Improving reliability of the supply of building materials at Dura Vermeer

Bachelor Industrial Engineering & Management

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Preface

In front of you lies my bachelor thesis, “Improving reliability of the supply of building materials at Dura Vermeer”. This report is part of my graduation assignment for my Bachelor of Industrial Engineering and Management. The research was performed at Dura Vermeer in Hengelo between April 2022 and July 2022. It researches aspects of a supply chain that influence the reliability of deliveries from suppliers to the construction site. The research reclassifies the delivery chains for one renovation project of Dura Vermeer in Groningen and analyses which alternative is the best option for future projects.

I wish to thank Dura Vermeer for the opportunity of doing this research and expand my skill set. I also wish to thank B. van der Tuuk, my company supervisor, for the continuous support at the office, but more importantly, for the trust and autonomy. I also want to thank all my colleagues in the office for the great working environment. It was a pleasure to be working with such cheerful and hard-working people.

Next, I want to thank L. van der Wegen and N. Pulles for the quality and distinct feedback on my reports. Their help was significant and essential for the state of this thesis. As a final note, I want to thank my family and friends for their continuous support, which has driven me to strive for higher achievements.

Have an excellent read,

Nils Meulenbroek, July 2022

Management Summary

Dura Vermeer has many construction projects all over the country, and currently, it has multiple ongoing renovation projects located in the City of Groningen. In the current situation, the delivery chains of building materials from the suppliers to the construction sites in Groningen are causing lower effectiveness in project production than is expected from the company due to unreliable suppliers. This is the core problem that the company experiences. This thesis investigates the renovation project at the Goeman Borgesiuslaan to solve this problem. The research solves the problem for this specific project, also to gain helpful knowledge for current and future renovation projects in Groningen.

From a systematic literature review, theory concludes that effects on the reliability of the deliveries in transport processes come mainly from the configuration of the process that is used, the transparency and communicative abilities of all the actors, the configuration of activities, the combination of resources, and the positions of actors. Literature also states that a supply network coordinated configuration reduces the number of transports arriving at construction sites which is a priority in dense urban areas. Material supplies are directed to a consolidation facility outside the area for storage. Deliveries to the construction site from the consolidation facility are carried out on demand. Moreover, literature describes the advantages between just-in-time and just-in-case strategies. A "just-in-time" delivery strategy refers to having inventory arrive precisely when people need it, reducing the likelihood of overordering and left-over supplies. A “just-in-case” delivery strategy refers to companies purchasing supplies proactively, within defined parameters, to prioritize preparedness over the cost and cash flow implications of holding stock. Using just-in-case strategies is critical when demand is unpredictable, and suppliers are unreliable.

The supply chain of the renovation project at the Goeman Borgesiuslaan contains five suppliers that deliver five types of building materials. The five delivery chains all combine building materials when they arrive at the distribution hub, the company LCW. LCW is a TPL provider that stores building materials before they are delivered to the construction site. The use of LCW as a distribution hub aligns with the supply network coordinated configuration, which is beneficial for the efficiency of the project since the construction site lies in a dense urban area, and there is no room for the placement of building materials at the construction site. The current supply chain makes use of a just-in-time delivery strategy. There seems to be a lack of transparency, and communicative abilities between Dura Vermeer and Company F, a TPL provider present inside the supply chain before building materials are delivered to LCW. Moreover, there is a high number of parties and activities present in delivery chains that include Company F, and this is where the chief of the construction site experiences errors. Moreover, he sometimes experiences a shortage of building materials stored at LCW.

Solution scenarios represent reclassifications of the supply chain, improving the delivery’s reliability. Scenario 1 removes Company F from two of the delivery chains to also remove their disability in being transparent and communicative. Scenario 2 bundles four building materials into one delivery chain and gives the responsibilities of Company F to LCW, which has better problem solving and customer adaptation abilities. In this scenario LCW picks up the building materials at the suppliers instead of having them deliver each building material to the distribution hub themselves. Scenario 3 increases the number of pallets that each activity moves and decreases its frequency so that the required number of pallets are delivered each week. This scenario uses a combination of just-in-case and just-in-time strategies to deal with unreliable suppliers and having no space at the construction site to store building materials. It also reduces the total number of activities that the supply chain performs. Scenario 4 is a combination of the adjustments of Scenarios 1 and 3, and Scenario 5 is a combination of the adjustments of Scenarios 2 and 3.

The attributes ‘Distance’, ‘Average truckload’, ‘Number of delivery chains’, ‘Number of activities’, ‘Lead time’, and ‘Costs’ help to evaluate the alternatives/solution scenarios in a multiple-criteria decision analysis. With results of analyses on the solution scenarios and the opinion of the logistics manager on the meaningfulness of each attribute, values of the attributes result in a weighted average score of the alternatives. Considering these scores and the costs of the alternatives the analysis gives results that show Scenario 5 being the best option.

The best way the delivery chains of the renovation project at the Goeman Borgesiuslaan can be adjusted is by bundling four building materials into one delivery chain. In addition to that, the number of pallets that are moved during each activity should increase, and the frequencies should decrease in a manner that the required number of pallets are delivered each week. The deliveries from the suppliers to the distribution hub should follow the just-in-case strategy, which is commonly applied when suppliers are unreliable. The deliveries from the distribution hub to the construction site should keep applying its just-in-time strategy to comply with the lack of space at the construction site. These adjustments do require high transparency and communicative abilities, but LCW performs these activities, and they have shown high problem-solving and customer adaptation abilities.

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Reader’s guide

This reader’s guide elaborates on the different objectives and chapters of the thesis. Different readers concern themselves with different chapters and sections. This section gives a structure to make the evaluation easier for the reader. The problem-solving approach divides the research into four stages, each creating one of the deliverables. Each stage also delivers an answer to one of the research questions. Chapter 1 explains these stages more thoroughly. The stages with their deliverables of this bachelor thesis are the following:

- Stage 1: Literature background that delivers knowledge on the core problem
- Stage 2: Visualisation of the current supply chain/delivery chains
- Stage 3: Reclassifications of the supply chain/delivery chains
- Stage 4: Multiple-criteria decision analysis on the solutions

Multiple chapters divide the thesis, and they discuss different topics. Chapters 2 to 5 provide the deliverables of the Stages 1 to 4 mentioned above, respectively. The subjects of the different chapters are the following:

- Chapter 1: Problem identification
- Chapter 2: Literature Background
- Chapter 3: Current situation
- Chapter 4: Formulation of solution scenarios
- Chapter 5: Selection of scenario
- Chapter 6: Conclusion, recommendations, and discussion

All chapters are of interest to my supervisors at the University of Twente. Chapter 1 identifies the problem that the company experiences, and it delivers the methodology that solves the problem. The first chapter also delivers the research questions that this thesis answers to solve the company’s problem. Chapters 2 to 5 discuss the four stages of the problem-solving approach mentioned above. Chapter 6 concludes the thesis by answering the research questions, giving recommendations to the company, and discussing the limitations of the research. It also recommends what future research could investigate.

Chapters 1, 3, 4, 5, and 6 are of interest to my company supervisor at Dura Vermeer. The first chapter analyses the problems that the company experiences and shows what approach the research uses to solve these problems. Chapter 3 describes the current situation with the help of visual figures. Chapter 4 elaborates on the impacts on reliability and how the delivery chains can be reclassified. Chapter 5 delivers the selection process of the best possible solution, considering all trade-offs between different criteria of the different alternatives. Chapter 6 is of most interest to the company since it gives the answer to the main research question and delivers recommendations for future actions.

All readers of this bachelor thesis are free to read through the document and provide feedback.

1. Problem Identification

The construction industry is one of the country's largest and most important sectors and delivers many benefits to society. It does not achieve this without any problems, and the industry keeps facing challenges and developments. For the completion of my bachelor's degree in Industrial Engineering and Management, an internship at Dura Vermeer was offered, where I would explore logistical issues that the company is currently facing. Section 1.1 introduces Dura Vermeer, and Section 1.2 delivers a clear description of the problem that the company faces. Section 1.3 describes how this research aims to provide a useful solution.

1.1 Introduction to Dura Vermeer

Dura Vermeer is a construction company specialising in residential construction, utility construction and infrastructure. As the leading company in Dutch construction, Dura Vermeer has a turnover of more than €1.5 billion and employs more than 2,800 people ("Over Dura Vermeer," 2018). Dura Vermeer is looking for opportunities to work more efficiently, be more customer-oriented, and sustainable. The company has multiple ongoing projects in the Netherlands. These projects are prepared extensively and executed over multiple months or even years, depending on the project size.

Currently, multiple projects are being executed in Groningen, a city in the north of the Netherlands. In these projects, buildings will be renovated. The projects are executed on construction sites, and due to the condensed city environment, there is limited space, which results in the need for an efficient process and workflow. To be efficient is to achieve maximum productivity with minimum wasted effort or expense. The company has already researched earlier projects where observations at the construction sites brought awareness to project effectiveness. To be effective is to have the capability of producing a desired result or the ability to produce the desired. The intended results of these renovation projects are to renovate the agreed upon sections of the building at the agreed upon times.

Furthermore, the company has alliances and contracts with many other parties, such as suppliers and logistical service providers. The company often speaks of the reliability of suppliers of building materials. This reliability is the trustworthiness and performance of the suppliers. Building materials can be delivered earlier as well as later than agreed upon, and this time deviation from the planned arrival of the building materials is used to give value to the reliability of the suppliers. The time deviation is measured in minutes, but in some cases, deliveries arrive a day later. In other cases, deliveries arrive too early. It depends on the situation if this is experienced negatively for Dura Vermeer. For example, if the area for the arrived building materials is not prepared, an early arrival is experienced negatively. If there is enough capacity, an early arrival has no negative effects, depending on the storage costs. Late deliveries are always experienced negatively since this requires adjustments to the workflow. One of the ways the company calculates the reliability of one delivery is with the following equation:

$$\text{Reliability} = |real\ \ time\ of\ arrival - agreed\ time\ of\ arrival|$$

1.2 Problem Description

This section delivers a clear description of the problem. Section 1.2.1 gives the perspective from the management of the company, and Section 1.2.2 delivers an analysis of all observed problems. Then Section 1.2.3 provides a statement that describes the core problem, and Section 1.2.4 elaborates on the difference between norm and reality.

1.2.1 Management Problem

When buildings need to be renovated, new challenges arise in comparison to standard construction projects. In renovation projects, there is limited space and often no room for storage around the building. Moreover, there are strict deadlines for finishing rooms inside the building at specific points in time due to the agreements made with the residents. These aspects make it of the utmost importance that deliveries of building materials arrive at the agreed upon times since a deviation of this impacts the effectiveness of the projects. The company experiences problems with these deliveries of building materials because some suppliers fail to honour existing commitments.

1.2.2 Problem cluster

Due to the broad scope of the management problem, a logistical analysis is conducted to identify a suitable core problem. In numerous interviews with the company's logistics manager, multiple underlying problems experienced in the company's projects are identified. After further analysing the problems, a cause-and-effect relationship between them is observed, allowing the possibility to visualise a problem cluster. A problem cluster is a model used to map different problems and their mutual relationships. A problem cluster serves as a means of structuring the problem context and is used to identify the core problem (Heerkens & Van Winden, 2017, p. 51). An arrow visualises the causes and effects, where the cause points to the effect. The action problem observed by the company is visualised with the colour red. An action problem is a discrepancy between the norm and reality, as perceived by the problem owner (Heerkens & Van Winden, 2017, p. 22). Figure 1 presents the problem cluster.

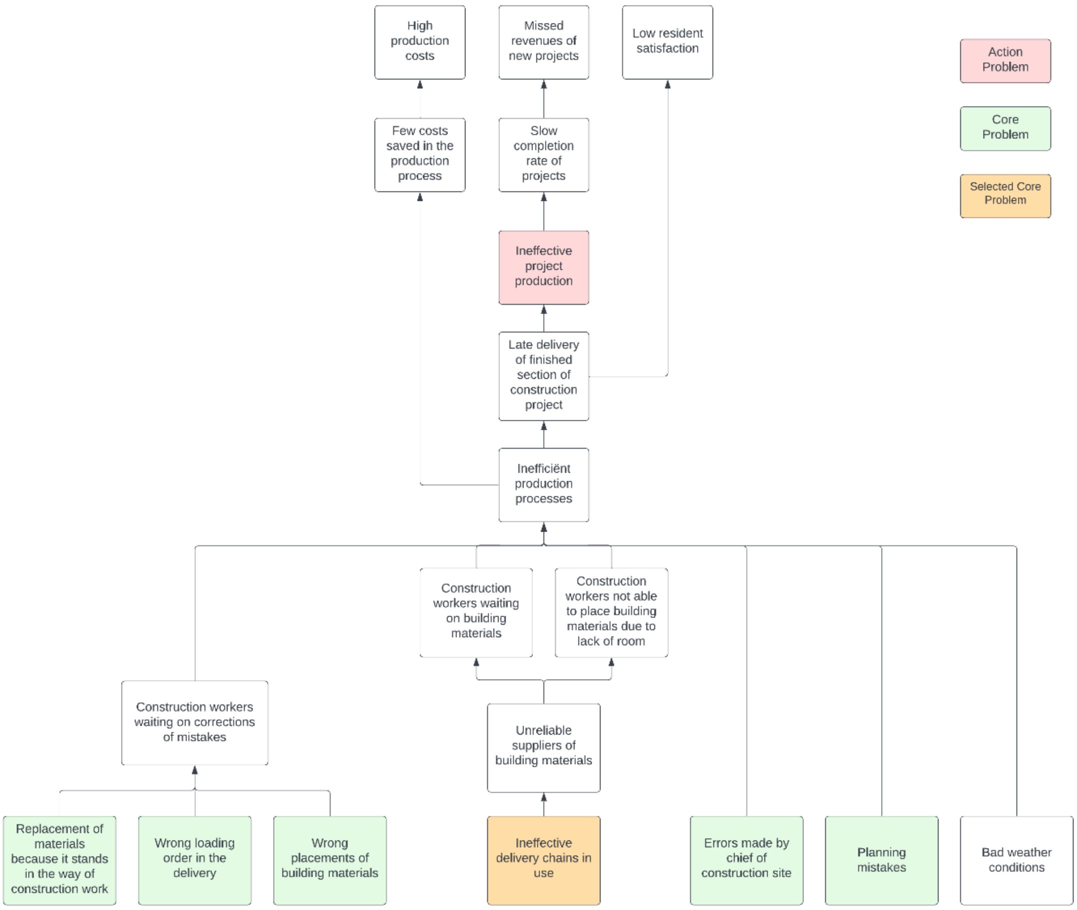

Figure 1: Problem cluster

The top of the problem cluster states the general problems that the company experiences. These problems mainly focus on high costs and missed revenue opportunities, which are general problems for many companies all over the world. The figure delivers the causes of these general problems, and one of these causes is ineffective project production. The company wishes to have effective project productions. It wishes to deliver finished sections of the construction project at the agreed upon times with the residents. This is their norm, and this is not always achieved in reality. The inefficient production processes cause the late delivery of a finished section of the construction project. Inefficiency is mainly caused by errors and mistakes made by different parties. These errors and mistakes are made by the chief of the construction site, planners in the project team, or unreliable suppliers. Unreliable suppliers are caused by the company's choice of what delivery chains to use for their supplies. A delivery chain/supply chain is a network between a company and its suppliers to produce and distribute a specific product to the final buyer (Kenton, 2021). Such a network includes activities, people, entities, information, and resources (Kenton, 2021). The delivery chains are observed by the company to be ineffective and are causing suppliers to be unreliable.

1.2.3 Core Problem

Core problems are those whose solutions will make a real difference (Heerkens & Van Winden, 2017, p. 41). In Figure 1 (last page), the potential core problems are visualised with the colour green, and the selected core problem is coloured yellow. It was observed by the logistics manager and the chiefs at the construction site in Groningen that the unreliability of the deliveries of building materials from suppliers is the main cause of a reduction in the effectiveness of the project production. The choice of the current delivery chains is causing the unreliable deliveries of building materials. Therefore, this is a better core problem to tackle than the other potential core problems. Tackling this problem leads to positive changes going up in the cause-effect relationships chain. The selected core problem is defined as:

In the current situation, the delivery chains of building materials from the suppliers to the construction sites in Groningen are causing a lower effectiveness in project production than is expected from the company due to unreliable suppliers.

1.2.4 Norm and reality

Reality is the state of things as they actually exist. At Dura Vermeer, the reality is that the supply of building materials does not arrive precisely at the moment that is agreed upon. The company lacks knowledge of the delivery chains and how they can be reorganised to improve the reliability of the deliveries. A large proportion of the deliveries arrive too late, which means the deliveries are not always reliable. One of the last measurements performed by the logistics manager stated that 26% of the scanned deliveries of a construction project near Hilversum arrived too late or on the wrong day (Van der Tuuk, 2021). There is no data on the performances at the renovation projects in Groningen, but the chiefs of the construction sites experience the problem of unreliable deliveries. This leads to ineffective project production, which means the company does not achieve the desired result. Their desired result for renovation projects in Groningen is to deliver renovated sections of the building to the residents at the agreed upon times. The norm is that Dura Vermeer receives deliveries of building materials at a time that is as close as possible to the time agreed upon, which means the deliveries are reliable. When these deliveries are reliable, the renovation projects do not experience difficulties delivering certain renovated sections of the building to their residents at the agreed upon time.

1.3 Problem solving approach and research design

This section explains the problem-solving approach and reports on the research design. Section 1.3.1 gives the scope of the research, and Section 1.3.2 delivers the methodology and the research questions. Then Section 1.3.3 provides the data collecting methods, and Section 1.3.4 elaborates on the data analysing methods. Section 1.3.5 follows with the deliverables.

1.3.1 Research scope

The company's scale is too large to look at all the projects all over the country. It is essential to adjust the scope of the research accordingly to make it more feasible. This research focuses on the renovation project of Dura Vermeer located at the Goeman Borgesiuslaan in Groningen. This construction site gives a good representation of the other renovation projects in Groningen, which is where the company aims to solve the core problem. The projects in Groningen have many different building materials, suppliers, and companies used as intermediate stages of the transportation process. Therefore, the research investigates only five delivery chains of building materials most important to the Goeman Borgesiuslaan. Note that the conclusions and recommendations can be considered for all renovation projects in Groningen because they are almost indistinguishable from each other, excluding their locations.

Moreover, the research focuses on the transport of building materials from the suppliers to the construction sites. When the reliability of suppliers is discussed, it is logical to investigate supply chain of building materials. Changes in the transport process could improve reliability, and Dura Vermeer requests to research this. In interviews with the logistics manager and the supply chain manager, it was concluded that the investigation of the supply chain leads to the most beneficial results because unreliable deliveries are a direct result of mistakes made inside the delivery chains; hence this is the scope of this research.

1.3.2 Methodology and research questions

The main research question of this thesis is:

"How can the delivery chains of building materials to the construction site at Goeman Borgesiuslaan in Groningen be adjusted to make deliveries more reliable?"

The final goal of the thesis is to provide a new version of the delivery chains that improve the reliability of the deliveries of building materials to the construction site. First, the background concerning existing literature is delivered to fill in the knowledge gap. A visualisation of the current situation follows to get a clear scope of the specific origin of the problem. Then the research examines adjustments and reclassifications in the supply chain and constructs multiple scenarios. To finalise the research, a clear assessment of the scenarios is made, considering additional criteria that affect the company's decision making. Considering this research design, it follows the characteristics of qualitative research. Given the unique purposes of qualitative research, it adopts typical research designs, uses non-probability sampling, and relies on smaller samples. This research gives the literature background of the research topics, describes the current situation, explains possible solution scenarios as alternatives, and thoroughly assesses the possible adjustments to the delivery chains.

The Managerial Problem Solving Method (MPSM) of Heerkens & Van Winden (2017) is a guide for this research methodology. The research is divided into multiple stages, with research questions in each stage that lead to an answer to the main research question. These four stages are the following:

Stage 1: Literature background

This first stage conducts a literature study to investigate the core problem and collect information for possible solutions. Theory in the field of the core problem is reviewed by performing a Systematic Literature Review (SLR). Knowledge gaps on buyer-supplier relationships, effects on delivery reliability, and uses of multiple-criteria decision models are filled in in this stage.

Research questions:

1.1 *What types of supplier relationships affect the reliability of deliveries in transportation processes?*
1.2 *What multiple-criteria decision models exist, and which multiple-criteria decision analysis should be used?*

The Systematic Literature Review answers Research Question 1.1. More existing literature answers Research Question 1.2.

Stage 2: Describing current situation
The second stage investigates the current situation of the company thoroughly. Information about all aspects of the problem is collected. The supply chain is visualised schematically. The information about suppliers and building materials is collected by interviewing companies that are involved and managers working on these projects. This stage highlights the problems present in the supply chain.

Research question:

2. *What do the delivery chains of the five most important building materials from the suppliers to the project at the Goeman Borgesiuslaan in Groningen look like?*

Sub questions:

2.1 *Which companies are involved?*
2.2 *Which building materials are the most important, and which suppliers are used for these materials?*
2.3 *Where are the different suppliers and warehouses of all the transport stages located?*
2.4 *What does the supply chain of building materials look like, and where does the chief of the construction site experience the problems?*
2.5 *What other factors need to be calculated in the current supply chain to be able to compare it to the solution scenarios?*

Sub questions 2.1 to 2.3 are answered by performing interviews with the supply chain manager, logistics manager, and the chief at the construction site. These questions are used to get the necessary information for the following sub questions. Sub question 2.4 uses the information from sub questions 2.1 to 2.3 to get a complete visualisation of building materials' supply chain, with their physical and informational flows. A physical flow/chain is the system of stakeholders and activities moving physical materials from a seller to a buyer. An informational flow/chain acquires, processes and distributes information in a way comparable to physical materials in a supply chain. The interview with the chief of the construction site also provides the problem areas present in the supply chain. Sub question 2.5 is answered by having a work session with the logistics manager to gather information on the necessary factors and values.

Stage 3: Formulating solution scenarios
Formulating the solutions is done by finding opportunities for improvements in the current situation. The current delivery chains are analysed, and the impacts on the reliability of the delivery of building materials are considered. Then, multiple reclassifications of the delivery chains are constructed to improve the current situation, with the help of the gathered knowledge in Stage 1.

Research question:

3. *How can the reliability of the delivery of building materials be improved?*

Sub questions:

3.1 What aspects of the delivery chains have the biggest impact on the reliability of the delivery of building materials?
3.2 What are the possible adjustments to the supply chain?
3.3 How can the delivery chains be reclassified?

Sub questions 3.1 to 3.3 are answered by performing desk research, with the information and knowledge received from Stages 1 and 2.

Stage 4: Selecting a solution scenario
This stage executes the selection of a solution. It performs the Multiple-Criteria Decision Analysis (MCDA) from Stage 1 and transcribes the results.

Research question:

4. *Which solution scenario suits the company best?*

Sub questions:

4.1 What are the attributes?
4.2 What are the results of the alternatives on the attributes?
4.3 What are the weights of the attributes?
4.4 What are the values of the attributes of the alternatives?
4.5 What is the result of the multiple-criteria decision analysis?

Sub questions 4.1 to 4.5 are answered by interviewing the logistics manager and performing desk research.

1.3.3 Data collection methods

There exist unstructured, semi structured, and structured interviews. Cooper and Schindler (2014) state that an unstructured interview has no specific questions or order of topics to be discussed, with each interview customised to each participant; it generally starts with a participant narrative. A semi structured interview generally starts with a few specific questions and then follows the individual's tangents of thought with interviewer probes. A structured interview often uses a detailed interview guide like a questionnaire to guide the question order and the specific way the questions are asked, but the questions generally remain open-ended. When using structured interviews, the probability that important information is missed out on is high. Therefore, this research uses mainly unstructured and semi structured interviews, with the choice of one of the options depending on the information that needs to be acquired. When the decision maker of the MCDA determines the weights and values of attributes, the research makes use of a structured interview.

Stage 1 uses existing literature to collect information that answers Research Questions 1.1 and 1.2. Databases from the internet are used to get to the existing literature. There exist many databases to find articles. This research is performed scientifically and scholarly, using unbiased and peer-reviewed articles. The appropriate databases that go hand in hand with these values are Web of Science and Scopus. Snowballing (following trails of references) is performed using the reference lists and the related documents list.

Stage 2 collects data via interviews. Different stakeholders (supply chain manager, logistics manager, and different employees of suppliers) are interviewed to fully understand the entire information and physical flow of the building material's transport process. This falls in line with qualitative data gathering.

Stage 3 also uses interviews and existing literature to understand what can be adjusted in the process. Stage 1 already gathered the knowledge needed in this stage. Interviews with the chief of the construction site at the Goeman Borgesiuslaan and the warehouse manager at the main supplier (LCW) are the most important. This stage uses qualitative data.

Stage 4 uses interviews, data, and literature to find the best possible solution for the company. Information about the other criteria involved is gathered through interviews with the company's management. The existing literature gives information on how to perform a multiple-criteria decision analysis, and the company's existing documents give insight into the values needed for the analysis. This is a combination of qualitative and quantitative data gathering.

1.3.4 Data analysis methods

The interviews collect qualitative and quantitative data that contains information that must be analysed to generate logical conclusions. The interviewed people are experienced in the department that exercises actions concerning the delivery of building materials to the construction site. The research collects the information from the interviewees in Excel and Word documents. Then, software programs like Photoshop and Lucidchart visualise the supply chain of the current situation and the solution scenarios. Excel performs the calculations on gathered data from the interviews to be able to draw conclusions.

1.3.5 Deliverables

The deliverables of this bachelor thesis are the following:

- Literature background that delivers knowledge on the core problem
- Visualisation of the current supply chain/delivery chains
- Reclassifications of the supply chain/delivery chains
- Multiple-criteria decision analysis on the solutions

2. Literature Background

This section contains the literature background concerning the research topics. It solves the knowledge gap by diving into existing literature and performing a Systematic Literature Review (SLR), which Appendix A presents. This chapter answers Research Questions 1.1 and 1.2:

1.1 What types of supplier relationships affect the reliability of deliveries in transportation processes?
1.2 What multiple-criteria decision models exist, and which multiple-criteria decision analysis should be used?

The SLR divides Research Question 1.1 into different concepts to get to the answer. The first three sections elaborate on the concepts, which increases our understanding of the subject. Then, Section 2.4 concludes the SLR and answers Research question 1.1 with the gained knowledge. Section 2.5 answers Research Question 1.2 by diving into the existing literature.

2.1 Supplier relationships

Supplier relationships are the connections and agreements that buying firms have with the supplying firms that deliver their needed resources. Many different buyer-supplier relationships exist in many different sectors and industries.

According to Bowersox (1990), logistical alliances lower distribution and storage operating costs. He states: “Today’s emphasis on leaner organization makes managers more likely to turn to external specialists to solve problems or perform tasks outside the organization’s sphere of expertise. The objective of competing more effectively—through greater asset utilization, higher leverage, and faster responsiveness—is a prime stimulant toward logistics collaboration.” This indicates that buyer-supplier relations were already becoming popular long ago.

When one thinks of a buyer-supplier relationship, one often thinks of the simple relationship between two parties. In today’s environment, this is not the case. For example, it is better to visualise the relationships as triads to indicate the existence of multiple suppliers for one buyer. Four different triads were found in a cross-case analysis of a study from 2021, indicating the interactions a buyer would have with multiple suppliers. Figure 2 shows the four categories of the possible triads from the cross-case analysis (Patrucco, Harland, Luzzini, & Frattini, 2021).

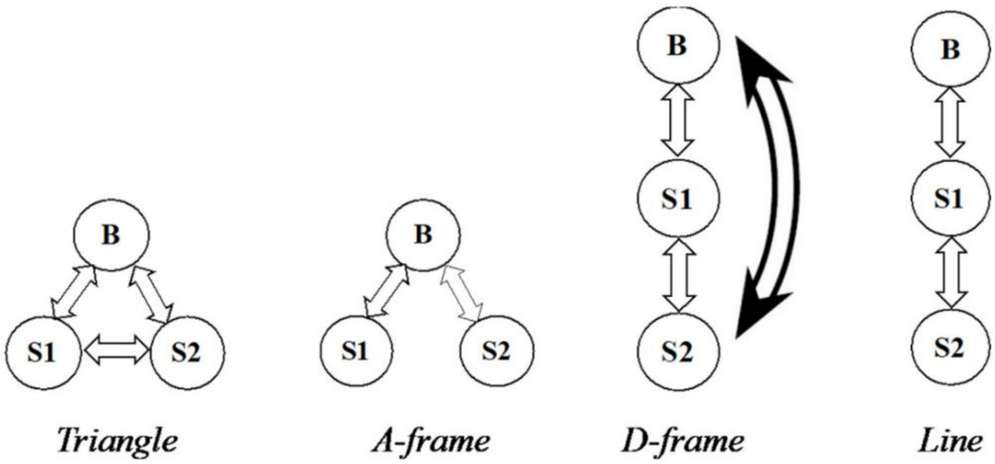

Figure 2: Types of supplier innovation triads (Patrucco et al., 2021)

In the Triangle triad, the buying firm has deep and direct relationships with each supplier and encourages connections between the two suppliers, thus forming a formal supplier-supplier relationship (Patrucco et al., 2021). In Triangle triads, the key to project success requires intense knowledge exchange with and between suppliers of different components, and implementing this can be a time-intensive task (Patrucco et al., 2021).

In the A-frame triad, the buying organization has relationships with each direct supplier, but it deliberately prevents those suppliers from connecting to form a supplier-supplier relationship. Compared to the Triangle triad, the A-frame is preferred due to the reduction of spillover risks, or regulations, or simply the need to limit project interfaces, providing suppliers could work effectively and independently of each other (Patrucco et al., 2021). Moreover, the A-frame triad aligns with cost performance expectations (Patrucco et al., 2021).

In the D-frame triad, the buyer has a relationship with the direct supplier and chooses to reach around that supplier to form a direct relationship with the second-tier supplier. These companies decide to adopt this governance structure because the design and development of the product (and component) innovation is highly complex, so there is a need to avoid misalignment between actors positioned at different tiers of the supply chain (Patrucco et al., 2021). In D-frame triads, knowledge exchange with and between first- and second-tier suppliers is critical due to the impact of both suppliers' design and development decisions on the buyers' activities, and cost performance seems to rely on the project management abilities of the buyer (Patrucco et al., 2021).

In the Line triad, the buying organizations do not establish any formal relationship with the sub-suppliers in the second tier due to the low impact of design and development activities of indirect suppliers on the buyers' project planning and execution. Moreover, the buyer empowers the first-tier supplier to manage the relationship with the indirect supplier, thereby saving coordination and organizational costs (Patrucco et al., 2021).

A good buyer-supplier relationship depends on the ability of the supplier to deliver consistent and complete orders at the time and location requested from the buyer (Bowersox, 1990). Moreover, it can be concluded that the larger an enterprise grows, the more it engages in many supply chains (Pech, Vaněček, & Pražáková, 2021). This leads to the use of Third Party Logistics (TPL) providers. Alfredsson and Hertz (2003) define a Third Party Logistics provider as "an external provider who manages, controls, and delivers logistics activities on behalf of a shipper". Such a provider always performs the execution of transport and warehousing. Figure 3 shows the categorization of TPL providers depending on their customer adaptability and problem solving abilities (Hertz & Alfredsson, 2003).

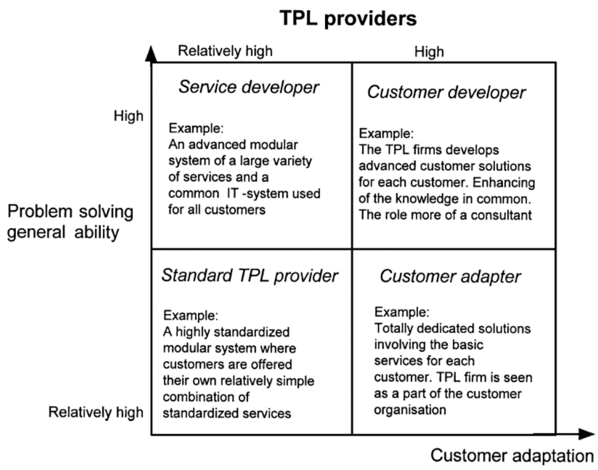

Figure 3: TPL firms classified according to abilities of general problem solving and customer adaptation
(Hertz & Alfredsson, 2003)

2.2 Types of transport in a construction company

The following three configurations exist concerning the transportation process of building materials to construction sites: (Dubois, Hulthén, & Sundquist, 2018)

- The de-centralised coordinated configuration
- The on-site coordinated configuration
- The supply network coordinated configuration

Figures 4, 5, and 6 show the visualization of these configurations, respectively, from left to right (Dubois et al., 2018).

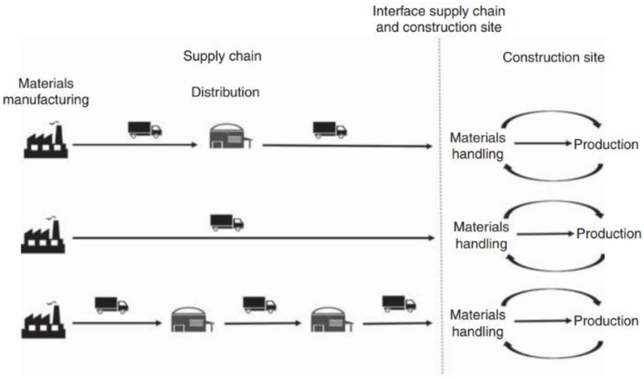

Figure 4: The de-centralised coordinated configuration (Dubois et al., 2018)

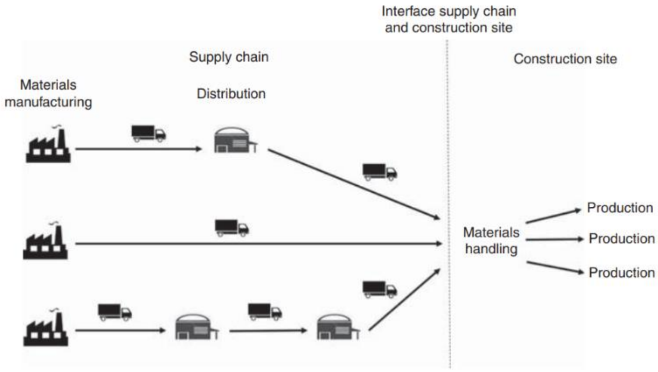

Figure 5: The on-site coordinated configuration (Dubois et al., 2018)

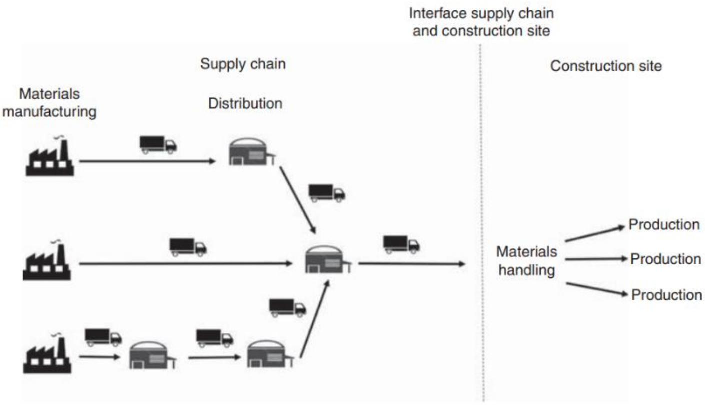

Figure 6: The supply network coordinated configuration (Dubois et al., 2018)

The study of Dubois, Hulthén, and Sundquist (2018) explains the configurations as follows:

The *de-centralised coordinated configuration* features contractors and subcontractors coordinating their own materials supply- and site logistics activities. Each contractor is responsible for its respective site logistics activities, making construction workers alter between materials handling and production activities. In the supply chain, manufacturers and distributors plan and carry out supply logistics activities without considering the consequences for materials handling on site. … The interface between the supply chains and the site is not organised with regard to joint planning and each delivery is handled with minimal coordination in relation to other deliveries. (Dubois et al., 2018)

The *on-site coordinated configuration* involves joint coordination of on-site logistics activities and the interface of the site and the supply chains. Thus, the transport activities interfacing with the site is jointly coordinated while the up-stream supply chains are not subject to joint coordination. Coordination of transport activities to the site regarding the delivery time and the amount of goods is crucial to ensure efficient on-site logistics. This configuration thus enables just-in-time solutions. In our illustration of this approach, the configuration involves a logistics co-ordinator, commonly a logistics actor specialising in on-site logistics activities. … Resource and materials flow analyses are often carried out before the project start, and the logistics specialist takes complete responsibility for the on-site logistics during the entire project. Consequently, construction workers are not involved in materials handling activities but can focus on production activities. (Dubois et al., 2018)

The *supply network coordinated configuration*, as in the on-site coordinated configuration, involves a logistics specialist. However, in this case, the scope of joint coordination extends beyond the site to include supply chains. This type of configuration reduces the number of transports arriving at construction sites which is a priority in dense urban areas. Material supplies are directed to a consolidation facility outside the area for storage. Deliveries to the construction site from the consolidation facility are carried out on demand. When the material is delivered to the construction site it is transferred to the appointed installation area. … A consequence of the supply network coordinated configuration is that the number of transports arriving at the site can be reduced. … Since this configuration relies on coordination across supply chains, it is challenging as it clashes with the strong project focus in the construction industry. Accordingly, not all actors can or want to comply with this approach due to their own practices of coordinating transport and logistics activities. (Dubois et al., 2018)

The efficiency of the construction site differs between the configurations. The study showed that the on-site coordinated and supply network coordinated configurations had a higher efficiency since the construction workers could focus on production activities, and there is improved utilisation of resources (Dubois et al., 2018). Note that the de-centralised coordinated configuration is less efficient, but also has the lowest coordination costs compared to the others (Dubois et al., 2018).

2.3 Effects on the reliability of the deliveries in transportation processes

In the previous section, efficiency was used to evaluate different configurations of transportation processes. Often in existing literature, the reliability of the delivery of supplies in a transportation process is part of the total efficiency of the process. More reliable deliveries from transportation companies mean higher efficiency.

Many factors influence the reliability of the deliveries in transportation processes. First, better information system compatibility is a vital development target for the communication systems between transportation companies and transport customers because it enhances deviation management in the supply chain and enables proactive resource allocation planning in transport companies (Rantala, 2009).

Moreover, expanding the network horizon of different stakeholders positively impacts transport efficiency (Eriksson, Hulthén, & Pedersen, 2020). For example, different issues are perceived as relevant and deserve the focus of the different actors. Some actors prioritise construction and construction site efficiency, while others prioritise warehouse efficiency, service levels, and effectiveness, and maybe another focuses on transport efficiency. These actors can collaborate to achieve better performances if they expand their horizons.

Furthermore, the sharing of information and communication by the two parties is important because it influences the reliability of the delivery of supplies regarding the wide variety of possible service delays and unavoidable interruptions (Gentry, 1993). The sharing of information is also one of the essential elements in supplier partnerships in comparison to information that is proprietary in traditional buyer-supplier relationships (Stuart, 1993).

Some studies prove other approaches to be helpful, such as the reconfiguration of activities, the recombination of resources, and the repositioning of actors inside the process (Sundquist, Gadde, & Hulthén, 2018). This means that the reliability of the delivery of building materials can be improved by reclassifying these aspects, or in other words, the delivery chains.

Additionally, it is essential to question the supplier's commitment in a buyer-supplier relationship. The resources must be delivered at the right time and in the right quality and quantity to fully satisfy the buying firm. It has been confirmed that business uncertainty perceived by suppliers in predicting the demand and future exchange with the buyer firm is detrimental to their commitment to the buyer-supplier relationship (Wong, Lai, Venus Lun, & Cheng, 2012). Once more, it turns out that improving the transparency of information related to the sales volume, demand requirements, order size, and order cycle can be helpful for the reduction of business uncertainty encountered by suppliers and entice them to the buyer-supplier relationship (Wong et al., 2012).

Lastly, choosing between just-in-time and just-in-case delivery strategies is extremely impactful when dealing with unreliable suppliers. The concept of "just-in-time" refers to having inventory arrive precisely when people need it, reducing the likelihood of overordering and left-over supplies (Jenkins, n.d.). Its disadvantage includes the inability to be ready for unexpected orders and the requirement for supplier stability since just-in-time inventory strategies depend on supplier responsiveness and consistency (Jenkins, n.d.). The concept of "just-in-case" refers to companies purchasing supplies proactively, within defined parameters, to prioritize preparedness over the cost and cash flow implications of holding stock (Jenkins, n.d.). Using just-in-case strategies is critical when demand is unpredictable and suppliers are unreliable (Jenkins, n.d.).

2.4 Conclusion of the SLR

The literature concludes that many types of buyer-supplier relationships positively affect multiple aspects of a business. Positive effects are the reduction of costs or the assistance in transportation and logistical services for large enterprises engaging in many supply chains simultaneously. Supplier relationships can be divided into triads, which have benefits and disadvantages that must be considered when choosing a delivery chain. TPL firms are often present in a supply chain and can be judged on their problem-solving abilities and customer adaptations. The most significant effects on the reliability of the deliveries in transportation processes regarding supplier-buyer relationships come from the following aspects:

- the coordinated configuration of the transport process that is used
- the transparency and communicative abilities of all the actors
- the configuration of activities, combination of resources, and positions of actors (just-in-time vs. just-in-case strategies)

The *coordinated configuration of the transport process* has been observed to impact the efficiency of the construction site. Different configurations lead to different ways of handling the delivered materials. It has been found that construction sites located in dense urban areas could best use the supply network coordinated configuration, which makes use of a closely located distribution hub. This is relevant for this research since the projects in Groningen of Dura Vermeer are also located in a dense urban area. The construction site has little room for the placement of building materials, and often it is not easily accessible for delivery trucks. The supply network coordinated configuration reduces the number of trucks making deliveries at the construction site, making it easier to receive deliveries on demand. Thus, an improvement could be made to the reliability of deliveries of building materials to the construction sites with the use of this configuration.

High *transparency and communicative abilities of all the actors* also positively impact the delivery's reliability. It reduces business uncertainty, enhances deviation management, and enables proactive resource allocation planning in transport companies. The logistics manager of Dura Vermeer observed that some parties in the delivery chains lack transparency and communicative abilities. An improvement in these abilities, or a removal of inadequate companies, leads to an improvement in reliability.

In a broader perspective, the *configuration of activities, combinations of resources, and positions of actors (just-in-time vs. just-in-case strategies)* could lead to improvements in the reliability. This is relevant for this research since it states that reclassifications could benefit the projects in Groningen, with a thorough assessment of activities, resources, locations. One example of making such reclassifications is changing the delivery strategy from just-in-time to just-in-case or combining both. The just-in-case strategies prepare companies for unexpected changes in the delivery schedule and unreliable deliveries from the suppliers.

All this information answers Research Question 1.1 stated at the beginning of this chapter since it provides knowledge on buyer-supplier relationships and what aspects affect the reliability of the deliveries in the transportation process.

2.5 Multiple-criteria decision making

This section explains the selection of the multiple-criteria decision method and elaborates on the needed knowledge to perform a well organised and accurate analysis. Section 2.5.1 describes which method is selected and why, and Sections 2.5.2 to 2.5.4 provide the missing knowledge to perform the chosen method.

2.5.1 Method selection

The concept of multiple criteria decision making (MCDM) refers to the act of making judgments when there are multiple, usually conflicting criteria to consider. We face MCDM problems every day. MCDM intends to support decision makers facing such problems. MCDM consists of constructing a global preference relation for a set of alternatives evaluated using various criteria and selecting the best actions from a set of choices, each of which is assessed against multiple and often different criteria (Patel, Vashi, & Bhatt, 2017).

Over the past few decades, many MCDM methods have been developed and implemented. Table 1 (next page) shows the results of a study performed in 2013. The table shows the advantages, disadvantages, and areas of application of multiple widely known MCDM methods. Methods like these can be extremely successful in their applications. Still, they are only the most effective if the right method is selected and executed correctly (Velasquez & Hester, 2013). Table 1 helps with selecting the right MCDM method for this research.

The area of application of this research is transport and logistics, and the methods in Table 1 that are best applied in this area are SMART, ELECTRE, PROMETHEE, and TOPSIS. The SMART method is also applied in the construction sector, and Dura Vermeer operates in this sector. The research needs a simple and clear MCDM method, because the researcher and chosen decision maker need to be able to perform the method adequatly. An assessment of the MCDM methods in Table 1 results in the decision to use the SMART method. The process and outcome of ELECTRE are too difficult to explain in layman's terms to the company. PROMETHEE fails to have a clear guide for assessing each criterion's weights during the MCDM method's execution. TOPSIS can be utilized quickly to review other methods, but the simplicity of the SMART method appears to make it the most popular (Velasquez & Hester, 2013). Moreover, the SMART method requires less effort by the decision makers, which is beneficial for this research since the company wants a fast and easy way to assess the weights and values of attributes. Note that all these methods can be considered as valuable, but the SMART method has the most advantages and association with the researched area of this thesis.

Table 1: Summary of MCDM Methods (Velasquez & Hester, 2013)

Method	Advantages	Disadvantages	Areas of Application
Multi-Attribute Utility Theory (MAUT)	Takes uncertainty into account; can incorporate preferences.	Needs a lot of input; preferences need to be precise.	Economics, finance, actuarial, water management, energy management, agriculture
Analytic Hierarchy Process (AHP)	Easy to use; scalable; hierarchy structure can easily adjust to fit many sized problems; not data intensive.	Problems due to interdependence between criteria and alternatives; can lead to inconsistencies between judgment and ranking criteria; rank reversal.	Performance-type problems, resource management, corporate policy and strategy, public policy, political strategy, and planning.
Case-Based Reasoning (CBR)	Not data intensive; requires little maintenance; can improve over time; can adapt to changes in environment.	Sensitive to inconsistent data; requires many cases.	Businesses, vehicle insurance, medicine, and engineering design.
Data Envelopment Analysis (DEA)	Capable of handling multiple inputs and outputs; efficiency can be analyzed and quantified.	Does not deal with imprecise data; assumes that all input and output are exactly known.	Economics, medicine, utilities, road safety, agriculture, retail, and business problems.
Fuzzy Set Theory	Allows for imprecise input; takes into account insufficient information.	Difficult to develop; can require numerous simulations before use.	Engineering, economics, environmental, social, medical, and management.
Simple Multi-Attribute Rating Technique (SMART)	Simple; allows for any type of weight assignment technique; less effort by decision makers.	Procedure may not be convenient considering the framework.	Environmental, construction, transportation and logistics, military, manufacturing and assembly problems.
Goal Programming (GP)	Capable of handling large-scale problems; can produce infinite alternatives.	It's ability to weight coefficients; typically needs to be used in combination with other MCDM methods to weight coefficients.	Production planning, scheduling, health care, portfolio selection, distribution systems, energy planning, water reservoir management, scheduling, wildlife management.
ELECTRE	Takes uncertainty and vagueness into account.	Its process and outcome can be difficult to explain in layman's terms; outranking causes the strengths and weaknesses of the alternatives to not be directly identified.	Energy, economics, environmental, water management, and transportation problems.
PROMETHEE	Easy to use; does not require assumption that criteria are proportionate.	Does not provide a clear method by which to assign weights.	Environmental, hydrology, water management, business and finance, chemistry, logistics and transportation, manufacturing and assembly, energy, agriculture.
Simple Additive Weighting (SAW)	Ability to compensate among criteria; intuitive to decision makers; calculation is simple does not require complex computer programs.	Estimates revealed do not always reflect the real situation; result obtained may not be logical.	Water management, business, and financial management.
Technique for Order Preferences by Similarity to Ideal Solutions (TOPSIS)	Has a simple process; easy to use and program; the number of steps remains the same regardless of the number of attributes.	Its use of Euclidean Distance does not consider the correlation of attributes; difficult to weight and keep consistency of judgment.	Supply chain management and logistics, engineering, manufacturing systems, business and marketing, environmental, human resources, and water resources management.

2.5.2 Value tree

According to Goodwin and Wright (2014), the first two stages of the SMART method are to identify the decision maker and the alternatives. The decision maker is the person who is responsible for making strategically important decisions when presented with different courses of action. These different courses of action are the possible alternatives. The next objective is to identify the attributes the decision maker considers relevant to his problem. An attribute is used to measure the performance of the alternatives in relation to the decision maker's objectives. The intent is to construct a set of attributes that mostly can be assessed on a numeric scale. Some attributes, when stated vaguely, need to be broken down into more specific attributes before measurements can be performed. Therefore, a value tree is a helpful tool for identifying the set of attributes.

A value tree is a visual representation of the attributes that the decision maker values as important. At the top, the overall value of an alternative is broken down into the general concerns of the decision maker, and there are no limits or requirements on the number of these concerns. These concerns can then be decomposed to a level on which they can be assessed. The decomposed levels are the attributes of the alternatives. If an attribute is still too difficult to assess or stated too vaguely, it can be decomposed further into better defined attributes. The visualisation of this process is the value tree of the alternatives.

A value tree needs to be accurate and a good representation of the decision maker's concerns. Keeney and Raiffa (1976) suggest the following five criteria to assess a value tree:

- Completeness
- Operationality
- Decomposability
- Absence of redundancy
- Minimum size

All concerns of the decision maker need to be included to make a value tree *complete*. All the lowest level attributes need to be specific enough to be able to evaluate and compare the alternatives, which makes the value tree *operational*. The attributes need to be independent, meaning one can be assessed without considering another attribute in the value tree. When attributes can be judged independently, the value tree is *decomposed*. The attributes should not duplicate each other, meaning if they represent the same thing, their values are counted twice, which results in objectives having undue weights. Removing these attributes that would not affect the final decision makes *redundancy absent* in a value tree. Lastly, attributes that do not distinguish themselves between the options should be removed to *minimize the size* of the value tree, to get a meaningful analysis of the alternatives. These five criteria should be considered when establishing an adequate value tree.

2.5.3 Value functions and direct rating

According to Goodwin and Wright (2014), the next stage of the SMART method assigns a value to each attribute to measure the performance of the alternatives on that attribute. Value functions are a method to assign the correct values to the attributes between the alternatives. An increase between two alternatives can be more attractive when comparing it to two other alternatives that have the same increase. For example, when considering the purchase of a new car, an increase from 50 horsepower to 250 horsepower could be more attractive than an increase from 750 horsepower to 950 horsepower. Value functions help to assign the correct outcomes of the attributes to make the evaluation of the alternatives well grounded. One way to construct a value function is the method of bisection, which is widely applied (Goodwin & Wright, 2014).

Bisection requires the decision maker first to identify the halfway point between the result of the least-preferred alternative and the result of the most-preferred alternative of one attribute. This halfway point does not need to be one of the results of one of the alternatives. The increase from the result of the least-preferred alternative to the halfway point equals in value to the increase from the halfway point to the result of the most-preferred alternative. When the midpoint value is identified, the same method is applied to identify the quarter points. Again, the increase from the least-preferred alternative to the quarter point equals the increase from the quarter point to the halfway point. There is another quarter point that shows the increase from the halfway point to the second quarter point equal to the increase from the second quarter point to the most-preferred alternative. Bisection should be applied to all attributes that have different results from the alternatives. Value functions show how the different alternatives value on an attribute depending on what result they have.

In cases where the attributes cannot be represented by quantifiable variables, direct rating is a method that helps assign values to the performances of the alternatives. Direct rating ranks the alternatives on the performance on the unquantifiable attributes. The alternative with the top rank gets a value of 100, and the last rank gets a value of 0. Then the decision maker is asked to rate the other alternatives in such a way that the difference between the values represents his/her strength of preference for one alternative over another. Improvements between alternatives can only compare to improvements between other alternatives. Direct rating compares intervals (improvements) between the alternatives because the allocation of a zero to represent the worst performance is arbitrary. For example, it cannot be said that water of 80 degrees Celsius is twice the temperature of water of 40 degrees Celsius. If it were measured in Fahrenheit this would not be the case. However, it can be said that an increase in temperature from 40 degrees Celsius to 80 degrees Celsius is twice as much as the increase from 40 degrees Celsius to 60 degrees Celsius. This method helps confirming the established values of the alternatives on attributes that are not quantified.

2.5.4 Swing weights

The attributes need weights to be able to evaluate the different alternatives. Some attributes are more important than others and therefore need a higher weight when calculating the score of the alternatives. When determining the weights of the attributes, it is important to consider the range between the least- and most-preferred options. The use of swing weights helps the decision maker assess the attributes, examining the ranges of the options.

The swing weights are derived by asking the decision maker to compare a change (or swing) from the least-preferred to the most-preferred value on one attribute to a similar change in another attribute (Goodwin & Wright, 2014). First, the decision maker imagines a hypothetical alternative with the attributes at their least-preferred levels. Then, the decision maker is asked which attribute he chooses if it could be moved to the best level. After that change is made, the decision maker decides again what attribute is next, which the decision maker would like to move to its best level. This continues until all attributes are ranked. The first attribute that was chosen is given the first rank with a weight of 100. The decision maker then decides on the swing from the least-preferred value to the most-preferred value of the following attribute, comparing to the least-preferred value to the most-preferred value of the first attribute. For example, the swing of the second attribute could be 80% as important as the swing of the first attribute. This method repeats for all the other attributes, and the created weights are normalized to get to the final result of the swing weights.

2.5.5 Calculation final scores of alternatives

Each alternative gets values of each attribute, and each attribute gets a weight. The next step is to calculate the final score of each alternative to compare them to each other. This computation uses the following equation:

$$\mathrm{V(a)} = \sum_i w_i * v_i(a)$$

where V(a) is the final score of alternative a, w_i is the normalized weight of attribute *i*, and $v_i(a)$ is the value for alternative *a* on attribute *i*.

If the decision maker chooses to assign values to all attributes, the provisional decision is to choose the alternative with the highest final score. However, often costs are not given a value since it is too difficult for the decision maker to compare improvements in costs against improvements in the other attributes. In that case, trade-offs between the final scores against the costs should be analyzed when making a provision decision.

3. Current situation

This chapter describes the current situation with the help of visual figures. It gives a clear answer to Research Question 2:

What do the delivery chains of the five most important building materials from the suppliers to the project at the Goeman Borgesiuslaan in Groningen look like?

Section 3.1 provides the information on companies, their building materials, and locations. Section 3.2 gives the visualisation of the supply chain and provides information on the problems that are present. Section 3.3 discusses the factors needed to compare the current situation with the solution scenarios. In closing, Section 3.4 concludes Chapter 3.

3.1 Companies, materials, and locations

The chief of the construction site is responsible for all activities during the execution of a construction project. A thorough delivery plan is prepared, but during the execution of a project, the chief of the construction site can make minor adjustments if the project's process varies. This entails that the chief of the construction site is closely related to the delivery of the building materials and has a lot of knowledge of the visualisation of the delivery chains. Hence, an interview was conducted with the chief of the construction site at the Goeman Borgesiuslaan.

From the interview, it became clear that the delivery processes have multiple companies involved. Dura Vermeer has many contracts with different companies, and these agreements impact the choice of manufacturing companies. A list was collected with the involved companies, their products, and locations of the delivery processes. The chief of the construction site stated that the construction project at the Goeman Borgesiuslaan in Groningen is a good example that can represent the other projects in the city. Table 2 shows the information on all companies and their products and locations used in the renovation project. The real identity of the suppliers is kept secret to reflect on them without impacting their reputation.

Table 2: List of companies, materials, and locations

Company	Role	Product	City
Company A	Manufacturer	Doors	Groesbeek
Company B	Subcontractor	Wholesaler	Doetinchem
Company C	Subcontractor	Plates and floors	Assen
Company D	Manufacturer	Kitchens	Dinxperlo
Company E	Manufacturer	Tiles	Brunssum
Company F	Subcontractor	Third Party Logistics	Utrecht
			Groningen
LCW	Distribution Hub	Third Party Logistics	Groningen
Dura Vermeer	Construction Site	-	Groningen

Table 2 fails to show the distances of the locations of stakeholders relative to each other on a map. Figure 7 shows the locations of the stakeholders on a simple map of the Netherlands with a focused view of Groningen. The figure shows how some stakeholders are closely located to the construction site and that some suppliers must travel long distances to deliver.

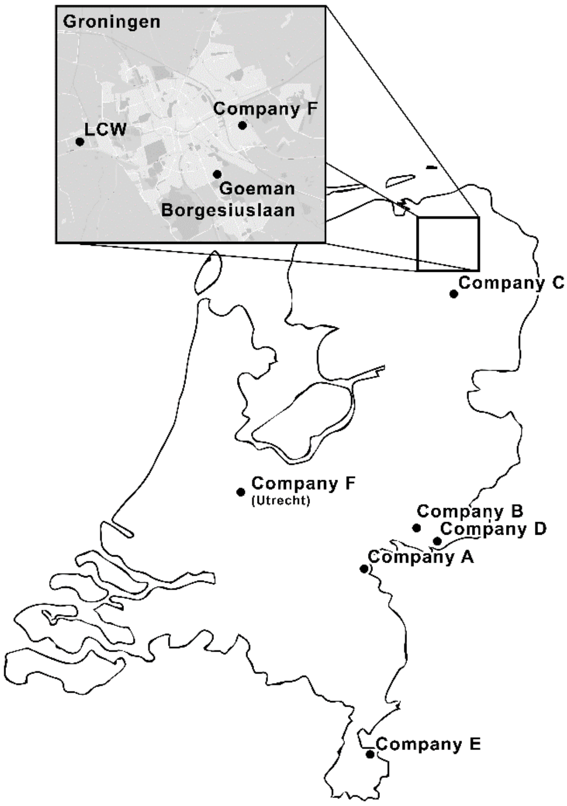

Figure 7: Locations of stakeholders

3.2 Supply chain visualisation

The visualisation of the supply chain involves identifying the physical connections between stakeholders and with whom they exchange information. A physical flow shows the system of stakeholders and activities involved in moving physical materials from a seller to a buyer. This is, in the case of this research, the movement of building materials from the suppliers to the construction site. An informational flow or link shows the acquiring, processing, and distributing of information in a way comparable to physical materials in a supply chain. In the case of this research, this is comparable to the negotiations on contracts and orders between stakeholders or the agreements made on times, locations, and order sizes. These information flows are essential to understand what stakeholders of the supply chain exchange information, or which stakeholders do not. A delivery chain is the pathway through which one type of building material follows the supply chain. Some delivery chains can merge if combined in the transport operation from and to certain stages inside the supply chain.

From the interview with the chief of the construction site at Goeman Borgesiuslaan in Groningen, a general visualisation of the supply chain was collected. The distances and information flows make the visualisation of the supply chain complete. Figure 8 (next page) shows the final visualisation of the total supply chain of the selected suppliers in Section 3.1.

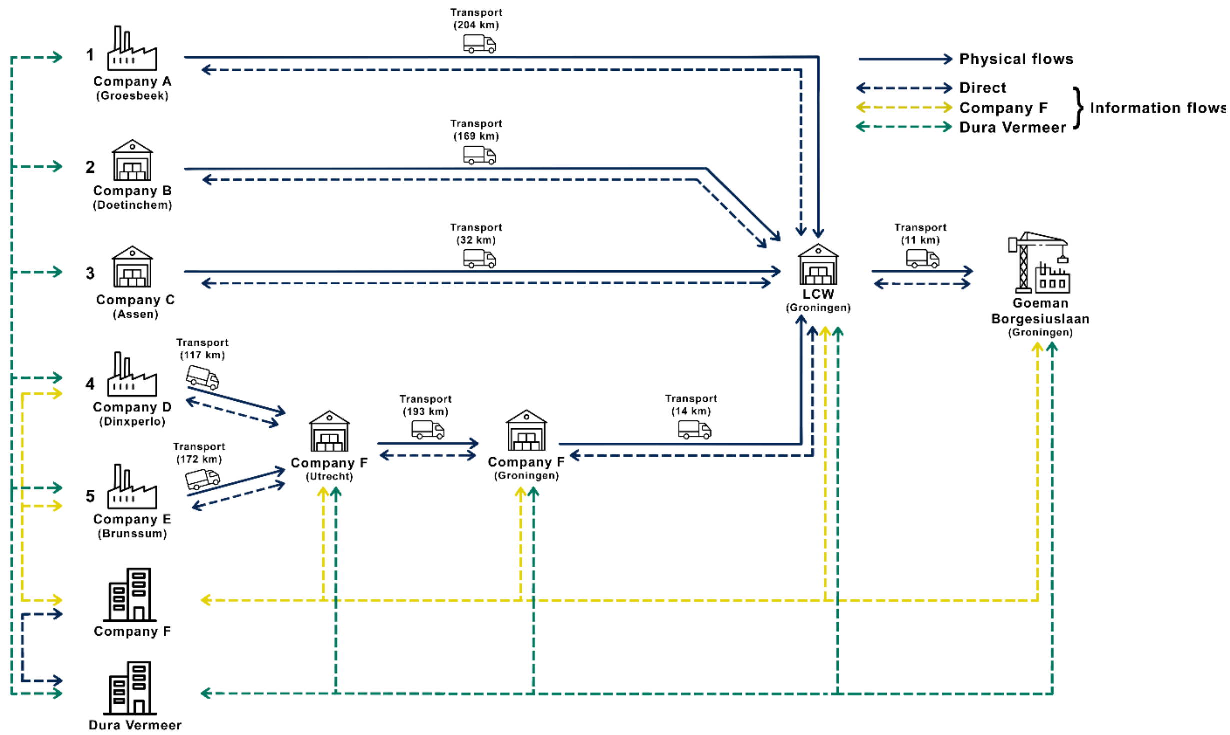

Figure 8: Supply Chain visualization

The numbers next to the manufacturers on the left describe where each delivery chain starts. The solid arrows show the building materials' physical routes until they are delivered to the construction site. Table 2 helps with the collection of the distances between stakeholders. Above the schematic trucks, the distances of the transport are shown. The dotted arrows show the informational flows between the stakeholders. The dark blue coloured dotted arrows show links between two parties that directly communicate with each other. The yellow and green dotted arrows show the exchange of information from Dura Vermeer (green) and Company F (yellow). Dura Vermeer is linked to all stakeholders, while Company F is only connected to relevant stakeholders inside their chain.

After the supply chain was visualized, information on the problems in the supply chain was collected via interviews with the chief of the construction site, supply chain manager, and logistics manager. Figure 9 (next page) shows the problem areas inside the supply chain.

In problem area 1, there is a lack of communication and transparency on inventories at the intermediate stages inside delivery chains 4 and 5. The lack of sharing of information and communication by the parties influences the reliability of the delivery of supplies regarding the wide variety of possible service delays and unavoidable interruptions (Gentry, 1993). Moreover, because of the large number of parties involved in these delivery chains, there is a higher chance of disruptions when delivering building materials. The commitment of the company Company F is questioned since they fail to deliver the building materials at the agreed upon moments. The lack of information on inventories and order cycles leads to increased business uncertainty (Wong et al., 2012). Furthermore, delivery chains 4 and 5 use the D-frame triad, where the buyer has a relationship with the direct supplier and chooses to reach around that supplier to form a direct relationship with the second-tier supplier. This governance structure is often used because the project is highly complex, so there is a need to avoid misalignment between actors positioned at different tiers of the supply chain.

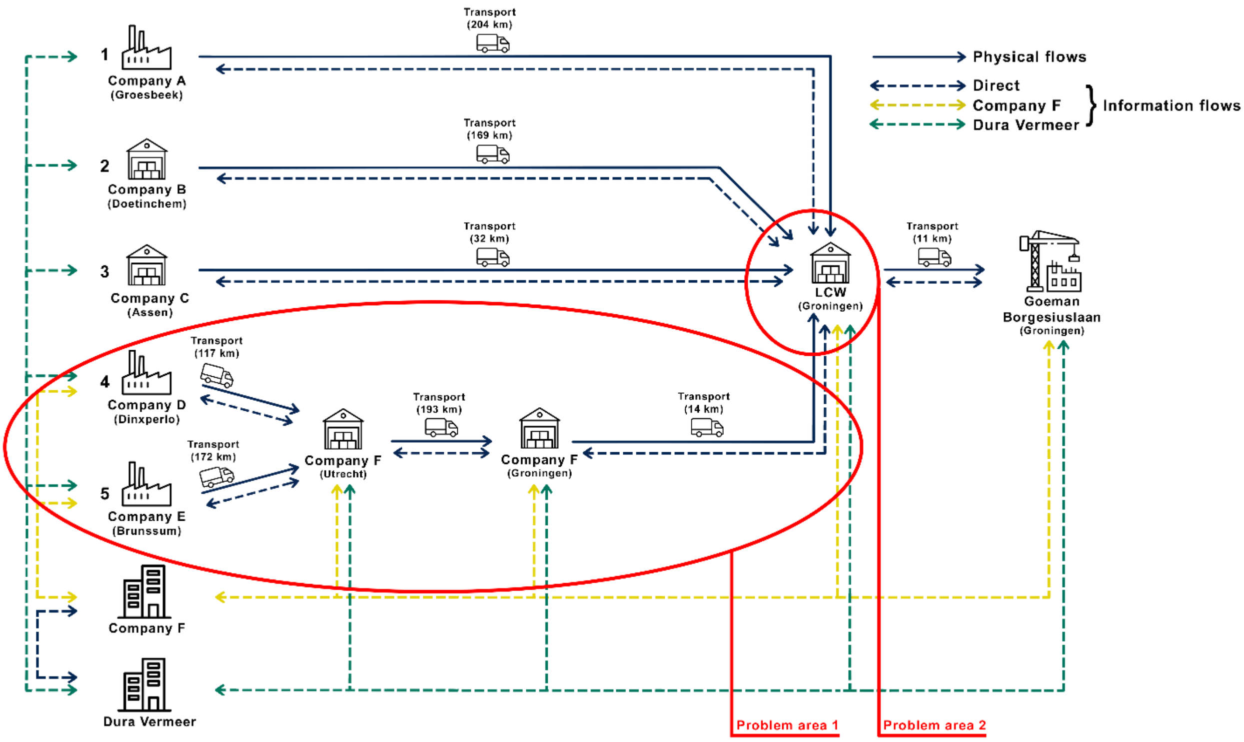

Figure 9: problem areas inside the supply chain

Knowledge exchange with and between first- and second-tier suppliers is critical due to the impact both suppliers' have on the project (Patrucco et al., 2021). However, the problem of unreliability is partially caused by the misalignment between Company D, Company E, Company F, LCW, and Dura Vermeer.

In problem area 2, the distribution hub LCW is highlighted. The use of LCW reduces the number of transports arriving at construction sites which is a priority in dense urban areas. This configuration, the supply network coordinated configuration, has been proven more efficient and reliable than the de-centralised coordinated configuration and the on-site coordinated configuration (Dubois et al., 2018). The problem that is experienced at LCW is the lack of inventory of building materials. Each week the materials are delivered to LCW, and this frequency of the deliveries impacts the reliability. Renovation projects need just-in-time deliveries at their construction site because there is no room to store the building materials. "Just-in-time" means having inventory arrive precisely when needed. Disadvantages of just-in-time deliveries are the inability to meet unexpected demand and the high need for supplier stability because a just-in-time inventory strategy's success relies on suppliers' timeliness and consistency (Jenkins, n.d.).

Both the problem areas contain a company that provides Third Party Logistics, namely Company F and LCW. From the interview with the chief of the construction site at Goeman Borgesiuslaan, judgements were made on these TPL services. There is a natural tendency for TPL companies to increase their problem-solving and customer adaptation abilities (Hertz & Alfredsson, 2003). High values of these abilities would make it possible for Dura Vermeer to change their delivery chains. From experiences with Company F and LCW, the chief of the construction site stated that Company F is a standard TPL provider with relatively high problem solving and customer adaptation abilities. It would be difficult for them to adjust their services to improve the supply chain of the construction projects of Dura Vermeer. LCW is a customer developer with high problem solving and customer adaptation abilities.

In an interview with the warehouse manager of LCW, cooperation to solve the present problems was observed, and adaptions to possible supply chain changes were considered. LCW is highly involved in the projects of Dura Vermeer, and they can change their way of working to make new delivery chains possible.

3.3 Analysis of the supply chain

This section gives the factors of the supply chain to compare the current situation to the solution scenarios. Section 3.3.1 elaborates on the activities that are performed inside the supply chain to aid in calculating the selected factors by the logistics manager. Then, Section 3.3.2 shows the results of the analysis.

3.3.1 Factors to be analyzed

The logistics manager stated in an interview that the following activities and factors are of importance in the analysis of the supply chain.

Activities:

- Loading a truck
- Transportation of a truck via roads
- Unloading a truck
- Storing materials

These are activities performed when delivering building materials from suppliers to the construction site. Each delivery chain performs these activities, and sometimes multiple delivery chains perform one activity together when building materials are combined. These activities give data on certain factors, such as costs, truckloads, distances, etc. The factors selected by the logistics manager are the following.

Factors:

- Sustainability
- Reliability
- Costs

Some factors fail to have a quantified value, so they are divided into subfactors. Sustainability is divided into the values of distance and the average truckload. The total distance driven over a certain period is a simple representation of emissions, and the logistics manager wishes it to be as low as possible. Moreover, the average truckload represents wasted space inside of the trucks, and the logistics manager wishes to have a high average truckload to make the transport emissions as valuable as possible. Reliability is also divided into subfactors that are quantifiable. It is divided into the number of delivery chains, the number of performed activities in a period, and the lead time for the delivery of building materials. Dura Vermeer wishes for the reliability to be as high as possible, so they wish to have a low number of delivery chains, a low number of performed activities, and a lead time that is as low as possible. Lastly, costs are defined as the total costs that are made inside the supply chain. The costs are divided into three categories which are transport costs, labour costs, and storage costs. Each activity has its own cost value. The sum of all these values in a chosen period leaves us with the value of the total costs. Note that these are not the final attributes of the multi-criteria decision analysis. Chapter 5 discusses how a value tree decomposes the factors to be able to asses them as attributes.

3.3.2 Results of the analysis

Appendix B contains the information on how excel calculates the factors. The table in excel delivers the results of each activity performed in the supply chain. Appendix B.3 shows this table, and Appendix B.4 explains the calculations of the results of each activity. Table 3 shows the results of the analysis of the current supply chain. The results show values for the period of four weeks and the period of one year. The results of the activities are added and multiplied times the frequency to get the final results in Table 3. These results are calculated to compare to the results of the solution scenarios created in the next chapter. In addition to that, it also provides the company with a thorough assessment of the current situation.

Table 3: Results of the analysis of the supply chain

Information on total supply chain	Per 4 weeks	Per year
Total Distance driven (in km)	2057.5	26747.5
Average Truckload (in pallets)	5.1	5.1
Lead time (in days)	4	4
Total number of delivery chains	5	5
Total number of activities	78	1014
Total costs	€ 4.064,04	€ 52.832,57

3.4 Conclusion

In closing, the supply chain in the selected research scope contains five delivery chains of the five most important building materials. Eight companies are present in the supply chain, and they make use of nine different locations. The distribution hub LCW collects all building materials and combines them into one delivery to the construction site. Companies A, B, and C deliver straight to the distribution hub. Companies D and E deliver first to Company F which makes use of two distribution centres as intermediary stages before the building materials are finally delivered to the distribution hub. The supply chain executes this delivery process every week to fill the demand of the construction site while dealing with the fact that there is no room at the construction site for the placement of building materials. Existing literature states that using a distribution hub such as LCW is beneficial for the efficiency of the project since the construction site lies in a dense urban area. The chief of the construction site observes some problems inside the supply chain. There seems to be a lack of transparency and communicative abilities between Dura Vermeer and Company F. Moreover, there are many parties and activities in the delivery chains that include Company F. This is where the chief of the construction site observes the occurrence of errors. He also sometimes experiences a shortage of building materials stored at LCW. The logistics manager selects the factors ‘Sustainability’, ‘Reliability', and ‘Costs’ to be analysed in the supply chain to be able to compare the current situation with the solution scenarios. The analysis on the supply chain divides the process into activities which all have data on the selected factors. The sum of this data gives the final results of the analysis.

4. Formulation of solution scenarios

This chapter elaborates further on the impacts on reliability and how the delivery chains could be reclassified. It gives a clear answer to Research Question 3:

How can the reliability of the delivery of building materials be improved?

Section 4.1 discusses what aspects of the supply chain have the biggest impact on the delivery's reliability. Section 4.2 provides the specific adjustments on the supply chain concerning this specific construction project. Section 4.3 delivers the reclassifications of the delivery chains that improve the delivery's reliability. In closing, Section 4.4 concludes the chapter.

4.1 Impacts on reliability

The use of LCW as a distribution hub aligns with the supply network coordinated configuration. It is considered highly efficient because the construction workers can focus on production activities, and there is improved utilisation of resources (Dubois et al., 2018). However, not all actors can or want to comply with this approach due to their own practices of coordinating transport and logistics activities, which impacts the supply network's total efficiency and reliability (Dubois et al., 2018). This entails that this configuration is the best choice for high reliability of deliveries, and the use of LCW as a distribution hub should stay when reclassifying the delivery chains. However, reducing the total number of actors would reduce the chance that actors do not comply with this delivery approach, as this was found to be a bottleneck in this configuration.

Furthermore, configurations of activities, combinations of resources, and actors' positions impact the reliability of the delivery of building materials to the construction sites (Sundquist et al., 2018). Reliability improves when the correct routes are used, the correct number of pallets are moved, and the correct frequency is applied to deliver the required number of pallets each week. Moreover, the just-in-case strategy helps to deal with unreliable suppliers (Jenkins, n.d.).

Lastly, the impact of transparency and communicational abilities between actors on reliability is too significant to leave out. Multiple studies showed that these values are essential. When Dura Vermeer, LCW, Company F, and the construction site increase their transparency and communicational abilities, the deliveries of building materials become more reliable. If one actor cannot improve, another solution is to remove that company from the delivery chains.

4.2 Supply chain adjustments

The possible adjustments are the following:

- Removing Company F from the supply chain
- Bundling multiple delivery chains into one
- Changing the number of pallets that is moved during each activity and changing its frequency in a manner that the required number of pallets is delivered each week

Removing Company F reduces the number of activities and the physical and information flows. The reduction of all these aspects leads to fewer chances of errors performed by other parties. It would also lower the number of actors that could not comply with the delivery approach due to their own practices of coordinating transport and logistics activities. The lack of transparency and communicative abilities between Dura Vermeer and Company F hurts the reliability. The buyer-supplier relationship changes from a D-frame triad to a Triangle triad. In the D-frame triad, there is a high need to avoid misalignment between actors (Patrucco et al., 2021). Removing Company F also removes their misalignments, and the communicative abilities of Dura Vermeer can focus on the direct suppliers.

The bundling of multiple delivery chains into one leads to a reduction in the number of delivery chains since multiple building materials are combined in one delivery chain. This again reduces the number of activities and the physical and information flows. This adjustment leads to more reliable deliveries for the same reasons as before. LCW will execute the bundled delivery of building materials. LCW has high problem solving and customer adaptation abilities, and the warehouse manager stated in an interview that LCW could provide these services. Note that this increases the requirement of communicative abilities, because a more collaborative supply chain is formed. When bundling these delivery chains, Company F is removed, and LCW's involvement increases. Chapter 3 concluded that Company F is considered as a standard TPL provider, while LCW is capable of problem solving and making adaptations for their customers. Understanding a customer's situation and developing knowledge about the project is necessary to be trustworthy and reliable as a TPL (Hertz & Alfredsson, 2003). LCW is such a TPL provider that can take over the responsibilities that Company F fails to deliver.

Changing the number of pallets that is moved during each activity and changing its frequency so that the required number of pallets is delivered each week leads to fewer activities per period. This makes the process more predictable and again reduces many factors. Moreover, it increases the storage at LCW to manage unexpected changes in the delivery planning schedule. Instead of having the total supply chain apply the just-in-time strategy, a combination of just-in-time and just-in-case is applied. Just-in-case inventory strategies require companies to purchase supplies proactively to meet any level of demand, within defined parameters, to prioritize preparedness over the cost and cash flow implications of holding stock in reserve (Jenkins, n.d.). Just-in-case strategies are valuable when demand is unpredictable, and suppliers are unreliable (Jenkins, n.d.). It protects Dura Vermeer from falling behind in production because it improves the reliability of deliveries from the distribution hub to the construction site by storing building materials to meet any demand. The deliveries to the distribution hub follow a just-in-case strategy, while the deliveries from LCW to the construction site do not change and still follow a just-in-time strategy. Note that storage costs could increase when changing these aspects.

4.3 Reclassifications of the delivery chains

This section gives five new scenarios reclassifying the supply chain in specific ways that improve reliability.

Scenario 1

The first scenario removes Company F entirely from the supply chain network. This means that Company D and Company E deliver their building materials directly to LCW. From an interview with the warehouse manager of LCW and the chief of the construction site at the Goeman Borgesiuslaan in Groningen, it became clear that the extra steps that Company F takes to get the building materials from Company D and Company E to LCW result in a lot of uncertainty and the supply becomes unreliable. This scenario aims to increase reliability by delivering directly from Company D and Company E to LCW. The deliveries from Company A, Company B, and Company C have no changes in the supply chain network. There is also no difference after all building materials are delivered to LCW. Figure 10 shows the visualisation of the supply chain network in this scenario. Note that this scenario still has five delivery chains because the delivery chains are not bundled, and all building materials are still delivered to LCW separately. All these deliveries still follow a just-in-time delivery strategy. Appendix C.1 shows the table that gives information on all activities of Scenario 1.

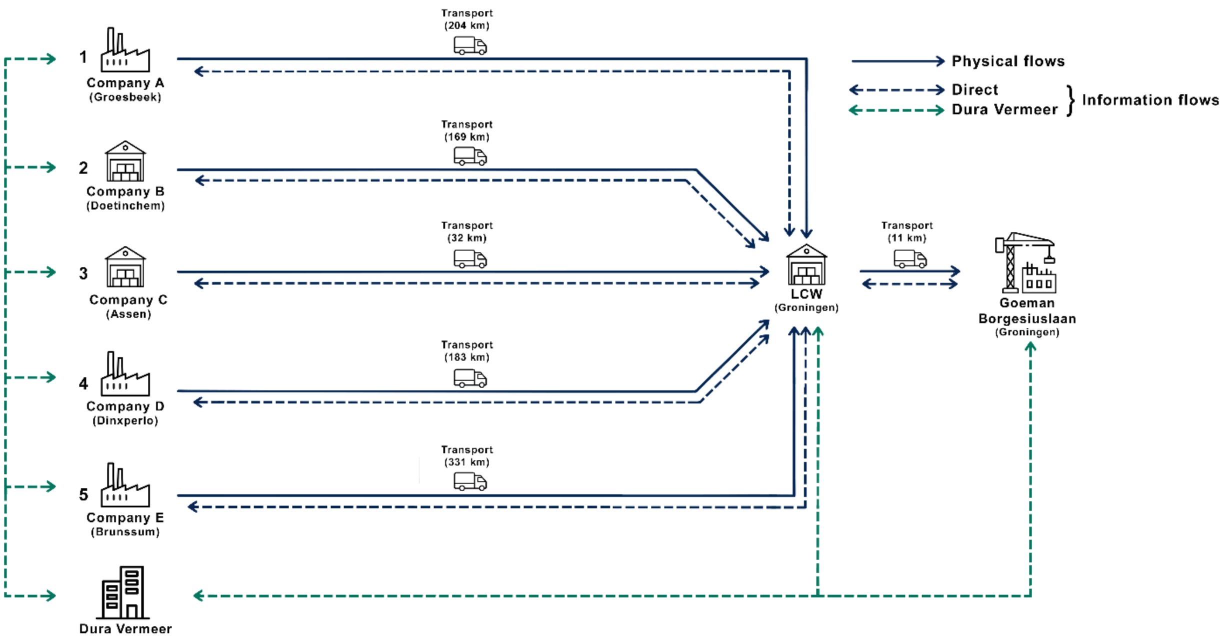

Figure 10: Visualization of Scenario 1

Scenario 2

The second scenario also removes Company F entirely from the supply chain network, but now Company F is removed because delivery chains 1, 3, 4, and 5 are bundled. This means that one truck driver goes from Company E to Company A to Company D to Company C, and then to LCW. From the interview with the warehouse manager at LCW, it became clear that if a total of five expected deliveries is reduced to only two expected deliveries, the overall expected number of late deliveries is reduced. Adding to this, the suppliers do not perform the deliveries; LCW does, which makes the delivery of the supplies more flexible and therefore more reliable. The deliveries from Company B have no changes in the supply chain network because they deliver specific products such as central heating boilers, heat pumps, and PV. These products require specific services that an external firm executes. It is better to exclude these products from the bundled delivery chain, to make those services and their products independent from the other products. There is again no difference after all building materials are delivered to LCW. Figure 11 shows the visualisation of the supply chain network in this scenario. Note that this scenario has two delivery chains, and all deliveries follow a just-in-time delivery strategy. Appendix C.2 shows the table that gives information on all activities of Scenario 2.

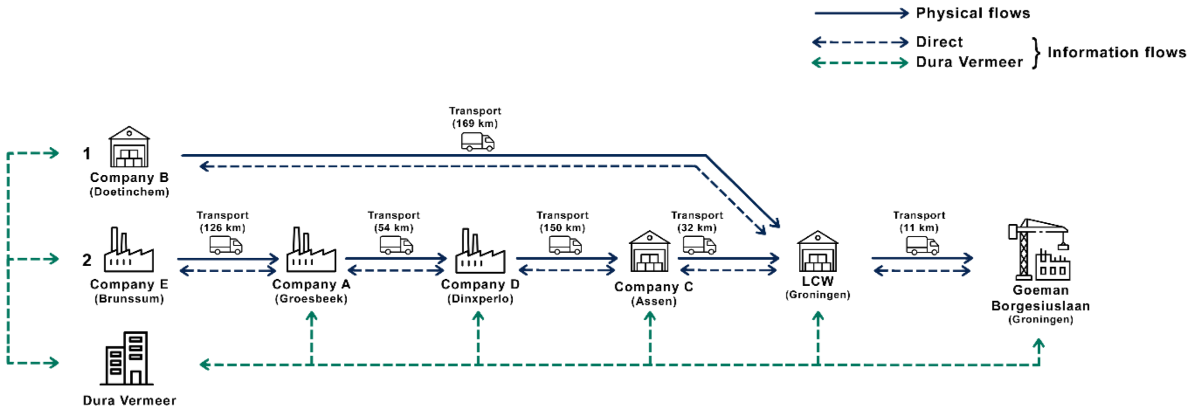

Figure 11: Visualization of Scenario 2

Scenario 3

The third scenario does not change any of the routes and does not remove any parties. This scenario increases the number of pallets that are moved during each activity and decreases the frequencies so that the required number of pallets are delivered each week. The frequency is the number of times the deliveries are executed in a certain period. The main objective of this scenario is to store more building materials to increase the security of supply. From an interview with the warehouse manager of LCW, it became clear that deliveries from several suppliers arrive later than expected. This results in unreliable supply. Deliveries from LCW to the construction site are just-in-time, but the deliveries from the suppliers to LCW are changed to a just-in-case strategy. Higher storage leads to more structure in the warehouse of LCW and more certainty of the deliveries from LCW to the construction site. This scenario achieves precisely that. Also, by increasing the load size of the deliveries and decreasing the frequency, the total number of activities decreases; therefore, the chance that an error occurs also decreases. Figure 12 (next page) shows the visualisation of the supply chain network in this scenario. Note that the figure shows the just-in-case and the just-in-time strategies. Appendix C.3 shows the table that gives information on all activities of Scenario 3.

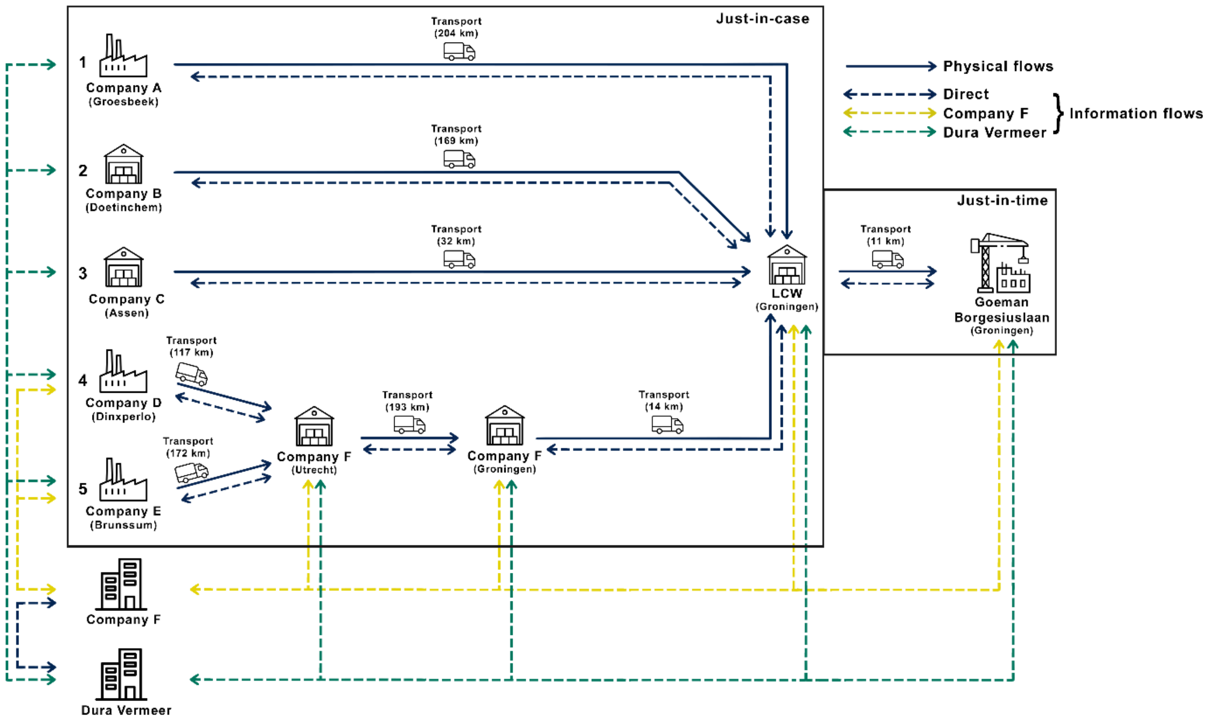

Figure 12: Visualization of Scenario 3

Scenario 4

The fourth scenario is a combination of Scenario 1 and Scenario 3. All of the benefits from the previous two scenarios are combined into one new scenario. This is possible because Scenario 1 focuses on changing the routes and removing Company F, and this has no effect on what Scenario 3 changes, which is the load size of the deliveries and their frequencies. Their adjustments are independent of one another and can be combined into one new scenario. The combination of benefits leads to higher reliability of the deliveries of building materials to the construction sites. Figure 13 (next page) shows this scenario's visualisation of the supply chain. Note that the figure shows the just-in-case and the just-in-time strategies. Appendix C.4 shows the table that gives information on all activities of Scenario 4.

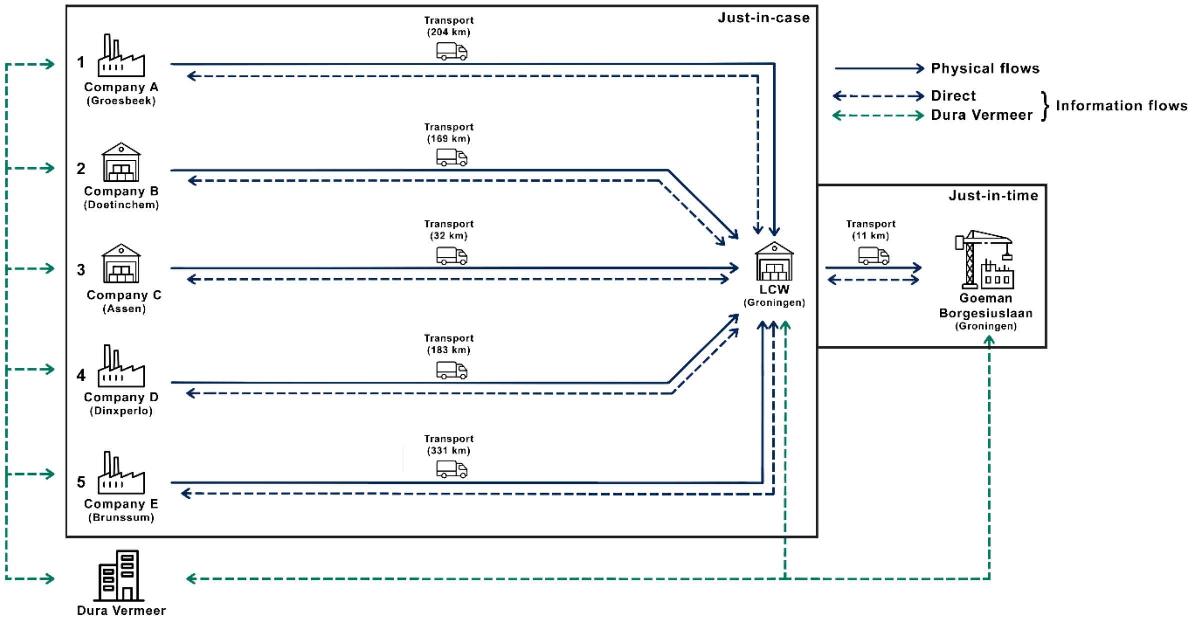

Figure 13: Visualization of Scenario 4

Scenario 5

The fifth scenario is again a combination. This time Scenario 2 and Scenario 3 are combined, which is again possible since the adjustments made in Scenarios 2 and 3 are independent of one another. The benefits of both these scenarios are combined, resulting in higher reliability of the deliveries of building materials to the construction sites. Figure 14 shows the visualisation of the supply chain network in this scenario. Note that the figure shows the just-in-case and the just-in-time strategies. Appendix C.5 shows the table that gives information on all activities of Scenario 5.

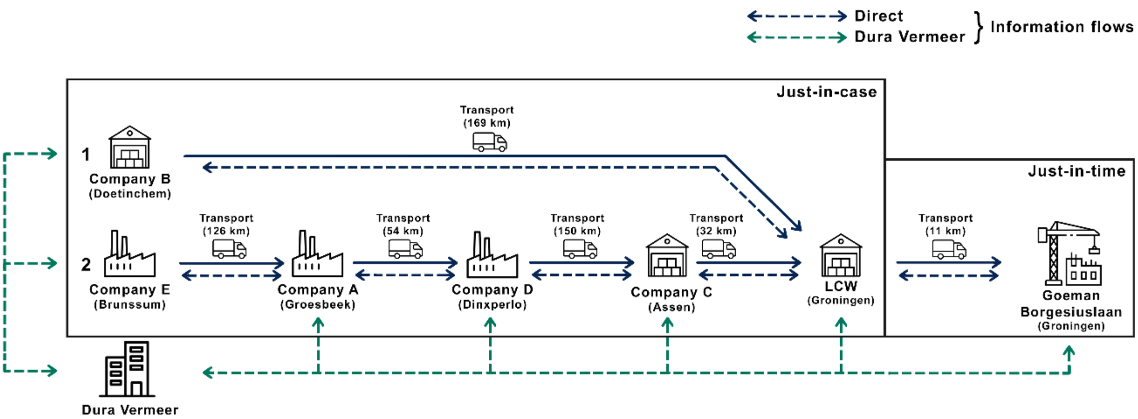

Figure 14: Visualization of Scenario 5

4.4 Conclusion

In short, the reliability of the deliveries of building materials can be improved by making reconfigurations of activities, recombining resources, and repositioning actors. The adjustments that have a positive impact on the reliability are the following. Removing Company F from the supply chain removes their disability in being transparent and communicative. Bundling building materials reduces the number of delivery chains and gives the responsibilities of Company F to LCW, which has better problem solving and customer adaptation abilities. Changing the number of pallets that is moved during each activity and changing its frequency increases the storage at LCW to manage unexpected changes in the delivery planning schedule. It also reduces the number of activities performed every period to decrease the chance that errors occur. Moreover, instead of having all deliveries follow a just-in-time strategy, reliability can be improved by dividing the supply chain into two sections and changing the deliveries from suppliers to the distribution hub to a just-in-case strategy. The solution scenarios represent the reclassifications of the supply chain where they apply the adjustments mentioned before.

Scenario 1 removes Company F from two delivery chains to eliminate their disability in transparency and communication. Scenario 2 bundles four building materials into one delivery chain and assigns the responsibilities of Company F to LCW, who’s problem-solving and customer adaptation skills are better than those of Company F. Instead of having the suppliers deliver each building material to the distribution hub themselves, LCW collects the pallets at the locations of the suppliers. Scenario 3 changes the number of pallets that each activity moves and changes its frequency so that the required number of pallets is delivered each week. This scenario uses a combination of just-in-case and just-in-time strategies to deal with unreliable suppliers and having no space at the construction site to store building materials. Another result is that the supply chain performs fewer activities. Scenario 4 is a combination of the adjustments of Scenarios 1 and 3, and Scenario 5 is a combination of the adjustments of Scenarios 2 and 3.

5. Selection of scenario

The solution scenarios positively impact the reliability of the deliveries from the suppliers to the construction site. They do differ in costs, distances, and other attributes. This chapter delivers the best possible scenario selection process, considering all trade-offs between different criteria. It gives a clear answer to Research Question 4:

Which solution scenario suits the company best?

Section 5.1 follows the stages of the SMART method from the book by Goodwin and Wright (2014). Section 5.2 concludes the chapter.

5.1 Stages of the multiple-criteria decision analysis

The book by Goodwin and Wright (2014) states eight stages to fulfilling the SMART method. The logistics manager gave all the necessary information in a work session performed with the researcher. Questions were well prepared and precisely formulated to receive the best data for executing the SMART method.

Stage 1: The decision maker

The first stage identifies the person(s) who makes the decision. The decision maker is the person who is responsible for making strategically important decisions when presented with different courses of action. In the case of this research, the logistics manager is responsible for informing and advising the company Dura Vermeer on ongoing and upcoming construction projects. He is the decision maker.

Stage 2: The alternatives

This stage identifies the alternatives to be evaluated. The possible alternatives are the different courses of action. This stage is mainly executed in earlier chapters. The current situation from Chapter 3 and the five solution scenarios from Chapter 4 are the alternatives. Note that the current situation needs to be one of the alternatives to include the possibility that changing nothing is the best option. The alternatives are the following:

- Current situation
- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5

Stage 3: The attributes

This stage identifies the attributes which are relevant to the decision problem. Section 2.5.2 explains how a value tree visually represents the relevant attributes. It also states five criteria to assess the adequacy of a value tree. Figure 15 (next page) shows the value tree of this multiple-criteria decision analysis. Section 3.3.1 already discussed some of the factors presented in the value tree.

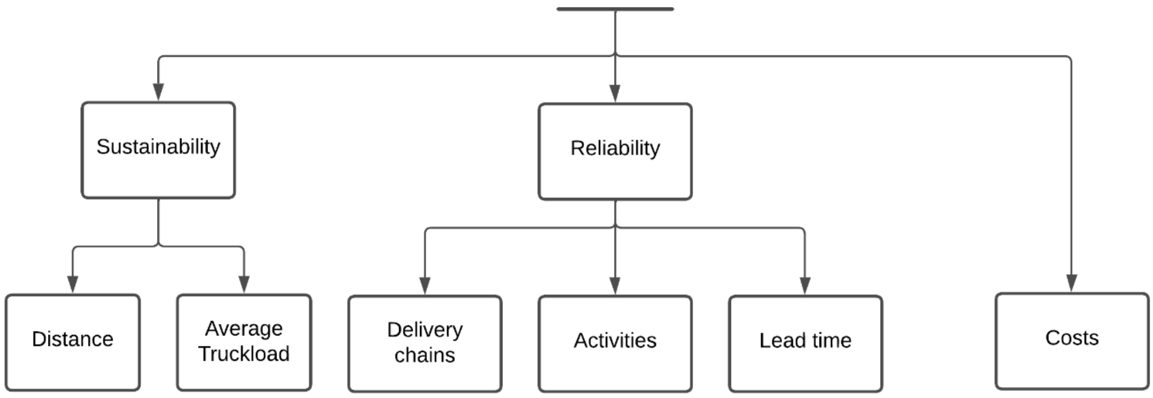

Figure 15: Value tree for the solution scenario selection problem

The logistics manager selected sustainability, reliability, and costs as relevant attributes when comparing the current situation and the solution scenarios.

The logistics manager mentioned the attribute 'distance' to understand which alternative has the highest emissions. This falls under the attribute ‘sustainability’. The value tree uses the total distance driven in a certain period to get a quantified value of the alternatives on their emissions. The decision maker wishes to have the total distance driven in a certain period be as low as possible. When discussing the sustainability of the different alternatives, another attribute presents itself. To have a sustainable supply chain, the logistics manager wishes to have an average truckload as high as possible, so no emissions are discharged for unused room inside the trucks. Note that fuller trucks do not necessarily mean less distances. The average truckload and distance are independent of one another. A scenario could have a higher average truckload when comparing it to others, but if it uses drastically different routes the distance could still be worse.

The purpose of the solution scenarios is to improve reliability, so the value tree includes this attribute. It is impossible to judge the alternatives on ‘reliability’ alone, so the value tree divides the attribute into three other attributes that give a good representation of the reliability. These three new attributes have quantifiable values between the alternatives. The decision maker wishes for the number of delivery chains, the number of activities executed in a certain period, and the lead time of the delivery process to be as low as possible. As stated before, fewer delivery chains result in a lower number of physical and information flows. This makes the supply chain less complex and lowers the chance of errors. This increases the reliability of deliveries. Moreover, if the number of activities performed in a certain period is reduced, errors are less likely to occur, which increases reliability. Lastly, a shorter lead time makes the delivery of building materials more flexible. Planning schedules can be adjusted more quickly to perform the delivery at the right time. Therefore, a lower lead time increases reliability.

The last attribute is the costs. Costs are defined as the total costs that are made inside the supply chain. The costs are divided into three categories which are transport costs, labour costs, and storage costs. It is challenging for the decision maker to compare improvements in costs against improvements in the other attributes. Therefore, a later stage considers the trade-offs between the score of sustainability and reliability against the total costs of the alternatives.

Stage 4: Alternative performances on the attributes

This stage assigns values for each attribute to measure the performance of the alternatives. First a table delivers the raw values of all attributes of each alternative. With this information, each attribute of all alternatives is given a score between 0 and 100, where 0 represents the least-preferred value, and 100 represents the most-preferred value. Section 2.5.3 discussed the use of bisection to construct value functions to get an adequate evaluation of the alternatives on the attributes.

Table 4 shows all raw values of the attributes of the alternatives. Appendices B and C explain the calculations developing the results of Table 4. Section 3.3.2 already calculated the attributes for the current situation. Appendix C shows the solution scenarios' activities; per activity, information is given to calculate the attributes.

Table 4: Raw values of the attributes for each alternative

Attributes\Alternatives		Current Situation	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Sustainability	Total Distance driven (in km/4 weeks)	2057.5	3720.0	2168.0	384.9	326.8	578.7
	Average Truckload (in pallets)	5.09	3.33	6.67	16.55	14.44	14.18
Reliability	Lead time (in days)	4	2	2	4	2	2
	Total number of delivery chains	5	5	2	5	5	2
	Total number of activities per 4 weeks	78	76	64	32	21	29
Costs	Total costs per 4 weeks	€ 4.064,04	€ 3.733,29	€ 3.008,19	€ 3.859,23	€ 2.782,98	€ 2.416,92

From the work session with the logistics manager, halfway points and quarter points were selected between the value of the least-preferred alternative and the value of the most-preferred alternative for each attribute. The attributes 'lead time' and 'total number of delivery chains' have no value functions since they have only two different values between the alternatives, which means that these get scores of 0 and 100, and there is no need to ask for halfway points and quarter points. Figures 16, 17, and 18 show the value functions of the other attributes that are direct results of the work session with the logistics manager. Bisection (see Section 2.5.3) was used to attain these value functions. The figures demonstrate how specific increases/decreases of the attributes have different increases/decreases in value. These value functions help construct the value table in Stage 6 of the SMART method.

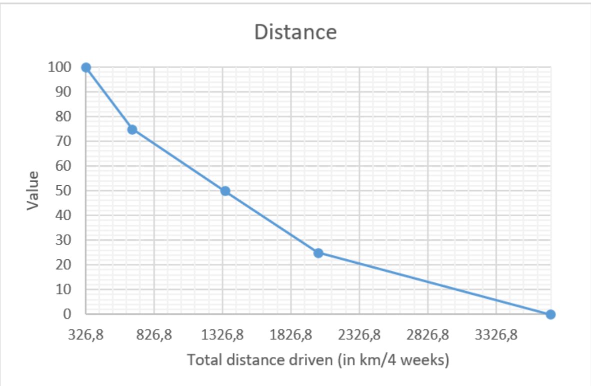

Figure 16: Value function for the distance

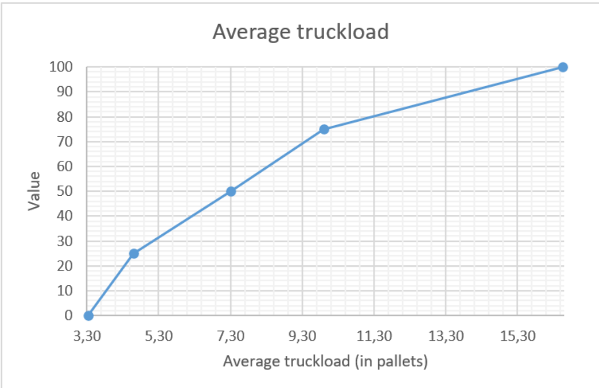

Figure 17: Value function for the average truckload

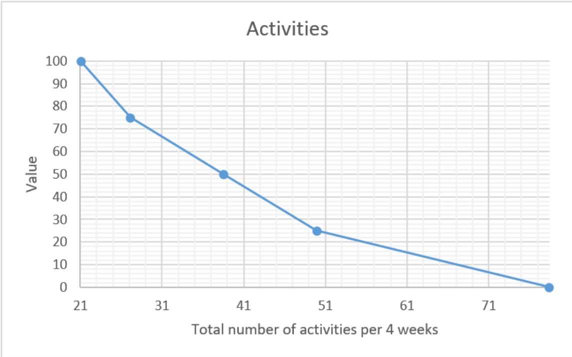

Figure 18: Value function for the activities

Stage 5: Weight specification

This stage determines the weight of each attribute. It reflects how meaningful the different attributes are according to the decision maker. Section 2.5.4 discussed the use of swing weights to define the weights of the attributes. In the work session with the logistics manager, he was asked to imagine a hypothetical alternative with all attributes at their least-preferred level. Then, he was asked which attribute he would wish to go from the least-preferred level to the most-preferred level first. This attribute is put on the top of the rank list. Then, he was asked, which attribute he wishes to move to its best level next, and this attribute gets the following rank. This is done for all attributes to get the following rankings:

1. Distance
2. Delivery chains
3. Activities
4. Average truckload
5. Lead time

The top rank gets a weight of 100. The logistics manager was asked to compare a swing from an alternative with the largest distance to the smallest distance with a swing of an alternative from the largest number of delivery chains to the lowest number. He decides on percentages of importance for all the attributes lower than the top rank. For example, he decides that the swing in the number of delivery chains is 90% as important as the swing in the distance, giving the attribute 'delivery chains' an original weight of 90. Table 5 shows the attributes' final normalized weights by dividing each original weight by the sum of the original weights (385).

Table 5: Weights of the attributes

Swing weights			
Rank	**Attribute**	**Original weights (out of 100)**	**Normalized weights (out of 1)**
1	Distance	100	0.26
2	Delivery chains	90	0.23
3	Activities	85	0.22
4	Average truckload	60	0.16
5	Lead time	50	0.13

Stage 6: Scores of the alternatives

This stage calculates for each alternative the weighted average of the values assigned to that alternative. That weighted average is the score of each alternative on how they perform, considering the sustainability and reliability. Table 6 (next page) shows the attribute values of all the alternatives collected from the value functions in Stage 4. The attributes 'Lead time' and 'Total number of activities per 4 weeks' only have values of 0 and 100 since each attribute has only two different values crossing all alternatives (see Table 4). In addition to the attribute values, the table also includes the weights from Stage 5 of the SMART method, and with these values and weights, it calculates the final score of all the alternatives.

Table 6: Value table of the alternatives

Attributes\Alternatives		Weight	Current Situation	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Sustainability	Total Distance driven (in km/4 weeks)	0.26	24.5	0	22.9	95.7	100	81.4
	Average Truckload (in pallets)	0.16	29.5	0	44.2	100	92.1	91.1
Reliability	Lead time (in days)	0.13	0	100	100	0	100	100
	Total number of delivery chains	0.23	0	0	100	0	0	100
	Total number of activities per 4 weeks	0.22	0	1.8	12.5	63.6	100	70.5
		Score	**11.0**	**13.4**	**52.0**	**54.5**	**75.4**	**87.3**

Table 6 calculates the values from the value functions of Stage 4 by constructing a formula of the line in the value function that represents the attribute value of the alternative and then filling in the exact result from Table 4. For example, the table calculates the value of the total distance driven of the current situation as follows. The current situation has a total distance driven of 2057.5 kilometres per four weeks, and Figure 16 informs us that the value of this attribute for this alternative lies between 0 and 25. Excel calculates what formula this line uses, which is the following:

$$v(x) = -0{,}0147x + 54{,}8026$$

where v(x) represents the final value that Table 6 represents, and x is the result of an attribute of an alternative that Table 4 provides. The result in this example is the following:

$$v(2057{,}5) = -0{,}0147 * 2057{,}5 + 54{,}8026 = \pm 24{,}5$$

Table 6 presents all attribute values of the alternatives calculated similarly to this example. The table rounds the values to numbers with one decimal. Note that each attribute for each alternative has its formula, depending on where the value lies on the value function.

Stage 7: Provisional decision

This stage makes a provisional decision with the information from the earlier stages. The performance scores of the alternatives in Table 6 do not consider the costs. They only represent the attributes 'sustainability' and 'reliability'. It was too difficult for the decision maker to compare improvements in costs against improvements in the other attributes. However, the trade-offs between the score of sustainability and reliability against the total costs of the alternatives should be analyzed when making a provision decision.

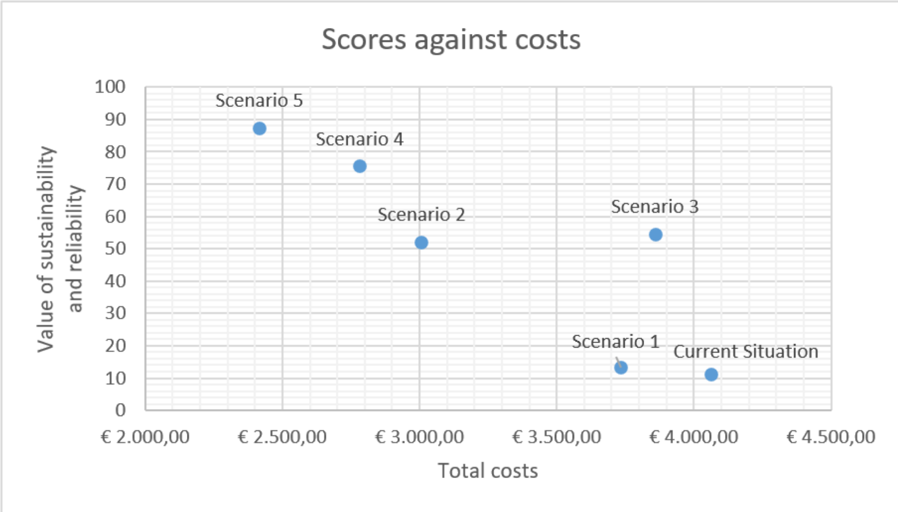

Figure 19: Sustainability and reliability score of alternatives plotted against costs

Figure 19 shows the scores of the alternatives plotted against their costs. Immediately it becomes clear that Scenario 5 is a definite winner among the alternatives when considering their value of sustainability, reliability, and costs. Figure 19 shows that Scenario 5 has the lowest costs and the highest score. Scenario 4 is an excellent second option since it has marginally higher costs and a lower score. Scenario 2 is the next alternative that strives to have low total costs, but the score drops significantly compared to Scenarios 4 and 5. Scenario 3 shows only a slightly better score when comparing it to Scenario 2, and the total costs are about 128% higher, making Scenario 2 the better option between the two. The current situation and Scenario 1 are alternatives with the highest amount of total costs and lowest values in sustainability and reliability, making them the worst choices for the provisional decision. Note that it is logical that Scenarios 4 and 5 score relatively good. Chapter 4 explains that Scenarios 4 and 5 apply two adjustments, while Scenarios 1, 2, and 3 only apply one adjustment. Scenarios 4 and 5 are combinations of Scenarios 1 to 3, and the more adjustments they apply the more improvements the results will show. To conclude, according to the results of the multiple-criteria decision analysis, the provisional decision is to choose Scenario 5, as it is the best option considering all attributes.

Stage 8: Sensitivity analysis

This stage performs a sensitivity analysis to investigate how robust the decision of Stage 7 is to changes in the decision maker's preferences. This research focuses on improving the reliability of the deliveries of building materials to the construction site. Therefore, the weight that reliability is given (in other words, the added weights of the attributes that represent reliability) is a point of interest when making a sensitivity analysis. The total weight of reliability is 0.58. What if the decision maker values the reliability much lower or higher than he currently does? What if the weight of the reliability was lower or higher? What would that do to the scores of the alternatives, and would the provisional decision change?

Adjusted weights			
Reliability weight	**0.000**	**0.58**	**1.000**
Total Distance driven (in km/4 weeks)	0.625	0.26	0.000
Average Truckload (in pallets)	0.375	0.16	0.000
Lead time (in days)	0.000	0.13	0.222
Total number of delivery chains	0.000	0.23	0.400
Total number of activitiesbper 4 weeks	0.000	0.22	0.378

Table 7: Adjusted weights when changing the decision maker's judgement on reliability

Table 7 shows how the weights of the attributes change when the judgement on the reliability of the decision maker changes. When reliability is the only factor that matters, the attributes that represent sustainability get a weight of 0, and the original weights of the attributes that represent reliability are normalized. When reliability matters not at all, the attributes that represent sustainability are normalized from their original weights, and the attributes that represent reliability get a weight of 0. With these new weights, the scores of the alternatives concerning sustainability and reliability change accordingly.

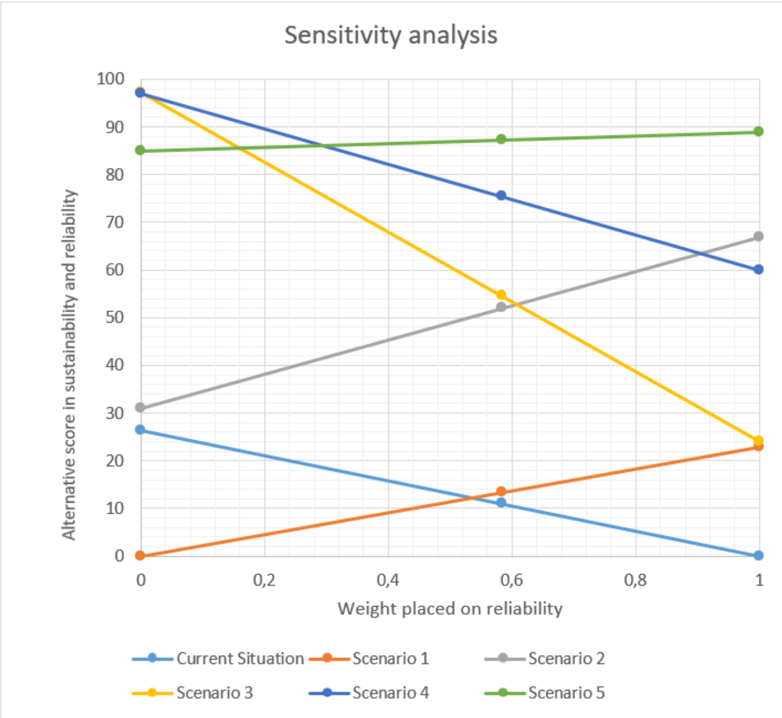

Figure 20: Sensitivity analysis concerning weight of reliability

Figure 20 shows how the scores of the alternatives change depending on the weight of the reliability. When the weight of reliability increases, no other alternatives get a higher score in sustainability and reliability than Scenario 5, meaning that if the decision maker considers the reliability to be more important, the provisional decision would be the same. However, when the weight of reliability decreases, Scenarios 3 and 4 eventually get a higher score than Scenario 5, making them more attractive. The tipping point of Scenario 4 overtaking Scenario 5 lies at a reliability weight of 0.29, which is almost half of the weight of reliability received from the logistics manager. Another examination between the trade-offs of scores and costs would be necessary. Would the provisional decision change when the decision maker discards reliability?

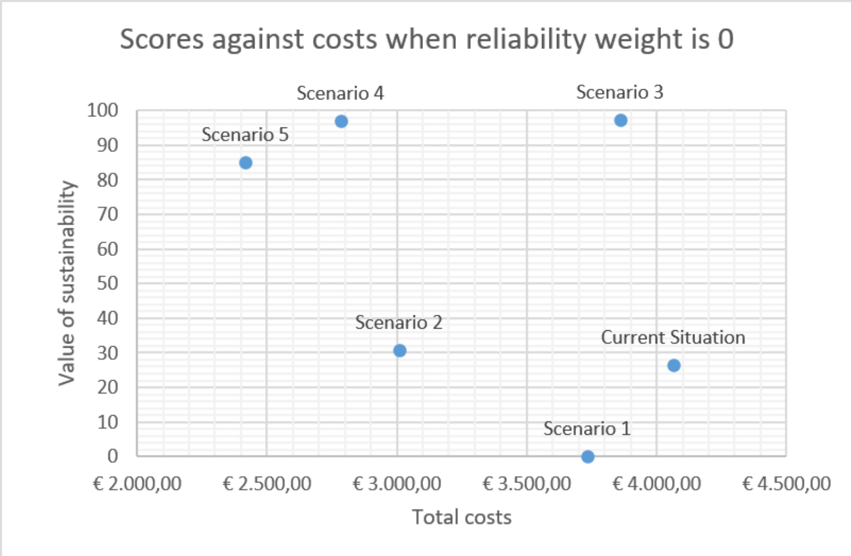

Figure 21: Alternative scores plotted against costs when the decision maker discards reliability

Figure 21 shows the scores of the alternatives plotted against their costs again, but now the reliability is given a weight of 0. Between Scenarios 3 and 4, which have the highest scores out of the alternatives, Scenario 4 is a better option since it has nearly the same score and much lower costs. Between Scenarios 4 and 5, it is more difficult to make a choice. Both scenarios have a high score, and they only differ slightly in their total costs. Scenario 4 could be chosen as the best alternative, which would change the provisional decision in Stage 7. However, considering that the purpose of this study is to improve the reliability, it is illogical to lower the weight of reliability and change the provisional decision to choose Scenario 4. Still, the sensitivity analysis did inform the decision maker on how the situation changes if he adjusts his opinion about reliability. This makes the provisional decision well established, and it provides extra support to the final decision of this multi-criteria decision analysis.

5.2 Conclusion

To conclude, Scenario 5 is the best solution scenario that suits Dura Vermeer the best. Scenario 5 changes the supply chain in the following manner. It bundles four building materials into one delivery chain and assigns the responsibilities of Company F to LCW. It also changes the number of pallets that each activity moves and changes its frequency so that the required number of pallets are delivered each week. The execution of the SMART method gives results that show this scenario having the highest score considering sustainability and reliability. In addition to that, it has the lowest total costs when comparing it to the other alternatives. From the interview with the logistics manager, the decision maker, the weight of reliability was set at 0.58. When this weight reduces to a value lower than 0.29, another scenario overtakes the current provisional decision. However, the purpose of the study is to improve reliability and the decision maker is confident that the weight of reliability should not be lowered in any case. The results also show that if the company does not bundle four building materials into one delivery chain, but only removes Company F from two delivery chains, and they still change the number of pallets and frequency of each activity, then there is little difference between the scores and total costs.

6. Conclusion, recommendations, and discussion

This chapter concludes the research and makes recommendations for Dura Vermeer and future research. Section 6.1 answers the main research question by answering the research question of the earlier chapters. Section 6.2 makes recommendations for Dura Vermeer that fall in line with the answer to the main research question. Section 6.3 discusses the limitations of this research and how it reflects on the results. In closing, Section 6.4 dives into the recommendations for future research.

6.1 Conclusion

The main research question of this thesis is:

"How can the delivery chains of building materials to the construction site at Goeman Borgesiuslaan in Groningen be adjusted to make deliveries more reliable?"

The reliability of the deliveries in transportation processes regarding supplier-buyer relationships is a direct result of the supply chain configuration used, the transparency and communicative abilities of all the actors, the configuration of activities, the combination of resources, and the actors' positions. In the investigation of the project at the Goeman Borgesiuslaan in Groningen, the general concept of the supply chain was visualised. Five delivery chains deliver five types of building materials from different suppliers to the construction site. The solution scenarios improve reliability in the supply chain by the following adjustments. Removing Company F as intermediate stages in Delivery chains 4 and 5 removes their disability in being transparent and communicative. Bundling building materials reduces the number of delivery chains and gives the responsibilities of Company F to LCW, which has better problem solving and customer adaptation abilities. Changing the number of pallets that are moved during each activity and changing its frequency to increase the storage at LCW makes unexpected changes in the delivery planning schedule manageable. It reduces the number of activities performed every period to decrease the chance of errors. Moreover, it combines the just-in-case and just-in-time delivery strategies to deal with unreliable suppliers and having no space at the construction site to store building materials. The SMART method helps select the suitable alternative on what solution scenario is the best option for the company. Scenario 5 has the best score considering sustainability and reliability, and in addition, it has the lowest total costs compared to the other alternatives.

To conclude, the best way the delivery chains can be adjusted is by creating the supply chain that bundles the building materials from companies A, C, D, and E. In this supply chain, there are only two delivery chains. In the delivery chain that bundles the building materials, LCW drives through the country and collects the orders at each supplier location. The suppliers only set up the orders on the specified days at their own locations, which reduces the amount of effort their companies need to put in these deliveries. This supply chain design does require high transparency and communicative abilities, but LCW performs the delivery process, and LCW has shown high problem-solving and customer adaptation abilities. In addition, the number of pallets that are moved during each activity increases, and the frequency, the number of times the deliveries are executed in a certain period, decreases so that the required number of pallets are delivered each week. For example, instead of having four suppliers deliver two pallets every week, one delivery takes place every 21 days and delivers 24 pallets, six pallets from each supplier, which meets the demand of the construction site. This reduces the number of activities performed in the supply chain in each period, which creates a lower chance that one delivery fails. The deliveries from the suppliers to the distribution hub follow the just-in-case strategy, which is commonly applied when suppliers are unreliable. The deliveries from the distribution hub to the construction site keep applying its just-in-time strategy to comply with the lack of space at the construction site.

6.2 Recommendations

There are five possible new supply chain designs for the project at the Goeman Borgesiuslaan in Groningen. Scenarios 4 and 5 are the best options between the possibilities. Both these options increase the number of pallets that are moved during each activity increases. They also decrease the frequencies of the activities in such a way that the required number of pallets is delivered each week. These adjustments increase the storage at LCW and reduce the number of deliveries performed in the supply chain per period. Without a doubt does this research recommend making these adjustments.

The difference between Scenarios 4 and 5 is the additional adjustments on the supply chain design. Scenario 4 removes Company F from two delivery chains and creates five direct deliveries from the suppliers to the distribution hub. The suppliers perform the deliveries in this supply chain design. Scenario 5 bundles the building materials from companies A, C, D, and E into one delivery chain that LCW executes by driving through the country picking up the orders at the locations of the suppliers. The results show that the best scenario is Scenario 5, so this is what this research recommends.

However, the research also recommends that the new design of the supply chain should be tested and evaluated after a few months to get knowledge on the improvement in reliability of the deliveries. If errors occur and reliability is low when applying the supply chain design of Scenario 5, the research recommends changing the supply chain design of Scenario 4. Scenarios 4 and 5 do not differ in their results of this research significantly, so it is recommended to try both scenarios if one fails at its goal. The results have shown that the designs of Scenarios 4 and 5, as combinations of the other scenarios, are the best way forward for the company.

It is important that the company understands the adaptation to errors of the suppliers. If one of the suppliers fails to produce the order, the impact on the supply chain differs between the solution scenarios. Scenario 4 can adapt to such errors more easily in comparison to Scenario 5. If Dura Vermeer expects that the suppliers will not be able to deliver their orders at their own locations in the selected period that this research recommends, it would be better to apply Scenario 4 because the building materials all have their own delivery chain to the distribution hub. An adjustment to the error of the supplier is easier to apply in this situation because the delivery from that specific company can be executed on another day. However, if Dura Vermeer expects that the suppliers can ready the orders at their own locations in the selected period, Scenario 5 should be chosen, which bundles the building materials from companies A, C, D, and E into one delivery chain. One argument is that the chance that the suppliers fulfil their agreements is higher since they need to put less effort into the completion of their orders. This research recommends that Dura Vermeer discusses the possibilities of a supply chain design with all parties involved, before implementing it.

In closing, the research recommends implementing a storage system with information of the stored building materials at the distribution hub. There is no insight into the number of building materials stored, which blinds the chief of the construction site, and adjustments in planning schedules become hard to deal with. Since completing sections of the renovation project has hard deadlines, Dura Vermeer can only expect good insight into storage in their distribution hub. LCW has shown excellent cooperation in the past, so it is highly recommended to increase transparency and communication about storage amounts in the future. Furthermore, the research recommends evaluating transparency and communicative abilities of/between stakeholders inside the supply chain. The delivery chains can be adjusted to make them more efficient and reliable, but from the existing literature, it became evident that transparency and communication between all parties is one of the most critical aspects of improving reliability.

6.3 Discussion

The lack of data limits this research. When analysing the five most important suppliers of the construction project, data helps understand how they perform. They are not only present in the specific project at the Goeman Borgesiuslaan, but other renovation projects in Groningen and other parts of the Netherlands. Data on their performance on reliability is helpful to get hard evidence on the problem's existence, and it helps to locate the exact location in the delivery chains where errors occur. In this research, most information was collected via interviews, which reflect the opinions of the managers and employees. This limits the research in avoiding biases.

One objective of this study is to compare the results of the analyses on the current situation and the solution scenarios, which are the alternatives. The logistics manager gave indicators that help with the construction and evaluation of the results of the different alternatives. However, in the process of getting these results, many assumptions are made (see Appendix B.4). These assumptions question the validity of the data used in the performance measurements. There may be other methods to calculate the performance of the alternatives. One other example of this is that the result of the research could change when the SMART method of Chapter 5 chooses a different decision maker that values the attributes differently. With the time limitation of this research, the validity is as high as possible because choices on, for example, methods and decision makers in the execution of the problem-solving approach were carefully selected and argued with the help of existing literature that Chapter 2 presents.

Moreover, this research investigates only the project's situation at the Goeman Borgesiuslaan in Groningen. The results are also helpful in improving other renovation projects of Dura Vermeer in Groningen since their projects are very similar. However, suppose a company experiences the same problem in a different province of the Netherlands or a different industry sector. In that case, getting a good solution out of this research becomes difficult. Still, the general findings of this research are relevant if the same problem occurs externally. The literature background provides information on what factors impact the reliability of deliveries of building materials to construction sites, and the adjustments made to the supply chain could be analysed when comparing them to other construction projects.

Also, the research was limited in its scope when analysing the different alternatives. For example, when comparing sustainability, the research only regarded the distances of this specific supply chain. However, it does not consider the impacts of the alternatives on other related supply chains. The transport of another supply chain could also use Company F as intermediary stages, and if Dura Vermeer removes Company F, the removed distances could very well still be driven in another supply chain. This research does not consider these possibilities, and Dura Vermeer should consider this limitation when they consider the conclusions and recommendations.

6.4 Future research

This section divides the recommendations for future research into two categories. There are recommendations for future research for this specific project in the company, and there are recommendations for future research performing the implemented solving methods at other projects. Section 8.4.1 discusses the recommendations for future research considering this renovation project at Dura Vermeer. Section 8.4.2 discusses the recommendations for future research performing the implemented solving methods at other projects.

6.4.1 Future research for the renovation project of Dura Vermeer

The research recommends further collection of data in this specific renovation project at the Goeman Borgesiuslaan in Groningen. Dura Vermeer needs to evaluate its suppliers and their performance concerning reliability. Reliability is a complex topic to discuss without hard evidence of the suppliers' performances. Moreover, the origin of late deliveries is found more quickly if the performance is measured at each intermediate distribution center/hub inside the delivery chains. The impact of changes in the supply chain should be evaluated by measuring a supplier's reliability performance.

To improve the evaluation of the delivery chains even further, the research also recommends making an extra evaluation of the TPL providers inside the supply chain. This research has already evaluated the problem-solving and customer adaptation abilities of the TPL providers. This evaluation helps to divide specific responsibilities inside the supply chain to different involved TPL parties. Further analysis of these parties could develop more information on what activities these parties could perform, which can be beneficial for the reliability and total efficiency of the supply chain.

This research also recommends analysing which stakeholders own what percentage of the attributes. The logistics manager was interested in the total cost, distance, etc., but this failed to show which stakeholder would pay or drive for what amount. The objective was to improve the total supply chain, but how do the different alternatives affect the different parties inside the delivery chains? This could be analysed further in future research.

6.4.2 Future research for other projects

In future research of other projects performed externally, the research recommends further exploration of supply chain configurations for different types of construction projects. Construction companies have many different types of construction projects, and this research focuses on renovation projects. Each type of construction project has different challenges to tackle. For example, the construction sites of new buildings often have a wide variety of suppliers and a lot of space at the construction site. In contrast, renovation projects have much fewer suppliers and almost no space for building materials where they operate. Existing literature gave different configurations for different situations, but they do not dive into the different categories of construction projects (infrastructure, office buildings, renovations, etc.).

This research also recommends future research to investigate the difference between just-in-time and just-in-case deliveries concerning reliability. The difference between building materials arriving precisely when needed or storing them to prioritise preparedness in construction projects has yet to be explored extensively. Renovation projects seem to need a just-in-time delivery at their construction site every certain period, but to improve the reliability of these deliveries, a just-in-case delivery strategy to the distribution hub seems beneficial. The differences are already familiar in the existing literature. Still, specifically, in the supply chains of construction companies that use a distribution hub, the combination of these strategies can be discussed and investigated further.

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Appendices

Appendix A: Systematic Literature Review (SLR)

Research question

What types of supplier relationships have what effects on the reliability of deliveries in transportation processes?

Key concepts

The key concepts of the research question are the following:

- Supplier relationships
- Reliability
- Deliveries
- Transportation processes

Search matrix

The key concepts are not enough to find valuable literature. More concepts are needed to broaden the scope of the search. Synonyms are generated in a search matrix to create more terms. Table 8 shows the search matrix.

Table 8: Search Matrix

Key concepts	**Related terms (synonyms)**		**Broader terms**	**Narrower terms**
Supplier relationships	Distributor Provider	Bonds Connections Agreements	Supply theory	Push or pull concepts
Reliability	Loyalty Truthfulness Honesty			Time deviation of arrival
Deliveries	Loads Batches Shipments		Supplies	Truckloads Lorryloads
Transportation processes	Moving Transference	Procedures Operations Jobs Tasks Methods Approaches Systems Techniques Practices	Transport	Truck deliveries

Selection criteria

Before valuable literature can be found, criteria must be selected to make the search simpler. Inclusion and exclusion criteria help with this. Inclusion criteria help with requirements that the literature must meet for it to be of any value. All literature used must meet the inclusion criteria. Exclusion criteria help to exclude any literature that is of no value. All literature that meets the exclusion criteria can be disregarded.

The inclusion criteria are:

- The article is published in a language that I understand (English, Dutch)
- The article contains information about the transport of good via roads, since other transportation methods are not applicable to the situation of the company

The exclusion criteria are:

- The article is not attainable, since the information needs to be accessed
- The article is about processes within a single company, since the problem is about suppliers outside of the company
- The article is published before 1990, since it would be outdated

Databases

There are many databases that can be used to find articles. This research is performed scientifically and scholarly, where unbiased and peer-reviewed articles are used. The appropriate databases that go hand in hand with these values are Web of Science and Scopus. Snowballing (following trails of references) is performed with the use of the reference lists and the related documents list.

Search log

To explain how I found the sources it is important to document the search that is performed. This makes the research transparent and honest. Table 9 shows the search log, which indicates the date, database, search string, number of found articles and the number of articles selected.

Table 9: Search log

Date	Database	Search string	Articles found	Articles selected
18-04-22	Scopus	(TITLE-ABS-KEY (((suppl* AND relationship*) OR distributor* OR bond* OR provider* OR connection* OR agreement* OR "Supply theory" OR push OR pull)) AND TITLE-ABS-KEY ((reliab* OR loyal* OR truthful* OR honest* OR honer* OR "Time deviation of arrival")) AND TITLE-ABS-KEY ((deliver* OR load* OR batch* OR shipment* OR suppl* OR truckload* OR lorryload*)) AND TITLE-ABS-KEY ((transport* AND process* OR moving OR transference OR operation* OR method* OR approach* OR system* OR technique* OR practice* OR "Truck deliver*")))	1258	Too many to assess
18-04-22	Scopus	(TITLE (((suppl* AND relationship*) OR distributor* OR agreement* OR "Supply theory" OR push OR pull)) AND TITLE-ABS-KEY ((reliab* OR loyal* OR truthful* OR honest* OR honer* OR "Time deviation of arrival")) AND TITLE-ABS-KEY ((deliver* OR load* OR batch* OR shipment* OR suppl* OR truckload* OR lorryload*)) AND TITLE-ABS-KEY ((transport* AND process* OR moving OR transference OR operation* OR method* OR approach* OR system* OR technique* OR practice* OR "Truck deliver*")))	8	1
18-04-22	Scopus	(TITLE (((suppl* AND relationship*) OR suppl* OR relationship* OR "Supply theory")) AND TITLE-ABS-KEY ((reliab* OR loyal* OR truthful* OR honest* OR	4	2 (1 from snowballing)

		honer* OR "Time deviation of arrival")) AND TITLE-ABS-KEY ((deliver* OR load* OR batch* OR shipment* OR suppl* OR truckload* OR lorryload*)) AND TITLE ((transport* AND process* OR technique* OR "Truck deliver*")))		
19-04-22	Scopus	TITLE ("Supplier* relationship*") AND (LIMIT-TO (OA , "all"))	122	2
19-04-22	Scopus	(TITLE ("Supplier* relationship*") AND TITLE-ABS-KEY (transport*))	3	1
19-04-22	Scopus	(TITLE-ABS-KEY ("Supplier* relationship*") AND TITLE (transport*))	7	8 (4 from snowballing)
19-04-22	Web of Science	Transport* (All Fields) AND "supplier* relationship*" (All Fields) AND deliver* (All fields)	9	1

Key findings

Table 10 shows the details of the articles that have been selected to help answer the research question.

Table 10: Key findings

Number	Title	Author	Year	Key findings
1	Strategic development of third party logistics providers	Susanne Hertz, Monica Alfredsson	2003	Categorization of different types of firms that are used as suppliers in different kind of businesses.
2	The Strategic Benefits of Logistics Alliances	Donald J. Bowersox	1990	Benefits and reasons for failure of logistical alliances
3	INFORMATION FLOWS IN SUPPLY CHAIN MANAGEMENT	Jarkko Rantala	2009	Better information system compatibility is an important development target for the communication systems between transport companies and transport customers
4	How Do Industry 4.0 Technologies Boost Collaborations in Buyer-Supplier Relationships?	Andrea Patrucco, Antonella Moretto, Daniel Trabucchi & Ruggero Golini	2022	Digital technologies improve performance and reduce costs considering buyer-supplier relationships
5	Managing triadic supplier relationships in collaborative innovation projects: a relational view perspective	Andrea Patrucco, Christine Mary Harland, Davide Luzzini, Federico Frattini	2021	Different types of supplier innovations triads
6	Complexity, continuity, and strategic management of buyer–supplier	Martin Pech, Drahoš Vaněček, Jaroslava Pražáková	2021	Larger enterprises engage in more supply chains than smaller ones

	relationships from a network perspective			
7	Improving transport performance in supply networks: effects of (non)overlapping network horizons	Victor Eriksson and Kajsa Hulthén, Ann-Charlott Pedersen	2020	The importance of awareness of the network horizon of different stakeholders to improve reliability of the delivery of supplies.
8	Risk Management Strategies in Transportation Capacity Decisions: An Analytical Approach	Jiho Yoon, Hakan Yildiz, and Srinivas (Sri) Talluri	2016	The strategies 3PL companies can take to improve on-time deliveries
9	Strategic Alliances in Purchasing: Transportation Is the Vital Link	Julie J. Gentry	1993	The importance of sharing information, new technologies and communication between the service providers and buyers, because it has influence on the reliability of the delivery of the supplies.
10	Supplier Partnerships: Influencing Factors and Strategic Benefits	F. Ian Stuart	1993	Elements of traditional supplier relationships and supplier partnering. Moreover, supplier partnerships lead to short-term benefits and long-term gains.
11	Organising logistics and transport activities in construction	Anna Dubois and Kajsa Hulthén, Viktoria Sundquist	2018	Different configurations of transport processes from suppliers to construction sites, and what impact they have on efficiency (reliability) and costs.
12	Reorganizing construction logistics for improved performance	Viktoria Sundquist, Lars-Erik Gadde & Kajsa Hulthén	2018	Strategic actions to improve construction performance (i.e. reliability of deliveries) through enhanced connections between on-site and off-site logistics.
13	Simulation of vehicle movements for planning construction logistics centres	Fei Jin Ying, Michael O'Sullivan, Ivo Adan	2021	Improvements that can be achieved by using logistical centres, in the transport process of building materials to construction sites
14	Variety in freight transport service procurement approaches	Klas Hedvall, Anna Dubois, Frida Lind	2017	Different approaches on handling transport services and how they impact vehicle utilization.
15	A study on the antecedents of supplier commitment in support of logistics operations	Christina W.Y. Wong, Kee-hung Lai, Y.H. Venus Lun and T.C.E. Cheng	2012	Antecedents of supplier commitment and causes for unattained performance goals (i.e. reliable deliveries)

Conceptual matrix

A conceptual matrix checks if there are gaps in the research. It checks for each source which concepts are discussed. Table 11 shows the conceptual matrix. Some articles only give information about some of the concepts, and others cover all concepts. It is a necessity that all concepts are checked and that is the case for this SLR.

Table 11: Conceptual matrix

Articles	**Concepts**			
	Supplier relationships	**Reliability**	**Deliveries**	**Transportation processes**
1	x			
2	x			
3	x			x
4	x	x		
5	x			
6	x			
7	x	x	x	x
8	x	x	x	x
9	x	x	x	X
10	x	x	x	x
11	x	x	x	x
12	x	x	x	X
13	x	x	x	X
14	x	x	x	x
15	x	x	x	x

Appendix B: Transportation service invoices

Appendix B.1 LCW invoice

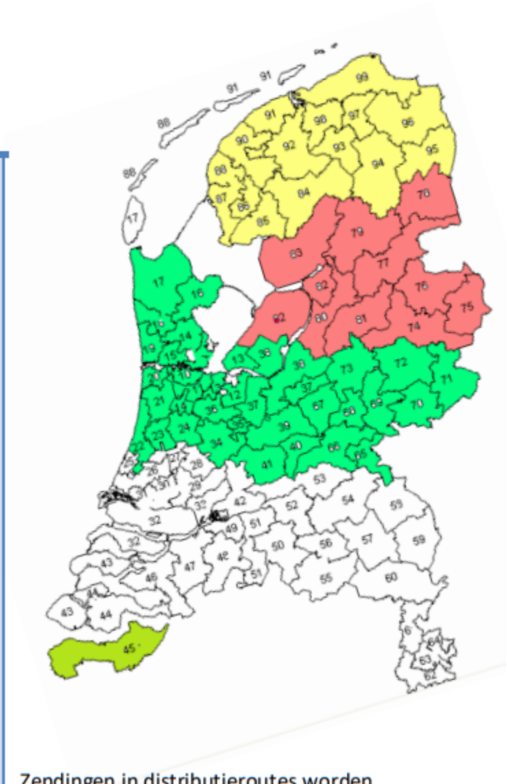
4 zone pallet tarief 2022

Tarief afhankelijk van ingenomen vloerruimte en postcode bezorggebied.
Goederen zijn verpakt op pallets en kunnen zonder extra bescherming worden getransporteerd
De goederen zijn gelijk of kleiner dan de pallet maat. Als een pallet oversteekt is dit niet extra kwetsbaar.

Planning: **050-3667230**
E-Mail : **orders@lcw.nl**

Postcode

pallets	84 t/m 99	74 t/m 83	10 t/m 24 34 t/m 41 65 t/m 73	25 t/m 33 42 t/m 64	45
1	€ 60,89	€ 67,53	€ 73,10	€ 85,26	Zeeuws Vlaanderen Toeslag € 75,00
2	€ 83,03	€ 96,35	€ 111,75	€ 137,33	
3	€ 94,12	€ 110,74	€ 130,96	€ 163,35	
4	€ 105,22	€ 125,12	€ 150,18	€ 189,36	
5	€ 116,26	€ 139,51	€ 169,40	€ 215,37	
6	€ 127,35	€ 153,95	€ 188,56	€ 241,38	
7	€ 138,45	€ 168,34	€ 207,78	€ 267,45	
8	€ 149,49	€ 182,72	€ 227,00	€ 293,46	
9	€ 160,16	€ 195,78	€ 243,24	€ 314,43	
10	€ 170,88	€ 208,84	€ 259,43	€ 335,40	
11	€ 181,55	€ 221,90	€ 275,68	€ 356,42	
12	€ 192,22	€ 234,96	€ 291,92	€ 377,39	
13	€ 202,95	€ 248,07	€ 308,11	€ 398,36	
14	€ 213,62	€ 261,13	€ 324,36	€ 419,38	
15	€ 224,24	€ 274,08	€ 340,49	€ 440,19	
16	€ 233,58	€ 285,55	€ 354,77	€ 458,56	
17	€ 242,97	€ 297,02	€ 369,00	€ 476,92	
18	€ 252,32	€ 308,48	€ 383,23	€ 495,35	
19	€ 261,66	€ 319,90	€ 397,45	€ 513,71	
20	€ 271,00	€ 331,36	€ 411,68	€ 532,08	
21	€ 280,40	€ 342,83	€ 425,91	€ 550,50	
22	€ 289,74	€ 354,30	€ 440,14	€ 568,87	
23-26	€ 299,09	€ 365,76	€ 454,36	€ 587,24	



Zendingen in distributieroutes worden aangeleverd tussen 7:00 uur en 17:00 uur
Tijdsafspraken kunnen alleen worden ingepland bij volle wagenladingen.

LCW Groningen bv

LCW distributie voorwaarden zijn van toepassing.

Appendix B.2 Combex Invoice

COMBEX bouwlogistiek

Aan: Dura Vermeer Bouw Hengelo
T.a.v. Bouwe van der Tuuk
Bosmaatweg 60
7550 AW HENGELO
NEDERLAND

Offertedatum:	17-09-2021
Geldigheidsperiode:	15-09-2021 t/m 31-12-2021

Offerte obv materiaal:	16 t kraan
Min. betalend gewicht:	15000 kg
Max gewicht:	30000 kg

Offertemodel: Tarief per ton per afstand (km)

DOT grondslag literprijs:	€ 1,13
DOT start percentage:	
DOT stijgingspercentage:	1%
DOT grondslag 1e dag van:	maand
DOT interval € / liter	€0,0400

Afstand	Tarief / ton
0-9	€ 6,20
10-19	€ 6,66
20-29	€ 7,11
30-39	€ 7,55
40-49	€ 7,98
50-59	€ 8,40
60-69	€ 8,81
70-79	€ 9,22
80-89	€ 9,61
90-99	€ 10,00
100-109	€ 10,37
110-119	€ 10,74
120-129	€ 11,10
130-139	€ 11,45
140-149	€ 11,79
150-159	€ 12,12
160-169	€ 12,44
170-179	€ 12,76
180-189	€ 13,06
190-199	€ 13,36
200-209	€ 13,65
210-219	€ 13,92
220-229	€ 14,19
230-239	€ 14,45
240-249	€ 14,70
250-259	€ 14,95
260-269	€ 15,18
270-279	€ 15,40
280-289	€ 15,62
290-299	€ 15,83
300-309	€ 16,02
310-319	€ 16,21
320-329	€ 16,39
330-339	€ 16,56
340-349	€ 19,55
350-359	€ 20,00

Randvoorwaarden offerte *Offertecode:* *duraheng_2021_9_17_1*

Annulering dag v laden	70,0 %
Ann. dag vr lad >16:00	25,0 %
Spoed	in overleg
Extra la/lo/stop adres	€ 49,50
Tolkosten	Exclusief
Tunnelkosten	Exclusief
Tijdslevering per adres	€ 45,00
Basis rondrit	rondrit afst.
Betalingstermijn dagen	30
Grondslag tarifering	TLN km
Grondslag DOT	BP adv prijs
NEA indexering	NEA per jr.

Aanvullende informatie:

Betrefdt vervoer af Calduran Harderwijk, Meppel, Zwolle, Apeldoorn.
Overige laadadressen op aanvraag
Projecten met meer dan 5 vrachten op aanvraag

Appendix B.3: Activity information table of the current supply chain

Activity	Delivery Chain	Company	Route	Distance (km)	Total loaded pallets in truck (pallets / execution)	Time of (un)loading execution (min)	Transport Costs (Euros / execution)	Labour Costs (Euros / (un)loading execution)	Storage Costs (Euros / week)	Performed on what working day	Frequency (executions per 4 weeks)
Loading	4	Bribus			16	45		€ 35,63		1	0,5
Loading	5	Mosa			16	45		€ 35,63		1	0,5
Transporting	4	COMBEX	Bribus - Stiho (Utrecht)	117	16		€ 197,62			1	0,5
Transporting	5	COMBEX	Mosa - Stiho (Utrecht)	172	16		€ 234,78			1	0,5
Unloading	4	Stiho (Utrecht)			16	45		€ 35,63		1	0,5
Unloading	5	Stiho (Utrecht)			16	45		€ 35,63		1	0,5
Storing	4, 5	Stiho (Utrecht)			32				€ 64,00	1	4
Loading	4, 5	Stiho (Utrecht)			16	45		€ 35,63		2	1
Transporting	4, 5	COMBEX	Stiho (Utrecht) - Stiho (Groningen)	193	16		€ 245,82			2	1
Unloading	4, 5	Stiho (Groningen)			16	45		€ 35,63		2	1
Storing	4, 5	Stiho (Groningen)			16				€ 32,00	2	4
Loading	1	Kegro			2	17		€ 13,46		3	4
Loading	2	Rensa			2	17		€ 13,46		3	4
Loading	3	Afbouw-Centrum			2	17		€ 13,46		3	4
Loading	4, 5	Stiho (Groningen)			4	21		€ 16,63		3	4
Transporting	1	LCW	Kegro - LCW	204	2		€ 111,75			3	4
Transporting	2	LCW	Rensa - LCW	169	2		€ 111,75			3	4
Transporting	3	LCW	Afbouw-Centrum - LCW	32	2		€ 83,03			3	4
Transporting	4, 5	LCW	Stiho (Groningen) - LCW	14	4		€ 105,22			3	4
Unloading	1	LCW			2	17		€ 13,46		3	4
Unloading	2	LCW			2	17		€ 13,46		3	4
Unloading	3	LCW			2	17		€ 13,46		3	4
Unloading	4, 5	LCW			4	21		€ 16,63		3	4
Storing	1, 2, 3, 4, 5	LCW			10				€ 20,00	3	4
Loading	1, 2, 3, 4, 5	LCW			10	33		€ 26,13		4	4
Transporting	1, 2, 3, 4, 5	LCW	LCW - G. Borgesiuslaan	11	10		€ 170,88			4	4
Unloading	1, 2, 3, 4, 5	LCW			10	33		€ 26,13		4	4

Appendix B.4: Explanation on calculations

Table

Appendix B.3 shows the table that gives information on each activity that is performed in the current supply chain. The delivery chain number is mentioned in the second column. The next three columns give information on transport activities, where the company, route, and distance are given. The sixth column describes the number of pallets that the activity handles, which is needed for the calculations of the time of (un)loading the trucks, transport costs, labour costs, and storage costs. The last column gives the frequency of the activity, which means the number of times that the activity is performed in four weeks. Note that some activities are performed only once every eight weeks with a higher number of loaded pallets, and other activities are performed every week with a lower load.

Calculations

The labour costs are calculated with the following formulas:

$$\text{Loading time (in min)} = 13 + 2 * \text{Number of loaded pallets}$$

$$\text{Labour costs (in euros)} = (\text{Loading time} \;/\; 60) * 47.50$$

The formula of the loading time is used by LCW to calculate the number of minutes it takes to load or unload a truck with a certain number of loaded pallets. On their invoices they state that it takes a standard 13 minutes per stop with 2 minutes per loading unit (pallet location). This formula can therefore be used at all activities of our supply chain since it gives a good representation on the amount of time it takes for the (un)loading activities. Then the labour costs are calculated with an hourly labour cost rate that is also collected from multiple invoices received from LCW, which is 47.50 euros per hour. Note that these formulas are used at all (un)loading activities of the total supply chain, while their origin comes from the company LCW, which is not involved at all activities. These formulas are used to get a general calculation on the labour costs, which are needed to investigate the effects that changes of the process could have. The only input needed at each (un)loading activity is the number of pallets that are moved.

The storage costs are calculated with the following formula:

$$\text{Storage costs (in euros)} = \text{Number of stored pallets} * \text{Costs per pallet}$$

From many invoices that are collected from LCW, an amount of 2.00 euros per square meter was found. For this research, an assumption is made what a general price of storing one pallet is per week. Because LCW uses 2.00 euros per square meter per week, this amount is taken as the general price per pallet per week. Note that this does not consider storing pallets onto each other and it simplifies the calculation of the storage costs, since it takes the costs per pallet and not per square meter. Also, the price differences between locations in the country is not regarded. These factors are not considered because this would make the calculations of the storage costs too complex and from the interview with the logistics manager, it was concluded that 2.00 euros per pallet is a good enough estimation of storage costs. The storage costs can therefore be calculated with the number of stored pallets as input.

Transportation costs mostly depend on the distance between the starting location and the destination, and the weight/size of the truckload that is transported. These are therefore the most important factors to analyse in our supply chain network. The transport costs are calculated with the distance of each transportation activity and an invoice from Combex or LCW. Combex is a construction logistics transport company, which is used to transport building materials from point A to B all over the Benelux. Their invoice on transport costs per kilometre can therefore be used as general transport prices for certain activities in our supply chain network. This is also the case for the LCW invoice. LCW is the logistical centre that is used as a distribution hub for multiple construction projects in Groningen. They provide storage and transport services. Appendices B.1 and B.2 show the invoices used to calculate the transportation costs.

Appendix B.1 shows the invoice collected from LCW. LCW uses different prices for different transportation services. The price increases per extra pallet that is transported. There is a minimum of one pallet and a maximum of 26 pallets, and the price increases until a number of 23 pallets is reached. The prices from the invoice of LCW can be used to calculate the transport costs from suppliers to LCW and from LCW to the construction site. The costs are collected from the invoice, considering the number of pallets that are transported and which postal code the location of the supplier or construction site uses.

Appendix B.2 shows the invoice collected from Combex. Just like LCW, the price varies between truckload sizes and transportation distances. Combex calculates their price per tons and kilometres. The price increases per 10 kilometres that are added to the total distance, and the price indicated on the invoice is per ton. One pallet is considered to weigh 1150 kilograms. This number is collected from the invoice description of LCW. The transport costs from the suppliers to the subcontractor Company F and the intermediate transportation between distribution centres of Company F can be derived from the invoice of Combex. Note that this invoice has a minimum of 15 tons. From interviews with the logistics manager, it was concluded that the transportation from suppliers to the subcontractor Company F and the transportation between distribution centres of Company F have a higher truckload (above the minimum 15 tons) and a lower frequency (number of times the service is executed in a period). This makes the Combex invoice ideal to calculate these transportations where intermediate distribution centres are present. The costs are again collected from the table, considering the number of tons that are transported and the distance between the starting point and destination of the service.

Assumptions

To describe each activity and make calculations, a lot of assumptions are made and need to be reported. The assumptions are the following:

- The only activities that are significant to scope out are loading the trucks, unloading the trucks, transporting the trucks, storing the building materials
- Distances between stakeholders collected from google maps are a good representation of reality
- The times of the transporting from point A to point B collected from google maps are a good representation of reality
- Company D and Company E deliver a higher truckload (above 15 tons) at a lower frequency to Company F in Utrecht
- Company F in Utrecht delivers a higher truckload (above 15 tons) at a lower frequency to Company F in Groningen
- From each supplier a total of 2 pallets per week is needed
- The formula with which LCW calculated (un)loading times is a good representation of reality for all (un)loading activities
- The invoice from Combex give a good representation of real general prices for transport costs of all transport activities before the arrival at LCW
- The invoice from LCW give a good representation of real general prices for transport costs of all transport activities to and from LCW

- The general hourly labour costs are 47.50 euros per hour
- The general storage cost is 2.00 euros per pallet per week
- One pallet has a weight of 1150 kg
- The diesel surcharge need not to be considered when calculating the transportation costs
- Special loading techniques for certain types of building materials are disregarded
- All activities are only performed for the construction site at Goeman Borgesiuslaan in Groningen, and possible other pallets for other customers are disregarded.
- The distances that trucks must drive without their load need not to be considered

Appendix C: Activity information tables of the solution scenarios

Appendix C.1 Activity information of Scenario 1

Activity	Delivery Chain	Company	Route	Distance (km)	Total loaded pallets in truck (pallets / execution)	Time of (un)loading execution (min)	Transport Costs (Euros / execution)	Labour Costs (Euros / (un)loading execution)	Storage Costs (Euros / week)	Performed on what working day	Frequency (executions per 4 weeks)
Loading	1	Kegro			2	17		€ 13,46		1	4
Loading	2	Rensa			2	17		€ 13,46		1	4
Loading	3	Afbouw-Centrum			2	17		€ 13,46		1	4
Loading	4	Bribus			2	17		€ 13,46		1	4
Loading	5	Mosa			2	17		€ 13,46		1	4
Transporting	1	LCW	Kegro - LCW	204	2		€ 111,75			1	4
Transporting	2	LCW	Rensa - LCW	169	2		€ 111,75			1	4
Transporting	3	LCW	Afbouw-Centrum - LCW	32	2		€ 83,03			1	4
Transporting	4	LCW	Bribus - LCW	183	2		€ 111,75			1	4
Transporting	5	LCW	Mosa - LCW	331	2		€ 137,33			1	4
Unloading	1	LCW			2	17		€ 13,46		1	4
Unloading	2	LCW			2	17		€ 13,46		1	4
Unloading	3	LCW			2	17		€ 13,46		1	4
Unloading	4	LCW			2	17		€ 13,46		1	4
Unloading	5	LCW			2	17		€ 13,46		1	4
Storing	1, 2, 3, 4, 5	LCW			10				€ 20,00	1	4
Loading	1, 2, 3, 4, 5	LCW			10	33		€ 26,13		2	4
Transporting	1, 2, 3, 4, 5	LCW	LCW - G. Borgesiuslaan	11	10		€ 170,88			2	4
Unloading	1, 2, 3, 4, 5	LCW			10	33		€ 26,13		2	4

Appendix C.2 Activity information of Scenario 2

Activity	Delivery Chain	Company	Route	Distance (km)	Total loaded pallets in truck (pallets / execution)	Time of (un)loading execution (min)	Transport Costs (Euros / execution)	Labour Costs (Euros / (un)loading execution)	Storage Costs (Euros / week)	Performed on what working day	Frequency (executions per 4 weeks)
Loading	2	Mosa			2	17		€ 13,46		1	4
Transporting	2	LCW	Mosa - Kegro	126	2					1	4
Loading	2	Kegro			2	17		€ 13,46		1	4
Transporting	2	LCW	Kegro - Bribus	54	4					1	4
Loading	2	Bribus			2	17		€ 13,46		1	4
Transporting	2	LCW	Bribus - Afbouw-Centrum	150	6					1	4
Loading	1	Rensa			2	17		€ 13,46		1	4
Loading	2	Afbouw-Centrum			2	17		€ 13,46		1	4
Transporting	1	LCW	Rensa - LCW	169	2		€ 111,75			1	4
Transporting	2	LCW	Afbouw-Centrum - LCW	32	8		€ 293,46			1	4
Unloading	1	LCW			2	17		€ 13,46		1	4
Unloading	2	LCW			8	29		€ 22,96		1	4
Storing	1, 2	LCW			10				€ 20,00	1	4
Loading	1, 2	LCW			10	33		€ 26,13		2	4
Transporting	1, 2	LCW	LCW - G. Borgesiuslaan	11	10		€ 170,88			2	4
Unloading	1, 2	LCW			10	33		€ 26,13		2	4

Appendix C.3 Activity information of Scenario 3

Activity	Delivery Chain	Company	Route	Distance (km)	Total loaded pallets in truck (pallets / execution)	Time of (un)loading execution (min)	Transport Costs (Euros / execution)	Labour Costs (Euros / (un)loading execution)	Storage Costs (Euros / week)	Performed on what working day	Frequency (executions per 4 weeks)
Loading	4	Bribus			26	65		€ 51,46		1	0,307692308
Loading	5	Mosa			26	65		€ 51,46		1	0,307692308
Transporting	4	COMBEX	Bribus - Stiho (Utrecht)	117	26		€ 321,13			1	0,307692308
Transporting	5	COMBEX	Mosa - Stiho (Utrecht)	172	26		€ 381,52			1	0,307692308
Unloading	4	Stiho (Utrecht)			26	65		€ 51,46		1	0,307692308
Unloading	5	Stiho (Utrecht)			26	65		€ 51,46		1	0,307692308
Storing	4, 5	Stiho (Utrecht)			52				€ 104,00	1	4
Loading	4	Stiho (Utrecht)			26	65		€ 51,46		2	0,307692308
Loading	5	Stiho (Utrecht)			26	65		€ 51,46		2	0,307692308
Transporting	4	COMBEX	Stiho (Utrecht) - Stiho (Groningen)	193	26		€ 399,46			2	0,307692308
Transporting	5	COMBEX	Stiho (Utrecht) - Stiho (Groningen)	193	26		€ 399,46			2	0,307692308
Unloading	4	Stiho (Groningen)			26	65		€ 51,46		2	0,307692308
Unloading	5	Stiho (Groningen)			26	65		€ 51,46		2	0,307692308
Storing	4, 5	Stiho (Groningen)			26				€ 52,00	2	4
Loading	1	Kegro			26	65		€ 51,46		3	0,307692308
Loading	2	Rensa			26	65		€ 51,46		3	0,307692308
Loading	3	Afbouw-Centrum			26	65		€ 51,46		3	0,307692308
Loading	4	Stiho (Groningen)			26	65		€ 51,46		3	0,307692308
Loading	5	Stiho (Groningen)			26	65		€ 51,46		3	0,307692308
Transporting	1	LCW	Kegro - LCW	204	26		€ 454,36			3	0,307692308
Transporting	2	LCW	Rensa - LCW	169	26		€ 454,36			3	0,307692308
Transporting	3	LCW	Afbouw-Centrum - LCW	32	26		€ 299,09			3	0,307692308
Transporting	4	LCW	Stiho (Groningen) - LCW	14	26		€ 299,09			3	0,307692308
Transporting	5	LCW	Stiho (Groningen) - LCW	14	26		€ 299,09			3	0,307692308
Unloading	1	LCW			26	65		€ 51,46		3	0,307692308
Unloading	2	LCW			26	65		€ 51,46		3	0,307692308
Unloading	3	LCW			26	65		€ 51,46		3	0,307692308
Unloading	4	LCW			26	65		€ 51,46		3	0,307692308
Unloading	5	LCW			26	65		€ 51,46		3	0,307692308
Storing	1, 2, 3, 4, 5	LCW			130				€ 260,00	3	4
Loading	1, 2, 3, 4, 5	LCW			10	33		€ 26,13		4	4
Transporting	1, 2, 3, 4, 5	LCW	LCW - G. Borgesiuslaan	11	10		€ 170,88			4	4
Unloading	1, 2, 3, 4, 5	LCW			10	33		€ 26,13		4	4

Appendix C.4 Activity information of Scenario 4

Activity	Delivery Chain	Company	Route	Distance (km)	Total loaded pallets in truck (pallets / execution)	Time of (un)loading execution (min)	Transport Costs (Euros / execution)	Labour Costs (Euros / (un)loading execution)	Storage Costs (Euros / week)	Performed on what working day	Frequency (executions per 4 weeks)
Loading	1	Kegro			26	65		€ 51,46		1	0,307692308
Loading	2	Rensa			26	65		€ 51,46		1	0,307692308
Loading	3	Afbouw-Centrum			26	65		€ 51,46		1	0,307692308
Loading	4	Bribus			26	65		€ 51,46		1	0,307692308
Loading	5	Mosa			26	65		€ 51,46		1	0,307692308
Transporting	1	LCW	Kegro - LCW	204	26		€ 454,36			1	0,307692308
Transporting	2	LCW	Rensa - LCW	169	26		€ 454,36			1	0,307692308
Transporting	3	LCW	Afbouw-Centrum - LCW	32	26		€ 299,09			1	0,307692308
Transporting	4	LCW	Bribus - LCW	183	26		€ 454,36			1	0,307692308
Transporting	5	LCW	Mosa - LCW	331	26		€ 587,24			1	0,307692308
Unloading	1	LCW			26	65		€ 51,46		1	0,307692308
Unloading	2	LCW			26	65		€ 51,46		1	0,307692308
Unloading	3	LCW			26	65		€ 51,46		1	0,307692308
Unloading	4	LCW			26	65		€ 51,46		1	0,307692308
Unloading	5	LCW			26	65		€ 51,46		1	0,307692308
Storing	1, 2, 3, 4, 5	LCW			130				€ 260,00	1	4
Loading	1, 2, 3, 4, 5	LCW			10	33		€ 26,13		2	4
Transporting	1, 2, 3, 4, 5	LCW	LCW - G. Borgesiuslaan	11	10		€ 170,88			2	4
Unloading	1, 2, 3, 4, 5	LCW			10	33		€ 26,13		2	4

Appendix C.5 Activity information of Scenario 5

Activity	Delivery Chain	Company	Route	Distance (km)	Total loaded pallets in truck (pallets / execution)	Time of (un)loading execution (min)	Transport Costs (Euros / execution)	Labour Costs (Euros / (un)loading execution)	Storage Costs (Euros / week)	Performed on what working day	Frequency (executions per 4 weeks)
Loading	2	Mosa			6	25		€ 19,79		1	1,333333333
Transporting	2	LCW	Mosa - Kegro	126	6					1	1,333333333
Loading	2	Kegro			6	25		€ 19,79		1	1,333333333
Transporting	2	LCW	Kegro - Bribus	54	12					1	1,333333333
Loading	2	Bribus			6	25		€ 19,79		1	1,333333333
Transporting	2	LCW	Bribus - Afbouw-Centrum	150	18					1	1,333333333
Loading	1	Rensa			26	65		€ 51,46		1	0,307692308
Loading	2	Afbouw-Centrum			6	25		€ 19,79		1	1,333333333
Transporting	1	LCW	Rensa - LCW	169	26		€ 454,36			1	0,307692308
Transporting	2	LCW	Afbouw-Centrum - LCW	32	24		€ 587,24			1	1,333333333
Unloading	1	LCW			26	65		€ 51,46		1	0,307692308
Unloading	2	LCW			24	61		€ 48,29		1	1,333333333
Storing	1, 2	LCW			50				€ 100,00	1	4
Loading	1, 2	LCW			10	33		€ 26,13		2	4
Transporting	1, 2	LCW	LCW - G. Borgesiuslaan	11	10		€ 170,88			2	4
Unloading	1, 2	LCW			10	33		€ 26,13		2	4