calls for a balanced approach that combines standardization and adaptability to achieve efficient and value driven logistics service modules in construction.

The findings highlight that trust and commitment are crucial for adding value in a loosely coupled system like construction. The paper also identifies
risks such as delayed actor involvement and lack of coordination between logistics service modules.

4.3.1 Contribution

This paper contributes to the thesis by demonstrating how coordinated logistics services can streamline operations, reduce congestion, and improve construction outcomes. By implementing a CLS that includes well-defined logistics services, the paper shows that it is possible to achieve better control of deliveries and transport, resulting in fewer delays and less congestion both on-site and in the surrounding areas. Logistics services allow for more efficient resource allocation and better coordination among the various actors, leading to significant time and cost savings. Additionally, the use of service blueprinting helps in visualizing and understanding the complex interactions and dependencies within the logistics system, facilitating better planning and execution of logistics activities. However, implementing logistics services is complex due to the involvement of various actors as service providers. Additionally, subcontractors often need to be convinced of the benefits, as they tend to view logistics services as adding more cost than value.

4.4 Paper IV: Clarifying the interface between construction supply chain and site – A key to improved delivery efficiency.

The purpose of the paper is to capture non-value adding activities of the order-to-delivery process at the interface between the construction site and the supply chain in order to identify efficiency improvement potentials.

The findings of the paper highlight a significant issue at the interface between the construction site and the supply chain: a state of fuzziness, indicating disorganization and lack of clarity. This research uncovers how delivery activities at this interface are often not clearly understood by both transporter and main contractor until the actual time of execution. This fuzziness is evident in the ambiguity surrounding where one actor’s responsibilities intersect with those of another, with a notable lack of clarity about their respective needs at this interface, aligning with the observations of Vrijhoef and Koskela (2000).

This fuzziness and lack of clarity leads to non-value adding activities such as waiting times for loading and unloading, unnecessary vehicle movements, and improper material storage. The primary cause of this fuzziness and lack of clarity is a fundamental misunderstanding among the involved actors about how preceding activities in the order-to-delivery process affect the efficiency of subsequent activities in the final delivery. The disconnect between planning
(an early stage in the order-to-delivery process) and the actual delivery creates a disorganized and unpredictable environment for those carrying out the delivery tasks, an aspect also highlighted by Thunberg and Fredriksson (2017). However, this paper goes further by quantifying the impact of this disorganization in terms of non-value adding times for delivery activities, thus contributing new insights to the field.

Furthermore, as suggested by Gholami et al. (2019) and Thunberg and Fredriksson (2017), these non-value adding times often arise from inadequate planning, poor communication among the involved actors, and the lack of SOPs for unloading, material storage, and waste collection. The absence of SOPs, including clearly marked loading and unloading zones at construction sites, leads to materials being unloaded in inappropriate locations. This results in improper storage, increased risk of damage, and unsafe working conditions, while also requiring additional time to move materials around the site.

4.4.1 Contribution

This paper contributes to the thesis by identifying non-value adding activities at the interface between the construction supply chain and the construction site. Through a detailed case analysis, the paper highlights issues such as waiting times, excessive material handling, and unnecessary vehicle movements, which result from poor planning, lack of communication, and the absence of SOPs. The paper emphasizes the critical need for better coordination at the interface and proposes actionable strategies to improve communication and planning among the involved actors. Additionally, the paper provides a clear overview of the roles of different actors in these non-value adding activities and offers suggestions to improve the efficiency of construction deliveries.

4.5 Paper V: Improving construction transport efficiency by digitalization.

The purpose of the study is to increase the understanding of how transport efficiency can be improved using digital tools in the transport flow of construction material.

The paper explores the impact of digitalization on improving CTE, specifically studying the use of a digital scanner. Despite the theoretical potential for digitalization to improve efficiency, the findings reveal that its current implementation has increased manual work and effort rather than reducing them. The paper uses the HTO model to analyze the use of digital tool, identifying that while progress has been made in the human dimension,
the technological dimension requires more attention to address technical issues and usability improvements. The organizational dimension, despite having a positive culture, needs better task delegation and workflow management. The research provides valuable insights into the role of digital tools in construction transport, highlighting both their benefits and challenges. It urges managers to consider digitalization as part of a larger integrated system rather than as a standalone solution, emphasizing the importance of careful planning and execution. Practical recommendations include improved training for drivers, better user interfaces, and additional functionalities such as suggested delivery routes. This paper also contributes to the academic discourse on digitalization in construction transport, offering a starting point for future research.

4.5.1 Contribution

The paper shows that while digitalization has the potential to improve CTE, its success depends on how digitalization is integrated. Poor use of digitalization can introduce additional complexity, as observed in this study. The paper contributes by suggesting, to fully harness the benefits of digitalization, its integration into existing processes needs to be efficient. Improvements to the user interface and functionality are also recommended. As indicated by Berglund et al. (2020) and Kjellsdotter Ivert and Jonsson (2011), merely employing technology is not sufficient; the organizational and human aspects are equally crucial to realize the technology’s full potential.
This chapter presents answers to the research questions, based on the findings from the papers included in this thesis.

5.1 Research question 1

RQ1a: What activities constitute construction transport?

Construction transport constitutes activities that involve movement of materials to, from and at construction site. In this thesis, two transport flows have been studied, i.e., material flow and waste flow (Study II and Study IV). Within material flow, the movement of materials from material supplier to construction site has been studied (Study II). Likewise, within waste flow, the movement of waste from construction site to sorting facility has been studied (Study II). Furthermore, the receiving, storing of material and collection of waste material at construction site have also been studied (Study IV). Both material flow and waste flow consist of activities that can be classified as value adding, non-value adding and necessary but non-value adding activities (Study II). For example:
Value adding activities in material flow are loading, transporting, and unloading. These activities are known as value adding activities because these activities are critical activities and directly contribute to material flow (Study II). Likewise, activities such as searching for the right address, finding unloading space, contacting the concerned person, and waiting to unload are considered as non-value adding activities because these activities do not directly contribute to the material flow and instead result in resource wastage and lack of efficiency. These non-value adding activities present potential areas for improving efficiency (Study II). Furthermore, activities like collecting picking lists, taking pictures of unloaded materials, marking deliveries, and travelling back empty are important for operational or regulatory reasons but do not add direct value to the material flow, therefore, these activities are considered as necessary but non-value adding activities (Study II).

Likewise, within waste flow, activities such as loading filled waste containers, transporting them to sorting facilities, dumping waste material, and returning empty containers to the site for reuse are considered as value adding activities since these activities are critical for waste flow. Activities such as waiting to lift the filled waste container and travelling back to the site solely to place the empty container back are considered as non-value adding activities since these activities result in resource waste and lack of efficiency. By improving non-value adding activities, lack of efficiency can be minimized. Moreover, activities such as securing the loaded container with a net, weighing the container, and handling paperwork are necessary but non-value adding activities since these activities are important for safety and regulatory reasons but do not directly contribute to the waste flow and can be further improved (Study II).

Based on the findings from Study II, it has been found that about 43% of the time is consumed in performing non-value adding and necessary but non-value adding activities within material and waste flow.

**RQ1b: What are the challenges in improving construction transport efficiency?**
The main challenges in improving CTE are lack of planning, lack of communication and lack of SOPs (Study IV). Lack of planning and poor communication between actors have been identified as the primary reason for non-value adding activities in construction transport, such as prolonged waiting times for loading and unloading, excessive waste accumulation on-site, unnecessary waste collection trips, and conflicts between incoming and outgoing transport. Furthermore, the lack of SOPs such as clearly marked loading and unloading zones and lack of systematic waste collection, further reduces efficiency (Study IV).

Study II and Study IV show that construction transport is not executed very efficiently at present. There exists a lack of efficiency within construction transport. For example, most deliveries at the construction site are not planned in advance, leading to several problems (Study II and Study IV). For example, long waiting times, conflicts between incoming and outgoing transport, long queues at the entrance and exit, and overall congestion at the construction site. Additionally, these unplanned deliveries often lead to material damage in a way that the main contractor does not have enough time to arrange for material storage (Study IV). As a result, materials are often unloaded at random places instead of the specific storage locations near where the material will be used. This results in frequent material handling which increases the risk of damage each time the material is relocated (Study IV). Moreover, this results in non-value adding activities which leads to resource wastage such as time, cost, labor, effort, and energy.

Additionally, since construction sites typically have limited storage space, and construction materials are usually heavy and voluminous, it becomes challenging to store all received material properly. Due to severe weather conditions, improperly stored materials are more likely to get damaged (Study IV). Furthermore, it has been found that there exists fuzziness at the interface between the construction site and the supply chain. The fuzziness typically results from the involvement of at least two actors (i.e. main contractor-transporter, main contractor-waste collector, transporter and waster collector) highlighting a lack of clarity about actor’s responsibilities in improving CTE (Study IV).

Table 5.1 summarizes some of the challenges highlighted in RQ1:
5. **Results**

<table>
<thead>
<tr>
<th>Challenges in improving CTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of planning</td>
</tr>
<tr>
<td>Lack of communication</td>
</tr>
<tr>
<td>Lack of SOPs</td>
</tr>
<tr>
<td>Waiting</td>
</tr>
<tr>
<td>Searching for unloading zones</td>
</tr>
<tr>
<td>Searching for the right address</td>
</tr>
<tr>
<td>Contacting the concerned person</td>
</tr>
<tr>
<td>Empty travelling</td>
</tr>
<tr>
<td>Unnecessary vehicle movements/trips</td>
</tr>
<tr>
<td>Frequent material handling</td>
</tr>
</tbody>
</table>

Table 5.1: Challenges in improving CTE

### 5.2 Research question 2

**RQ2: How can logistics services, digital tools and information sharing improve construction transport efficiency?**

The way logistics services, digital tools and information sharing improve CTE is as follows:

#### 5.2.1 Logistics services

##### 5.2.1.1 Material management

The logistics service – material management involves transport planning, unloading, material movement and material storage at site. Material management begins with the TPL provider sending an email to transporter, main contractor, subcontractors, and material supplier. The email is sent to confirm unloading area and resource availability for booked time slots regarding material delivery. Considering the need to move material into the building after unloading, adjustments are made accordingly in terms of booking time slots and resource availability. To ensure efficiency, guidelines for packing and moving material are provided according to storage locations and areas for handling equipment. Main contractor and subcontractors plan deliveries and book time slots by a booking system. TPL provider then approves the deliveries to avoid congestion and conflicts between incoming and outgoing transport. Resources such as personnel and equipment are booked for material unloading and night shift workers are arranged to move material to specific storage locations to make material available
for work in the morning. Furthermore, TPL provider and the main contractor conduct weekly meetings to plan transport for the upcoming weeks. Transport and CO2 data are compiled and shared in an Excel spreadsheet, which is reviewed by the TPL provider and the main contractor on a monthly basis (Study III).

Material management is used by all actors on-site, including the main contractor and subcontractors. However, subcontractors are required to use material management as part of the contract with the main contractor. Opinions differ between the main contractor and subcontractors regarding material management. The main contractor believes that material management saves time, which is a shared view with the TPL provider. However, according to subcontractor while it saves time in performing tasks, it adds administrative time for managing bookings and in moving material into the building. The subcontractors acknowledge that material management allows consolidated deliveries which are easier to handle compared to numerous small deliveries. Despite this, subcontractors and TPL provider consider material management expensive and believe it adds more costs than benefits. (Study III).

Nevertheless, material management ensures better control of material deliveries, particularly in large, complex construction with limited space. Furthermore, material management minimizes or eliminates queues at delivery or pick-up areas and reduces congestion both on-site and in surrounding areas. Additionally, material management prevents delays caused by material shortages or misplacement (Study III).

5.2.1.2 On-site VMI

The logistics service – on-site VMI is a mobile shop for frequently used material. The material replenishment time is about one to two days. The ordered material is delivered on a daily basis to restock the shop. The logistics service within on-site VMI begins with the setting up of the shop and its equipment such as material, trolleys and cars by the material supplier. Main contractor and subcontractors forecast and plan material orders and pay the invoices. The TPL provider picks orders, refills trolleys and restocks material. Additionally, TPL provider handles various activities such as ordering,
5. Results

packaging, restocking, and receiving material which are not visible to the main contractor and subcontractors (Study III).

According to the TPL provider, the availability of frequently used material is ensured in the shop. However, as per the subcontractors the store prioritizes construction-related items and does not fully cater to all needs, such as electrical supplies. The TPL provider acknowledges the challenge in understanding the diverse requirements of both the main contractor and subcontractors.

Nonetheless, the on-site VMI module saves time by allowing orders to be placed on-site rather than requiring trips to a physical store off-site, thereby reducing the need for additional transport (Study III).

5.2.1.3 Waste management

The logistics service – waste management involves managing and organizing waste collection at construction site. It comprises setting up waste collection stations where workers can deposit full waste bins and pick up the empty ones. The logistics service within waste management begins with the use of waste bins and containers along with trucks to pick up the containers. Subcontractors sort waste materials into the appropriate bins and transport the bins to the waste collection station, while also picking up the empty bins. The bins are labelled to sort different types of waste and are marked with subcontractors identification numbers. The TPL provider plans waste management activities, including the number of personnel needed, the number of containers required, and the scheduling of night personnel. TPL provider also controls the sorting process to ensure it is done correctly, reports sorting and recycling rates, and transport materials to sorting facilities. The IT system used by the TPL provider supports ordering, reporting, and control of these activities. Additionally, the booking system is used for container transport, and determining the number of fractions to be sorted (Study III).

Waste management is highly regarded by the main contractor because it significantly saves workers’ time. Subcontractors acknowledge that using the elevators for waste removal at night is beneficial in a large project, as it prevents queues during the day. However, the main contractor generally views waste management more positively than the subcontractors. Subcontractors have raised
concerns about the risk of being charged for someone else’s waste, as workers may take bins belonging to others and return them to incorrect locations, making it difficult to find their own bins. Additionally, there are occasional shortages of bins, making it challenging to obtain a new one when needed (Study III).

5.2.2 Digital tools

The use of digital tools, such as digital scanners, improves CTE by improving communication, visibility, and transparency across material flow. Each scan creates a system entry that informs material supplier about the activity performed, the time it occurred, and the items involved, providing better visibility into the material flow (Study V).

However, challenges were identified, including interface and functionality issues, increased manual work, and organizational aspects like training and work structure. It has been found that while digital tools improve CTE in terms of improved communication and transparency, digital tools also increased manual work in some situations, contrary to the expectation of improved efficiency. Effective integration of digital tools into existing processes is essential to realize their full potential. The study also identified areas for improvement by using the HTO model. For example, drivers need better training and understanding of the digital tools, technological enhancements are required for better usability, and organizational improvements are needed in task delegation and workflow management. Despite some positive perceptions, particularly regarding organizational culture, the technology dimension requires more attention to address issues like scanner readability and notification system reliability (Study V).

5.2.3 Information sharing

There exists lack of information sharing within construction. This is because of several factors such as (Study I):

- Temporary, fragmented, and complex nature of construction involving many different actors with arm’s length relationships. The way construction is organized complicates information sharing.
• Actors such as transporter and material supplier often do not understand the importance of sharing information or are unaware of what specific information to share or what specific data is needed to improve CTE. Main contractor also struggles to determine whether the shared information is sufficient for improving CTE or not.

• Due to the dynamic nature of construction, deliveries are planned only a few days in advance rather than long-term. As a result, information about delivery times rarely reaches the construction project until the transporter arrives at the gates. Consequently, the booked delivery times are often much longer than necessary for unloading. This creates uncertainty and makes planning difficult for all involved actors. Furthermore, the approach to handling uncertainty is typically reactive rather than proactive, making it more challenging to manage uncertainties efficiently.

• There is a heavy reliance on traditional methods of recording information, with construction transport performance being monitored and analyzed manually. This manual approach indicates a lack of standardized information recording practices. Advanced information-sharing tools are rarely used, resulting in an overdependence on paper, emails, and phone calls.

However, to address these challenges it is crucial to share information among all involved actors. This will help reduce uncertainty and information asymmetry which will further help in improving CTE (Study I).

Table 5.2 summarizes the ways logistics services, digital tools and information sharing improve CTE.
Proposed solutions | Improve CTE
---|---
Material management | -Better control of material deliveries
| -Minimize or eliminated queues at delivery or pickup areas
| -Reduce congestion
| -Prevent delays caused by material shortage/replace

On-site VMI | -Time saving
| -Less transport

Waste management | -Time saving
| -Cleanliness at site

Digital tool | -Improve communication
| -Increase visibility
| -Increase transparency

Information sharing | -Reduce uncertainty
| -Reduce information asymmetry

Table 5.2: The ways logistics services, digital tools and information sharing improve CTE

The proposed solutions i.e. logistics service, digital tools and information sharing improve CTE by offering a systematic approach to manage transport flows. These solution help in improving CTE by addressing the challenges identified in RQ1. However, implementing these solutions is challenging due to the involvement of multiple actors and the lack of clarity regarding actor’s roles in improving CTE. Additionally, the existing fuzziness within construction transport complicates coordination.

5.3 Research question 3

RQ3: How does improving construction transport efficiency add value for the involved actors?

Improving CTE adds value for the involved actors in terms of technical, monetary, and perceived value. However, the importance of these values varies among different actors.

Improving CTE adds technical value in the following ways:
5. Results

- **Reducing delays**: Improving CTE directly reduces delays on construction site by ensuring that materials and equipment arrive precisely when needed. Delays often occur due to miscommunications, delivery complexities or unexpected issues in transport. By planning and coordinating deliveries and utilizing advanced tracking systems, construction can avoid these delays (Study II, Study III, Study V).

- **Availability of material vs needed**: Improving CTE ensures that materials are available exactly when they are needed, preventing idle time and increasing productivity. By having materials delivered at the right time, material shortages can be avoided which often force workers to stop or delay tasks (Study IV).

- **Minimizing waste on construction site**: Improving CTE minimizes waste by improving the quality of material deliveries. When material is delivered accurately and in right quantities, waste is reduced. Furthermore, improving CTE ensures timely removal of waste from the construction site, keeping the site clean and organized. This reduces scatteredness at site, keeps the passageways free from obstacles and allows sustainable construction by carrying out efficient waste management (Study IV).

- **Timely delivery of materials**: Timely delivery of material is critical for ensuring construction on schedule. By utilizing real time tracking and advanced planning tools deliveries can be coordinated to align well with construction timeline. In this way, the situations where workers are left waiting for materials can be minimized and productivity losses can be avoided (Study II, Study V).

- **Reduced CO2 emissions**: By consolidating deliveries, reducing unnecessary trips and empty travelling, improving CTE can significantly reduce CO2 emissions. Reduction in CO2 emissions not only helps in improving environmental sustainability but also aligns with regulatory requirements for construction (Study II, Study IV, Study I).
5.3. Research question 3

- **Planned and coordinated deliveries:** Planned and coordinated deliveries reduce conflicts between incoming and outgoing transport and reduce congestion both on-site and in the surrounding areas to ensure a smooth flow of materials. This systematic approach improves overall construction efficiency and reliability (Study I, Study III, Study IV).

- **Better control of transport flow:** Having better control over transport flow means that involved actors can manage the movement of materials and equipment with greater precision and reliability. Better control involves using digital tools and advanced tracking systems to monitor transport activities and do the adjustments accordingly. Better control of transport flow ensures that materials are not only delivered on time but also in the correct order and in the right condition. This control of transport flow reduces the risk of delays and ensures that the construction stays within budget and on schedule (Study V).

The technical value achieved by improving CTE, as described above, translates into the following monetary value:

- **Time savings:** Improved CTE results in significant time savings. For example, material and equipment arrive precisely when needed, which reduces the idle time for workers and machinery. This means that workers spend less time waiting for deliveries and more time on performing tasks, leading to timely completion of construction. Time savings also allow workers to complete their tasks within the scheduled hours without the need for overtime. Additionally, timely material deliveries prevent delays in construction timeline thus avoiding financial penalties or time delays (Study II, Study III, Study IV).

- **Cost savings:**
  - **Less queues and congestion at site and in the surrounding areas**
  Improving CTE reduces queues at unloading and storage areas. When materials are delivered in a coordinated manner, it ensures that the unloading is smooth and quick, preventing the building up of queues. This prevention of queues reduces the time workers
spend handling and moving materials, allowing them to focus on performing tasks. Furthermore, less queues and smooth unloading minimizes the risk of damage to materials caused by prolonged exposure or improper handling. This results in cost savings from increased productivity, reduced material handling costs and lower risk of damage. Likewise, less congestion leads to lower fuel consumption and emissions from idling vehicles, contributing to cost savings and environmental sustainability (Study III, Study IV).

- **Reduced number of transports**

  By coordinating deliveries, the number of transport is reduced. Less transport means lower transportation cost including fuel, driver wages, and vehicle maintenance. Coordinated deliveries also mean that larger deliveries can be planned, optimizing the use of transport vehicles and reducing the frequency of smaller, less efficient deliveries. Larger, optimal deliveries leads to economics of scale, where the cost per unit of transported material decreases. Additionally, fewer transports reduce the environmental impact and align with sustainability goals, which can be financially beneficial in terms of compliance with environmental regulations and potential incentives (Study I, Study II, Study III).

Improving CTE adds perceived value to the involved actors in the following ways:

- **Close relationship among involved actors:** Improving CTE develops close relationship among involved actors such as transporter, main contractor, material supplier and waste collector. Improving CTE requires coordination and collaboration which help involved actors to understand each other’s needs in a more specific way. For example, when material supplier and main contractor work closely together, they coordinate material deliveries more efficiently ensuring that the right materials arrive at the right time (Study III, Study I).

  Close relationships reduce misunderstandings and lead to more innovative solutions to transport challenges since each involved actor brings expertise and insights to the table (Study III and Study I).
• Better trust and commitment: Improving CTE requires information sharing which in turn builds trust among involved actors. When deliveries are consistently on time and materials are handled properly, it develops reliability. This reliability develops trust as each involved actor can depend on the other to fulfill their roles effectively. Trust is further reinforced when involved actors communicate openly about the potential issues and work collaboratively to resolve them. With trust comes increased commitment since involved actors are more willing to invest time and resources into the relationship (Study III).

• Long term relations: Improving CTE builds long term relations among involved actors. When involved actors experience the benefits of efficient transport, it makes the involved actors continue working together in future. Long term relations add value by bringing stability and predictability to construction. Actors who have worked together more develop a deeper understanding of each other’s needs, preferences and expectations which further reduce the learning curve associated with new partnerships. These long term relations also encourage continuous improvement and innovation since actors are more likely to invest in shared goals and collaborations. Additionally, long term relations can lead to negotiated terms that benefit all involved actors such as discounts, preferred scheduling, and streamlined administrative tasks (Study I and Study III).

In addition to technical, monetary and perceived value, it has been found that improving CTE adds value to the involved actors as shown in the Table 5.3
5. Results

<table>
<thead>
<tr>
<th>Involved actors</th>
<th>Value added by improved CTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transporter</td>
<td>Improved delivery efficiency – maximum deliveries in given time</td>
</tr>
<tr>
<td>Main contractor</td>
<td>Improved productivity – material in right time, right form and right quantity</td>
</tr>
<tr>
<td>Material supplier</td>
<td>Material delivery assurance – delivery of materials as promised</td>
</tr>
<tr>
<td>Waste collector</td>
<td>Reduce unnecessary trips – minimise unplanned trips and maximise vehicle capacity utilisation</td>
</tr>
</tbody>
</table>

Table 5.3: Adding value to the involved actors by improving CTE

The findings from the RQs are depicted in the following Figure 5.1

Figure 5.1: Findings from RQs
This section presents conclusion and discussion in accordance with the purpose along with the contributions.

The purpose of the thesis is to investigate how to improve construction transport efficiency by using logistics services, digital tools and information sharing to add value for the involved actors.

The purpose is fulfilled by answering three RQs with the help of findings from five appended papers. RQ1a (what activities constitute construction transport?) has been answered by identifying activities within construction transport flows i.e. material flow and waste flow and classifying the identified activities into value adding, non-value adding and necessary but non-value adding activities. Value adding activities are those activities that need to be performed to carry out the material or waste flow. When managed efficiently, value adding activities can add value to all involved actors. On the other hand, non-value adding activities lead to resource wastage, such as time, cost, vehicle usage, energy, and effort, without significantly improving the material or waste flow. Necessary but non-value adding activities are
important, but their current execution results in more resource wastage than adding value.

Classifying activities into value-adding, non-value adding, and necessary but non-value adding is important for improving the efficiency of the material and waste flow, thereby increasing value. This classification helps all the involved actors to focus on activities that increase value, giving them a competitive advantage. Some of the identified activities such as loading, unloading, waiting, and unnecessary movements have similarities with previous studies (McKinnon, 2018; Sternberg, 2011; Villarreal et al., 2017). However, additional activities specific to the construction context have also been identified, such as putting on and taking off nets from filled waste containers, weighing filled and empty waste containers, and searching for unloading zones at construction sites.

RQ1b (what are the challenges in improving construction transport efficiency?) has been answered by exploring that “there is a lack of efficiency within construction transport”. For example, time delays, unplanned deliveries, unloading of material at undesignated locations, frequent on-site material handling which further leads to damages. When material does not arrive on time or in the right quantity, the construction gets impacted, wasting time and money. This situation makes it challenging for all involved actors in construction, from the main contractor doing the building to those paying for the construction, resulting in cost overruns and longer waiting times.

Construction transport is primarily concerned about ensuring material availability when needed (Kilibarda et al., 2013). This makes managing material and waste flows important within construction. However, the challenges such as lack of planning, lack of communication and lack of SOPs make construction transport less efficient and complex.

RQ2 (how can logistics services, digital tools and information sharing improve construction transport efficiency?) has been answered by providing detailed insights into the use of logistics services, digital tools and importance of information sharing all of which collectively improve CTE by minimizing delays and maximizing resource efficiency.
Logistics services, when efficiently used, ensure that the right materials are delivered to the right place at the right time, thereby minimizing cost overruns and idle time (Mentzer et al., 2001). The role of digital tools in this context is transformative, offering better tracking, visibility, and making the best use of resources. Through digital tools, involved actors can gain real-time insights into the status of materials and equipment, facilitating quick adjustments to construction as required also highlighted by Drugge and Rezaei (2020). However, it is important to note that “the adoption of digital tools will not automatically improve efficiency. In order to reap the full potential of digital tools, it is important to integrate the digital tools into the existing system”.

Furthermore, information sharing creates a culture of trust and collaboration, enabling a more cohesive approach to construction transport. This shared information ensures that all involved actors are aligned with project goals, schedules, and any changes in the plan, thereby improving CTE. Additionally, “information sharing increases coordination among involved actors” which is necessary for improved CTE.

RQ3 (how does improving construction transport efficiency add value for the involved actors?) has been answered by describing the ways improving CTE adds value for the involved actors in terms of technical, monetary, and perceived value (Gronroos & Helle, 2010). However, the significance of these benefits varies among different actors. For example, improving CTE adds value to transporter in terms of delivery efficiency, main contractor in terms of productivity, material supplier in terms of material delivery assurance and waste collector in terms of reducing unnecessary trips. In addition to technical, monetary and perceived value, “improving CTE adds value for the involved actors in terms of trust and commitment”.

Construction is a temporary organization (Bakker, 2010) involving multiple actors (Eriksson, 2019) such as transporter, main contractor, material supplier, waste collector. Consequently, construction has interdependencies (Bankvall et al., 2010) that necessitate improved planning and coordination. Although transportation is a major activity within construction (Eriksson, 2019), there exists low transport efficiency (Naz, 2022). This low transport efficiency not only leads
to increased CO2 emissions (Brusselaers et al., 2021) but can also negatively impact construction.

Temporariness and involvement of multiple actors make construction transport complex and makes it difficult to coordinate and collaborate to improve CTE. Furthermore, due to complexity and difficulty in coordinating, there exists a lack of trust and commitment. Moreover, involved actors remain in their own silos and keep information to themselves rather than sharing. For example, in most cases the exact time of material delivery remains unknown which further results in long queues at the entrance, congestion on-site, waiting and CO2 emissions.

Due to lack of information sharing and communication, involved actors remain unaware of each other’s needs or their roles in fulfilling the requirements to improve CTE and sustainability. Furthermore, it becomes difficult for the involved actors to understand how improving CTE adds value to each of them individually. Therefore, in this thesis the solution in terms of using logistics services, digital tools and information sharing has been proposed which helps the involved actors to coordinate and collaborate efficiently to achieve CTE which will further help the actors to add value via trust and commitment.

Furthermore, it is important to highlight that improving CTE varies depending upon the size and scale of construction. For small scale construction, where there are less resources, it becomes challenging to improve transport efficiency as compared to large scale construction. Since, in small scale construction, it is usually the main contractor looking after construction (the primary activity) and coordinating material deliveries. Due to large numbers of transport coming in and going at the construction site, it becomes challenging for the main contractor to handle all the activities i.e. construction as well as material deliveries. Therefore, it is proposed that there should be a dedicated personnel for managing and coordinating transport at construction site or at least there should be some transport related SOPs or regulations in place for each construction site despite the scale of it.
6.1 Theoretical contributions

Overall, this thesis contributes in the following ways:

- Transport activities specific to the construction have been studied thoroughly. Each activity within the transport flow has been identified, and the duration required to complete these activities has been recorded. Given the critical importance of time management in construction, this thesis provides significant value by detailing the time investment for transport-related activity.

- The quad model of construction transport efficiency, as illustrated in Figure 6.1 investigates transport flows within construction from the perspectives of four actors: transporter, main contractor, material supplier, and waste collector. This model, hence termed the quad model of transport efficiency, identifies that each actor finds value in unique aspects of the same transport flow. The thesis studies the roles that these different actors play in improving CTE. Specifically, it highlights that the four actors—transporter, main contractor, material supplier, and waste collector—each contribute uniquely to the overall efficiency of construction transport. The thesis suggests that improving CTE can be achieved by studying and enhancing various aspects of these actors’ roles as well as their interactions with one another. By focusing on both the individual contributions and the interplay between these actors, the thesis emphasizes that significant improvements in CTE can be realized.

Consequently, this model provides a robust framework for further research aimed at improving CTE through targeted improvements specifically within actors and generally within collaborations.

- The thesis investigates the roles of logistics services, digital tools, and information sharing in improving CTE. There is a notable scarcity of research exploring these aspects specifically from a CTE perspective.

- The thesis adds knowledge to the research stream of Logistics Management broadly and particularly fills the research gap within off-site transport in a construction.
6. Conclusion and Discussion

The managerial implications of the thesis are as follows:
6.2. Managerial contributions

- The thesis managerial implications highlight the importance of reducing non-value adding activities to save time and cost for managers. It demonstrates how improving CTE can generate value for all involved actors. Furthermore, by focusing on reducing non-value adding activities such as waiting, unnecessary vehicle movements managers can unlock significant benefits that ripple across the entire construction supply chain, ultimately contributing to improved construction and resource efficiency.

- The thesis shows a crucial insight that the mere adoption of digital tools is not sufficient to improve CTE. To fully realize the potential of digital tools, it is important to integrate digital tools in the existing processes. This integration allows for a more holistic approach to improving transport efficiency, where digital tools become drivers of streamlined transport flows rather than standalone solutions. For instance, integrating digital tools into scheduling and routing enables real-time monitoring and adjustments, optimizing transport routes and minimizing delays. Moreover, by integrating these tools with existing communication channels, stakeholders can enhance coordination and collaboration, leading to smoother and more efficient transport flows.

- To improve construction transport efficiency, it is important to identify and remove repetitive activities in transport flow. Additionally, there should be proper division of work so that the tasks are assigned and executed with precision and maximum efficiency. Furthermore, it is crucial to avoid relying on digital tools with limited functionalities as this may impede rather than facilitate the improvement process.

- Communication and information sharing act as a cornerstone for improving efficiency within construction transport. Effective communication ensures that all involved actors are well-informed about construction requirements, timelines, and transport challenges. Moreover, information sharing facilitates real-time updates on transport schedules, route changes, and material availability, enabling involved actors to make timely decisions and adjustments. This transparency and accessibility to information enhance coordination and minimize delays, ultimately improving
the overall efficiency of transport operations. Additionally, improved communication results in a sense of accountability among team members, encouraging greater collaboration and alignment towards common goals.
This final chapter presents the limitations of the thesis as well as suggestions for further research.

This thesis primarily relies on single case studies, which inherently limits the ability to generalize the findings to a broader context. This approach, while providing in-depth insights into specific instances, underscores the need for further research to explore the applicability of these results across different settings and contexts.

The scope of this thesis on logistics services reveals potential avenues for future research, particularly in understanding how the combination of different logistics services in construction can create synergies. Conversely, when there is overlap among logistics services, the resulting costs may exceed the benefits. It is also very interesting to dig into who should take care of the logistics services i.e. main contractor, LSP, waste collector or material supplier. Although this thesis has explored a selective range of logistics services, there remains a rich field of other logistics services like tracking and tracing, warehousing, and inventory management that require thorough examination.
Furthermore, inefficiencies may exist in value adding activities such as loading and unloading, which are not extensively covered in this thesis due to its focus on analyzing transport flows rather than individual activities. Digging deep into these activities could offer insights into ways of further improving CTE.

Moreover, while this thesis has adopted a logistics perspective to improve CTE, it also acknowledges the significant potential within procurement strategies (Eriksson, 2019). A deeper exploration into procurement, focusing on aspects like route optimization and fleet management, could provide valuable insights for improving CTE. Thus, procurement as research area presents meaningful directions for further research.

Additionally, the construction industry’s challenges, including managing supply chain interdependencies and achieving efficient coordination as highlighted by Bankvall et al. (2010), call for studying planning and coordination mechanisms. The prevalent power imbalances and dependencies within construction supply chains, as discussed by Walker and Toubouluc (2015) and Donato et al. (2015), further complicate construction challenges. Investigating how these dynamics influence construction, particularly the reliance on subcontractors and material suppliers for cost savings and resource supply, could provide insights into more equitable and efficient management practices. Building trust and encouraging collaborative partnerships are suggested as remedies for the adversarial relationships that currently hinder construction transport efficiency. Therefore, future research should aim to explore coordination, power, and trust within construction transport to develop strategies that strengthen involved actors’ relationships and improve overall construction supply chain.

In this thesis, three solutions have been identified to improve CTE: logistics services, digital tools, and information sharing. However, further research could beneficially explore the impact of electrification on improving CTE. While electric trucks are often recognized for their benefits in reducing noise pollution and CO2 emissions, a detailed investigation into how electrification specifically contributes to improved CTE would be valuable.


Drugge, O., & Rezaei, R. (2020). Digitalization within logistics management an increased use of digital tools on the construction site.


Bibliography


Papers

The papers associated with this thesis have been removed for copyright reasons. For more details about these see:

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