MASTER

Managing container sequencing to enhance the efficiency in the international transport chains

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Managing container sequencing to enhance the efficiency in the international transport chains

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Abstract

This thesis describes the sequencing process in the international transportation leg. Sequencing denotes the alignment of two or more flows in order to enhance the efficiency. The complexity of sequencing in the transportation leg exists because of governmental regulations and controls and the involvement of multiple partners. First a literature review about the transportation leg and the sequencing process is provided; subsequently a case study is presented of one of the customers of Seacon Logistics. This client is a manufacturer of high value goods. The vulnerability in the transportation leg of this client is that the components of their products are manufactured in two different countries, in Sweden and the Netherlands, but due to governmental regulations and controls the parts need to be sequenced during the transportation.

First, the lead-times of the current situation are determined to indicate the main problems of the transportation leg. In order to determine the causes and consequences of sequencing the current routes are modelled as a Bayesian Network. The main cause of disruptions in the sequencing process is caused by the decision of the ocean carrier to change the bookings of the containers. The consequences are especially high variances in the port's waiting times.

Management summary

This thesis provides the results of the impact of sequencing in the international transportation leg. Sequencing denotes the alignment of two or more flows in order to enhance the efficiency. The investigated transportation leg belongs to one of the customers of Seacon Logistics. Seacon Logistics is active as chain manager with a maritime character and is in this international transportation leg responsible for the arrangement of the transportation of the goods to Malaysia and Thailand.

This thesis focuses on the sequencing process in the international transportation leg. Sequencing is essential because the components of the client are manufactured at two different locations, in Sweden and the Netherlands. When the containers with the components are sequenced during transportation it results in financial benefits for the client. The import taxes are 12% lower if the containers from Sweden and the Netherlands arrive simultaneously in Malaysia. For Thailand the import taxes are 30% lower if the containers from Sweden and the Netherlands arrive at least four days from each other. Sequencing is a well-known subject in the production logistics and aims to enhance the efficiency by aligning two or more flows. However, sequencing in the transportation literature is an undiscovered field. Currently, the sequencing process for the client results in a more complex transportation leg with longer lead-times instead of enhanced efficiency. To address this problem the following research question is formulated:

How can Seacon Logistics manage the sequencing process in the international transportation leg?

The data analysis for both countries encompasses the track and trace information of 2014 and 2015 for batches sent from Sweden and the Netherlands to Malaysia and Thailand. Complete data is obtained for 52 and 35 batches respectively. For Malaysia the containers are transported via four different routes, in which the containers are sequenced in three different ports; the port of Rotterdam, Singapore or Tanjung Pelepas. The sequencing process in the transportation leg to Malaysia experiences long lead-times, which are mainly caused by tardy waiting times in the ports. The mean and variance of the waiting times are striking in the ports of sequencing and in Port Klang.

For Thailand the containers are transported via seven routes. In order to make the data more aggregated these seven routes are combined into four routes. These are selected based on the transhipment port; the port of Singapore and Tanjung Pelepas. The sequencing process in the transportation leg to Thailand results in almost no consequences for the waiting time in the ports. This is probably caused by the containers from Sweden and the Netherlands being considered as

individual flows as long as the containers arrive outside the four day interval. Conserving the limited impact of sequencing and the limited amount of available data, this transportation leg is not included in the data analyses.

The waiting times in the ports are modelled as Bayesian Networks (BNs). BNs are a directed acyclic graph that graphically describes the direct dependencies between variables. The structure of the BN consists of direct graphs that visualises the dependencies between the nodes and node probability tables (NPTs) which shows the probability distribution. The nodes present the waiting time in the ports and the NPTs show the probability distribution. The tardy waiting times are split up based on the particular causes in order to determine the causes and consequences of the tardy waiting time.

In total 72 containers experience tardiness due to sequencing. The conditional probabilities of the causes of these tardy waiting times are shown in Table 1. Based on this table it can be concluded that the main cause (40%) of tardiness related to sequencing is a 'vessel network change'. Except for the causes 'missing shipping instructions' and 'unforeseen contingency', all the causes (93%) originate from decisions of the ocean carrier.

Probability of sequencing in the transportation leg sorted by cause						
	Number of containers		Number of batches		Conditional probabilities	
	Acceptable WT	Tardy WT	Acceptable WT	Tardy WT	Acceptable WT	Tardy WT
Vessel network change	9	29	3	2	26%	40%
Limited vessel capacity	10	15	4	4	29%	21%
Unknown	16	0	3	2	46%	0%
Vessel cut and run		10		1	0%	14%
Omitted port		9		1	0%	13%
Cargo ETA earlied/advanced		4		1	0%	6%
Missing shipping instructions		3		1	0%	4%
Unforeseen contingency		2		1	0%	3%
Total	35	72	10	13	100%	100%

Table 1: Conditional probabilities of tardiness due to sequencing

To conclude, the consequences of sequencing are longer waiting times in the ports, which are caused by buffer times, tardy waiting times in the port where the containers are sequenced, and tardy waiting times in Port Klang. The first two consequences are direct related to the alignment of the two flows. However, the third consequence is not directly related. Containers that do not experience tardy waiting times related to sequencing also experience tardy waiting times in Port Klang. The containers that experience tardiness due to sequencing are for 93% related to decisions of the ocean carrier to change vessel, or to which change the departure and arrival details of the containers. If the ocean carrier adheres the planned booking of the containers, these tardy waiting times can be avoided. Besides avoiding re-scheduling, it is beneficial to book the sequencing process in the port of Rotterdam, which enhances the control of Seacon Logistics.

Preface

This report is the result of my graduation project that has been conducted at Seacon Logistics in completion of the Master Operations Management and Logistics at Eindhoven University of Technology. With the accomplishment of my Master, another phase of my live is finished. Therefore, I would like to thank same people who supported me during my graduation projects and my Master.

First of all, I would like to thank my mentor, and first supervisor of the TU/e, Albert Veenstra. I am thankful for his available time to support me during my project, to answer my questions, and to provide new insights and advises to help me to successfully finish this graduation project. I also would like to thank my second supervisor of the TU/e, Zümbül Atan, for her time to evaluate my project. Also I would like to thank Mete Sevinvç PHD student at the TU/e, who supported me with constructing the Bayesian Networks.

Secondly, I would like to thank all the people from Seacon Logistics who supported me and answered all my questions. Special thanks go to Joris Tenhagen, for his involvement, feedback, and enthusiasm for my project. I am also grateful for the support of Scott Raadschelders, who gave critical and useful comments on my report, and Johan Vosbeek who answered all my questions and provided insights for the case study. Next to them, I also would like to thank the colleagues of Business Development Department, Export Overseas Department, and Import and Customs Department for their help and feedback. I am also grateful to my contacts at the client and the ocean carrier who answered all my questions related to the case study.

Last but not least, I would like to thank my family and friends. Special thanks for my parents for the support and advises during these years. Next to them, also special thanks go to my boyfriend who helped me to improve my report and supported me when I needed it. Furthermore, I would like to thank my friends for their advices and feedback.

Daphne van Immerseel

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List of abbreviations

In this chapter the used abbreviations are explained.

Abbreviation	Explanation	Abbreviation	Explanation
ATA	Actual time of arrival	MYKLA	Port code for Port Klang
ATD	Actual time of departure	MYTPP	Port code for the port of Tanjung Pelepas
B/L	Bill of Loading	NL	The Netherlands
BN	Bayesian Network	NLRTM	Port code for the port of Rotterdam
BPM	Business Process modelling	LD	Lead-time
BPR	Business Process Reengineering	RCP	Regional Product Centre
CCD	Container Closing Date	SCC	Supply Chain Council
CRD	Container Ready Date	SCOR	Supply Chain Operations Reference
DMAIC	Define, Measure, Analyse, Implement and Control	SE	Sweden
ETA	Estimated time of arrival	SEGOT	Port code for the port of Sweden
ETD	Estimated time of departure	SGSCT	Port code for the port of Singapore
ICC	International Chamber of Commerce	TH	Thailand
IMO	International Maritime Organisation	THLCH	Port code for the port of Laem Chabang
ISRCM	International Supply Chain Reference Model	TQM	Total Quality Management
JTQC	Japanese Total Quality Control	WT	Waiting time
MY	Malaysia		

1. Introduction

This chapter provides some general information is provided about Seacon Logistics and the sequencing problem. Subsequently the research background, research questions, and research scope are provided.

1.1 Company description

Seacon Logistics was started in 1985 as a family-owned company that is specialised in overseas forwarding. Currently Seacon Logistics is active as chain director with a maritime character. They have a presence in more than 75 countries around the world which are accomplished by collaborations. Besides to overseas logistics, Seacon also offers warehousing, European distribution, and supply chain solutions.

At present, more than 700 employees are working at various locations all over the world. Their head office is located in Venlo, the Netherlands. Most other locations are in Europe, but some are located in Russia, United States, and India.

1.2 CORE project

This thesis is part of the CORE project, which stands for ‘Consistently Optimised REsilient’. CORE aims to develop solutions for protecting and securing global supply chains, and aims to reduce its vulnerability to disruptions, whilst guaranteeing a timely and efficient flow of legitimate commerce through the European Union (EU) and other continents. The CORE project elaborates existing solutions from reference projects, for example CASSANDRA, INTEGRITY, SUPPORT, EUROSKY, and e-Freight (CORE, 2015).

Seacon Logistics is one of the partners of CORE, and participates in a subproject focused on the Trusted Trade Lane concept. One of the lanes which is part of this project is used as a case study for this thesis. This company is a manufacturer of high value products and is a customer of Seacon Logistics. Due to confidentiality issues the identity of this company is kept anonymous, in this research this company is referred to as the ‘client’.

1.3 Research background

In the current situation, the client has to cope with vulnerabilities in their trade lane. This is mainly the case in the lanes to Malaysia and Thailand. Both lanes encounter risks because the manufacturing sides are split up in two countries, Sweden and the Netherlands, and due to country specific custom regulation and tariffs. Despite the two different loading locations, customs require that the containers belonging to same order need to arrive simultaneously in Malaysia. In Thailand the requirements of customs are opposite; the arrival of the containers from both loading locations should have at least four days in between. If these demands are not met, respectively 12% and 30%, extra import taxes need to be paid for the goods. For that reason it is beneficial to align the arrival of the containers from both loading locations in order to meet the custom demands. Sequencing containers in transportation legs is comparable to sequencing components in the assembly system. In an assembly system, components are combined to form subassemblies, which are eventually combined to form end items (Nahmias, 2009). Not every combination of parts into subassemblies is allowed, feasible assemblies have to meet the product and precedence constraints; "sequencing" deals with these combinatorial problems (Jiménez, 2011).

This thesis aims to investigate the possibility to apply sequencing in the international transportation leg. Aligning the containers for delivery in the port of destination includes sequencing two flows of containers, in which custom regulations and controls have to be taken into account. In the current literature, there is an absence of research about sequencing in the transportation leg. However, a lot of literature can be found about assembly and sequencing in the production environment, with well-known authors such as M.L. Fisher, A.J. Clark and H. Scarf. Well-known industries who apply assembly and sequencing are the electronic industry, e.g. Dell, and the automotive industry, e.g. Toyota, Hyundai and Renault. These industries are characterized by mass-production, high customization, and high product variability. Assembly and sequencing are mainly applied to enhance efficiency in internal logistics and material management. Applying sequencing in the transportation literature is a new dimension because it mainly focuses on external logistics.

1.4 Research questions

In both the transportation leg to Malaysia and Thailand the client deals with sequencing, which currently results in a more complex supply chain with longer lead-times. To investigate this problem the following research question is formulated:

How can Seacon Logistics manage the sequencing process in the international transportation leg?

In order to answer the research question, multiple sub-questions are formulated:

1. Which characteristics define the transportation leg?
2. What is the role of the distribution of responsibilities over partners?
3. What is the function of sequencing?
4. What is the impact of sequencing in the transportation leg?
5. How to measure effectiveness of control within the transportation leg?

1.5 Scope

The investigated transportation leg starts when the goods are loaded in containers which are used for transportation overseas, and finishes when the containers leave the gate in the port of destination. All transport activities before loading are not included and therefore do not influence the lead-time of the transportation leg. The port of destination in Malaysia is Port Klang and in Thailand it is Laem Chabang. Consequently, when the containers leave the port of destination the transportation time is not included in the lead-time of the transportation leg.

The lead-time is measured in days. Some arrivals or departures of containers during the transportation are noted with date and time features. Notation based on date and time features is more accurate than notation based solely on date features. However, not all steps are noted with time features, and therefore only the dates are used to determine lead-times. This implies that if containers are discharged in a port and loaded on a vessel on the same day the waiting time is zero days, while the containers stood at least a few hours in the gate.

The measured lead-times are split up in transit and waiting times. If waiting times are longer than the acceptable limits, which are defined in paragraph 4.4, the waiting time is considered as tardy. No official terminology is defined for unacceptable waiting times, therefore unacceptable waiting times are defined in this thesis as tardy waiting times or tardiness.

1.6 Methodology

The first step to answer the research question is performing a literature review. To collect literature, a list of search options was set up to search in books, journals and online databases. Appendix 1 shows the list of search options. The books that are used are mainly derived for educational facilities. The databases that are used are the databases accessible through the University of Technology Eindhoven and University of Maastricht. Based on the search options a list of articles is created. To structure the articles for use of this research the articles are screened on; the subject of the article based on the key words, the relevance, the reliability and the published date of the article. The reliability is tested based on the author, the institution where the author is from, and if it is used as source for other articles. Due to the screening on these aspects the articles can be compared to each other.

After the literature review a case study is carried out. A case study emphasizes the full and detailed contextual analysis of a single or more events/ conditions and their relations for a single subject or respondent (Blumberg et al., 2011). The primary data for this case study was collected from employees of the client, Seacon Logistics and the ocean carrier. The relevant employees at the client are involved with international transport and customs. At Seacon Logistics interviews are held with employees who arrange the import, export and custom activities. The interviews are conducted with an unstructured method; the interviews are used to get an insight in the current situation, perceived problems and to verify causes of disruptions in the transportation leg. Secondary data are track and trace information, which is provided by the ocean carrier, the client and Seacon Logistics and are combined into an integrated dataset.

After the data collection the transportation is analysed based on transit times and waiting times. Subsequently, an analysis is performed to determine the lead-time and the variability in the transportation leg. With this statistical analyse it is possible to provide an overview of the current performance and the problems resulting from sequencing errors. Based on these results the causes of deviation in the waiting times are investigated. If the causes are known, conditional probabilities are calculated to determine the origin of the waiting times. For instance, if additional waiting times occur due to sequencing, it is important to determine the reason that caused the long waiting time. The conditional probabilities provide insight in the probability of tardiness related to sequencing or other disruptions in the transportation leg.

1.7 Outline report

Chapter 2 summarises the available literature which contributes to answering the research questions. Chapter 3 provides insight in the case study. The trade lanes to Malaysia and Thailand are discussed in detail and both lead-times are split up in transit and waiting times. Chapter 4 analyses the causes and consequences of sequencing. Also it compares the expected lead-time of the client and the ocean carrier with the average lead-time obtained from the track and trace information. The last chapter includes the discussion, conclusion, limitations and further research, and recommendations.

2. Literature review

This chapter provides a literature review with insights in the characteristics of the international transportation leg, its partners, sequencing, and organisational approaches to control processes.

2.1 The role of transportation in the supply chain

Transport is a key function as it acts as a physical link between parties in the supply chain, enabling the flow of materials and resources (Naim et al., 2006). However, transport operations are generally not considered as an important part of the supply chain. It is more often the result of supply chain decisions (Veenstra et al., 2012) and is seen as a supporting partner instead of a primary partner (Świerczek, 2014). Transport operations are determined by decision making at higher levels of logistics management and global supply chain management, see Figure 1. Global supply chain management makes decisions based on strategic issues such as locations for manufacturing and markets. The decisions made by the logistics management covers subjects as inventory strategies, warehouse locations, choice of volume and frequency of transport, modes and port choices. Within that concept, transportation decisions take place (Veenstra et al., 2012).

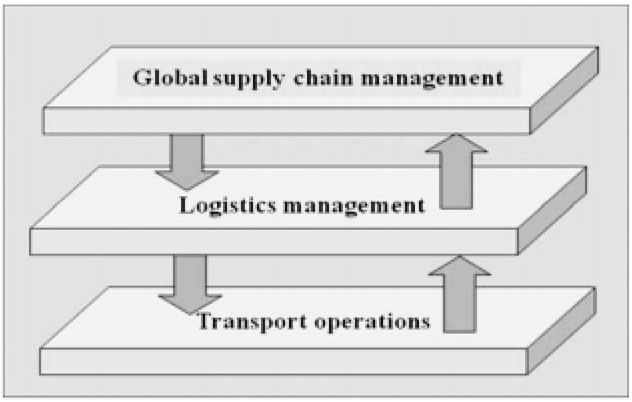

Figure 1: Supply chain-logistics-transportation hierarchy (Veenstra et al. 2012)

This thesis focuses on global transport operations, in which an important aspect is to deal with government regulations and controls. The control activities are performed by the customs department and occur if the physical movement of goods crosses country borders. This can make the movement of goods more complex; any person or organization moving people or goods across international frontier faces challenges and decisions that are not experienced when movements are entirely within one country (Higginson, 2013). The border of a country indicates a change in policies, procedures, rules and often cultures and ideologies. Activities at a border crossing are intended to maintain the security and eliminate threats to that border, or to the residents of that country (Higginson, 2013). Issues related to crossing borders are split up by Higginson (2013) into three general categories:

1. High cost of crossing borders; such as administrative costs or inventory carrying costs due to irregular crossing times.

2. Long and unpredictable waiting and inspection times; as a result of from scarce border infrastructure, complex processes and procedures, lacking information sharing, and technology and systems failures.
3. Miscellaneous issues; such as multiple jurisdiction and overlapping regulation which influence either or both time or costs.

Besides to the physical flow also an informational flow needs to be considered. The flow of information is related to identification, delivery and government control of transported goods. Trade documents enforce controls to ensure that imported and exported goods meet requirements laid down by international trade agreements, paid customs duties and trade control policies, e.g. health, safety and other regulatory requirements (Teo et al., 1997). Being able to control and improve cross-border trade processes could reduce logistic inefficiencies, encourage trade, improve supply chain performance and in the long run increase the competitiveness of countries. It is not just to monitor lead-times and operational costs; mistakes in cross-border processes could also result in significant penalties or fines, and causes additional delays in the transportation leg (Hausman et al., 2010).

Before controlling and improving processes, not only in cross-border activities, but in the total transportation leg, it is valuable to have full insight in all processes in the transportation leg. There is need for a way to structure the processes due to the complex processes and multiple partners. Mapping the transportation leg is a conceivable way for to gain insight in the processes. A well-known method for modelling processes is Business Process Modelling (BPM) which makes use of petri nets to illustrate processes and their relationships and simulate different scenarios. Another method, specifically developed to model supply chains is Supply Chain Operations Reference (SCOR). This model is developed by Supply Chain Council (SCC) and describes the processes involved in supply chain management, including planning and executing steps. The extension of the SCOR model is the International Supply Chain Reference Model (ISRCM), developed by UN/CEFACT/TBG-International Trade Procedures and Business Process Analysis Groups. This model is developed to provide a common reference for standards development, trade simplification actions, and harmonization of business and administrative burden. The strength of ISRCM is that it is feasible to model the physical and information flow in relations with the partners in one overview.

2.2 Partners in the transportation leg

The number of partners in the supply chain can be enormous, especially when all companies are included that are involved indirectly through suppliers or customers, from point of origin to point of consumption. In order to structure the partners in the supply chain, Lambert and Cooper (2002) define two types of partners; primary and supporting partners. Primary partners are defined as all autonomous companies or strategic business units who carry out value- adding activities in the business processes designed to produce a specific output for a particular customer or market. Supporting partners are companies that provide resources, knowledge, utilities or assets for the primary members of the supply chain; their activities do not acquire and transfer the ownership of the products.

In the transportation leg the two primary partners are the supplier and the buyer; the movement of goods exist because of the transaction between them. Past decades, the relationship between buyer and supplier is getting more important in the increasing competitive environment and therefore researchers describe these emerging relationships as "partnerships" or "strategic alliances" (Gentry, 1996; Lambert and Cooper, 2000). The responsibilities between buyer and supplier in a transportation leg are often determined based on incoterms. Generally, incoterms are a series of sales terms used by businesses throughout the world used primarily to facilitate easier transactions in international trade by clearly defining the terms, conditions, transactions cost and ownership or transfer of goods in transactions (International Chamber of Commerce (ICC), 2010). Figure 2 shows the incoterms 2010. However, facilitating trade is not the only function of incoterms, they can also realise financial benefits and reduces variability in the lead-time. Financial benefits are, for instance, reduced customs tariffs, terminal handling costs, and government export fees. Second, more flexible routing options are possible if the importer takes over control of inland carriage. Therefore, greater consistent performance of goods movement can be achieved due to higher control, especially by minimizing delays. Lastly, by validating the control and custody of freight in global supply chain, a preferred status can be created by customs (Kumar, 2010).

Gentry (1996) and Świerczek (2014) investigated the extended partnership between buyer-supplier with a carrier and both found a significant difference when a carrier is involved in the partnership. Implicating the carrier in the partnership can result in enhanced benefits. The effect of the extended partnership is likely to be greater if it is a combination of both cost and service factors; carriers can support both low-cost and differentiation strategies (Gentry, 1996).

An important feature for a successful partnership is trust (Çerri, S., 2012; Sahay, 2003; Svensson, 2004). Trust between parties is considered as crucial to the process of problem solving and enables creativity within this process (Anderson and Narus, 1984; Woolthuis et al., 2002). Also trust convert dissension into functional conflicts which can results in productivity advantages (Anderson and Narus, 1984; Morgan and Hunt, 1994). Another benefit is that trust can contribute to reducing cost, e.g. transaction and negotiation costs (Doney and Cannon, 1997; Madhok, 2006).

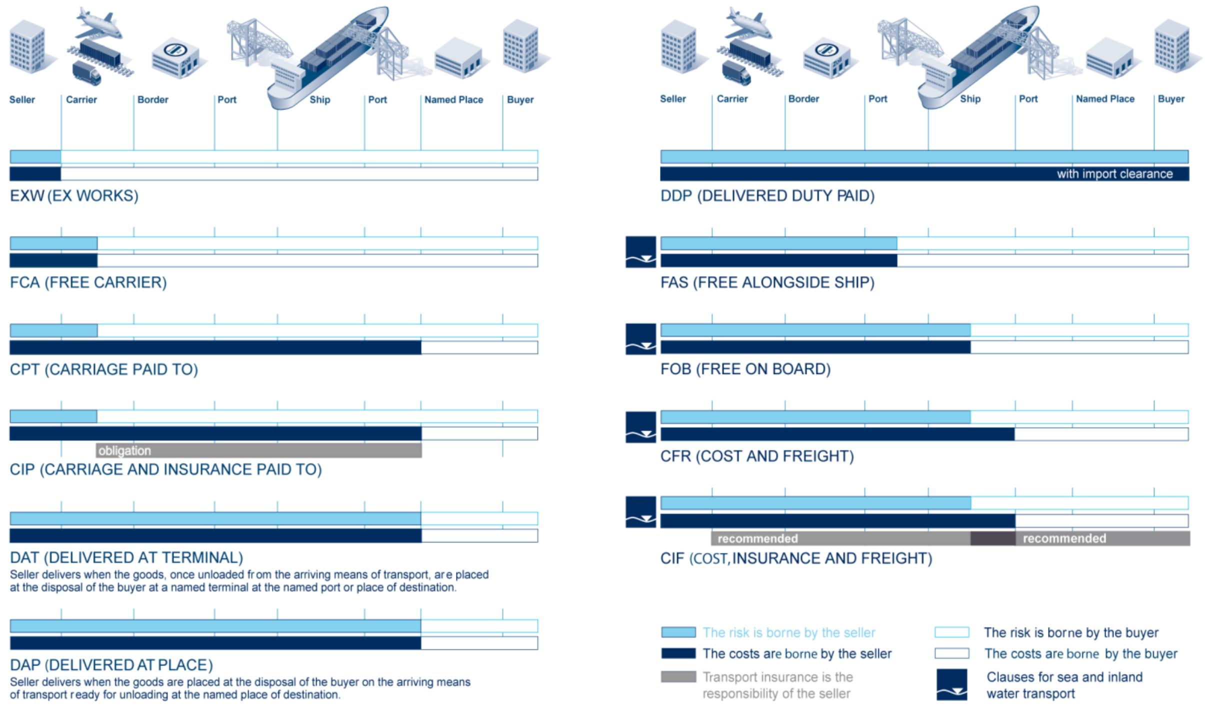

Figure 2: Incoterms 2010

Next to logistic service providers also customs, banks and ports play an important role in the international transportation leg. The activities at ports are crucial for international trade transactions; an improvement in port efficiency from 25th to 75th percentile reduces shipping costs by more than 12% (Clark et al., 2004). Part of the inefficiency in ports is caused by custom processes. Trade facilitation can help by gaining control on custom regulation and the interface between international traders and customs (Grainger, 2007). The banking and financial sector can reduce risks within the commercial transaction between buyer and supplier; unfortunately, not all banks are compliant with modern customs regarding document requirements.

2.3 Sequencing

Sequencing is defined as a particular order in which related things follow each other (Oxford dictionaries, 2015). Within the supply chain the aim for sequencing is to align the flows on a successful way. Traditionally, sequencing lies at the core of assembly planning, and implies finding a feasible sequence for the material flows (Jiménez, 2011). Assembly is a well-known approach in the production environment, especially in the built-to-order production. Most automotive producers implemented a built-to-order strategy to deal with customization in the increasingly competitive world markets (Meissner, 2010; Fredriksson and Gadde, 2005).

The assembly literature dates back to the start of the 19 century, whereby assembly is used as a strategy to provide high- speed mass production for a competitive price. Henry Ford developed the moving assembly line in 1913, the moving assembly line; bringing the product to the man instead of the man to the product in a nonstop continuous stream (Hopp and Spearman, 2008). The aim of the assembly process is to increase the efficiency by minimizing lead-times and reducing inventories. From a production view it is beneficial to sequence production jobs that have matching characteristics. For example, changeover cost can be decreased if jobs are executed consecutively painted with the same colour since cleaning painting machinery is timely and costly. Also sequencing of jobs that go to the same destination can diminish waiting time and transportation costs (Pinedo, 2009).

Sequencing assemblies are generally treated as a combinatorial problem; not every combination of items into subassemblies is permitted, feasible assemblies have to satisfy the contact and precedence constraints (Jiménez, 2011). Contact constraints are the requirements between the order in parts and precedence constraints are the requirements between processes. The term feasible assemblies with contact and precedence constraints are called the three step approach of assembly sequencing. Precedence constraints are defined as the generation of all feasible sequences and finally the choice between them (Jiménez, 2011).

Although sequencing activities are common in the production environment it also occurs in other parts of the supply chain. Often the term sequencing is used interchangeable with merging or consolidation. An example is consolidation of goods at a distribution- or cross-dock centre; the goods are consolidated to create transportation efficiencies. This seems similar to sequencing production orders; however, consolidation in a distribution centre is based on sequencing client orders instead of production orders. Another difference is that there are often no stocks available in the transportation leg, and possibly the physical consolidation is outsourced to an intermediary party (Jonsson, 2008).

Both in the production and distribution logistics efficiency is dependent on information sharing between partners. Sharing the information about the inbound flow of goods makes it possible to plan flows and to allocate space or capacity efficiently. This visibility of the inbound flow also facilitates the downstream transportation efficiency, e.g. transportation of goods towards the client (Vogt, 2010).

2.4 Impact of sequencing in the transportation leg

Literature in supply chain management recognises the role of transportation; however, it is often transportation management which is considered. Transportation management focuses more on existing transport possibilities (Stank and Goldsby, 2000) and integration of transport and warehousing (Mason et al. 2003). The development of integrative activities at the transport level is not considered (Veenstra et al., 2012). The lack of integration of transport operations is also noticed by Rodriques et al. (2008), who state that the integration of transport operations is critical to improve supply chain performance. An example of integration of transport operations is sequencing; aligning flows of goods to increase efficiency in time and costs. In this thesis sequencing contains an assigned delivery amount based on the (customer) order, no stocks are involved, and the flows originate from different locations. The order is packed in containers at the locations and not re-packed during the transportation leg; also the sequencing occurs at a non-fixed, predefined place along the transportation leg.

Despite the lack of literature on integrative activities at the transport level, some recent initiatives for integration exist in the practical field. For instance, the CORE project, whereof this thesis uses one of their trade lanes as case study. The aim of CORE is to consolidate solutions developed in reference projects, as for example INTEGRITY, CASSANDRA, SUPPORT, EUROSKY, e- FREIGHT, and CO^3. These projects are part of initiatives from the European Commission and aim to improve security related to freight transport. Common factors in these projects are the role of information management solutions, which enables data sharing between supply chain partners, in combination with a sufficient security level which satisfies the evolving international regulations and standards. These projects aim to achieve more integrated level of transportation with focus on security and enhanced cooperation in the transportation leg.

Sequencing in the transportation leg, compared to sequencing in the production environment, needs to overcome the issues related to security, government regulations, and customs controls. The projects mentioned above focus on these issues, taking into account the roles of the different partners. It is important to strengthen the relationship between partners to stimulate data sharing, overcome trust issues, and increase transparency in the transportation leg.

2.5 Control

The main global logistic indicators, according to Hausman et al. (2005), are time, variability, risks and costs. Based on previous paragraphs these four indicators match with the key measurements in the international transportation leg. The lead-time is the most effective measure to check the performance of a transportation leg, because the deviation of the minimal lead-time indicates the performance of the transport. Part of this deviation is included and acceptable in the lead-time, however, if the limit of this deviation is exceeded the lead-time is unreliable. Both variability and risk influence the lead-time, but they also influence the costs. The variability of the lead-time drives instability and uncertainty (Hausman et al., 2005; Christensen et al., 2007). Different types of risks can influence the transportation leg; examples of events that create risk are: natural disaster or terrorism. Nevertheless, risk represents the probability an event occurs times the impact the event causes. The fourth indicator, costs, is determined by the degree of occurrence of the other indicators. Minimizing these indicators is important due to increased competition, higher demanding customers, and harsh consequences of the global recession. In the last decades multiple organizational approaches are developed to process improvement and operational excellence (Heavey and Murphy, 2012).

Chiarini (2011) performed a meta-analysis on seven important organisational approaches; Japanese Total Quality Control (JTQC), Total quality Management (TQM), Deming's system of profound knowledge, Business Process Reengineering (BPR), Lean Thinking, Six Sigma, and Lean Six Sigma. Almost all of these well-known organizational approaches use a structured pattern to control projects and processes. The most applicable structure to apply in the transportation leg is the 'Define, Measure, Analyse, Improve, and Control' (DMAIC) pattern, which originates from Lean-Six-Sigma approach. It combines the 'speed' introduced by Lean and the capabilities of reducing variability of Six Sigma. Christensen et al. (2007) states that due to the established benefits of variance reduction in manufacturing processes it seems beneficial to apply it in other processes. Goldsby and Martichenko (2005) already applied it in their research the DMAIC pattern successfully to investigate waste in transportation.

Using the DMAIC pattern, does not imply that the Lean Six Sigma philosophy is applied. Mainly the five steps are used in order to get control and to improve the logistic indicators. The first step is to define the bottleneck in the process; describe the process that is relevant for the customer, and that provide significant benefits to the business when it is solved. Second, the process should be measured. For the transportation leg, the lead-time is the most important measurement. After this measurement the statistics can be calculated to get more insight. The third step is to analyse the process. In this step it is important to identify the causes that lead to the identified problem. Also the impact for the rest of the transportation leg should be analysed. The fourth step is to improve the processes which include developing, selecting and implementing the best solutions, with controlled risks. And the last step is, is to control the process. This step is to ensure the solutions are enclosed in the process, controls should be verifying the successfulness of the implementation.

2.6 Conclusion

The role of transportation is neglected in the literature. Transport operations are often the result of supply chain decisions instead of decisions that aim to increase efficiency by considering integrative activities. Thence, integrative activities as sequencing in a transportation leg is an undiscovered field of research especially compared to the literature of sequencing in the internal logistics. The essence of sequencing is equal for both fields; however, in the transportation leg extra complexity exists by crossing borders. Cross border issues are split up in three categories; time, costs, and a combination of both time and costs.

The number of parties involved in the transportation leg also creates additional complexity. The relationship between the primary partners, the supplier and the buyer, is shifting towards strategic alliances due to the changing competitive environment. Between these primary partners, responsibilities are split up with the aid of incoterms. Implicating the carrier into the relationship between supplier and buyer can result in lower costs and enhanced service factors, because carriers can support both low-cost and differentiation strategies. Besides to carriers also banks, customs and ports influence time and costs in the transportation leg.

Conserving the findings in the literature review it can be concluded that time is the most important logistic indicator related to the sequencing process in the transportation leg. A methodological framework is created to visualise the relationship of the sequencing with the logistics indicators. Variability and risk both influence time negatively while the sequencing process aims to enhance the efficiency in the transportation leg, and therefore has a positive impact on time. Unfortunately, if problems occur in the sequencing process it leads to delays which has a negative impact on time. The indicator time has a direct influence on costs. Figure 3 illustrates the relations between sequencing and the global logistic indicators.

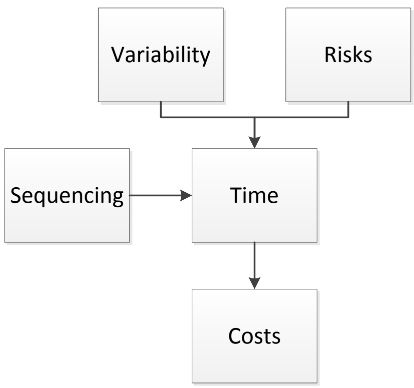

Figure 3: Framework: sequencing process related to logistics indicators

Controlling the logistic indicators can be done with the aid of the DMAIC pattern. The first step is to define the problem. Subsequently the processes can be measured and analysed. After analysing it is important to improve and control the processes; to make sure the performance of the transportation leg is optimal and stable.

3. Case study

This chapter provide insights in the current situation of the transportation legs to Malaysia and Thailand. First the transportation with respect to the total supply chain is illustrated, where after the joint characteristics for the trade lanes are provided. Subsequently, specific characteristics are provided for the separate transportation legs. Appendix 2 provides additional information about the used data for this case study.

3.1 Supply chain

The supply chain of the client is divided in six main parts; order management, production and ordering, transportation from production to mandatory services, transportation to the country of destination, final assembly, and preparing and transportation of the products to the final customer (Figure 4). The supply chain starts with the receipt of an order, which starts the order management, and provides a pre-calculated plan for ordering and production. A customer order can consist of one or more batches, because the production is located in different countries. The ordered and produced goods are gathered at the mandatory service locations, where the goods are pre-packed, sorted by batch number and prepared for transportation. When the goods are transported to the country of destination, they are transported to the Regional Product Centres (RPC), where the final assembly takes place. Subsequently, the finished products are stored until the order is completed. Lastly, the products are delivered to the final customer.

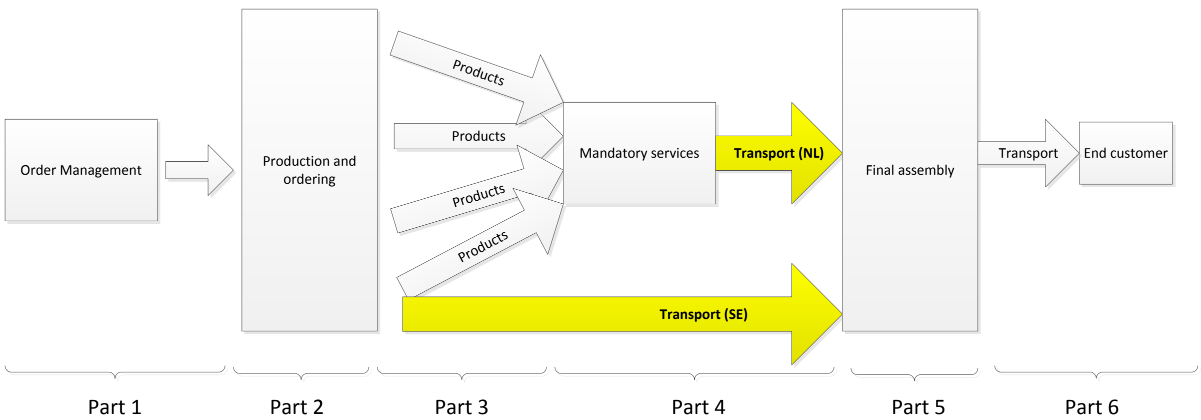

Figure 4: Supply chain of the client

3.2 International transportation leg

The focus in this thesis is on the international transportation leg of the supply chain (Figure 4, part 4); the transportation to the country of destination (yellow arrows). Two countries of destinations are investigated, Malaysia and Thailand. For both countries the transportation leg is vulnerable because the goods are shipped from two different loading locations, Sweden and the Netherlands, but in order to meet governmental regulations and controls the goods are sequenced during transport. The production process for half of the parts is executed in Sweden, subsequently the goods are loaded in containers and shipped to the port of Gothenburg (port code: SEGOT). The production process for the other half of parts is executed in the Netherlands; these goods are consolidated at the client in the Netherlands with the ordered products from the suppliers. The goods are also loaded in containers and shipped to the port of Rotterdam (NLRTM).

Sequencing provides financial benefits in import taxes based on local governmental regulations and tariffs for both Malaysia and Thailand. However, the sequencing process for Malaysia and Thailand differ from each other. For Malaysia the containers belonging to one batch need to arrive simultaneously at Port Klang (MYKLA). It is possible to sequence the containers physically in the port of Rotterdam, Singapore (SGSCT) or Tanjung Pelepas (MYTPP). For Thailand, an arrival interval of at least four days is required in the port of Laem Chabang (THLCH) between the two batches. The transportation legs to Malaysia and Thailand are contrary to each other, but for both legs the order of arrival is important. In the following paragraphs, both transportation legs will be discussed in detail. First, general information is provided which is relevant for both legs.

The responsibilities of the client are split up in different divisions throughout the world. For example, the Netherlands division represents the Netherlands; the Malaysian division represents Malaysia etcetera. The consequence is that the client represents both the buyer and supplier in this transportation leg. In order to divide these responsibilities the incoterm 'Delivery At Place' (DAP) is applied, which entails that division the Netherlands is responsible to deliver the containers at a specified place, after the delivery of the containers the responsibilities transfer to the Malaysian division. In this case, the specified places are Port Klang for Malaysia and the port of Laem Chabang for Thailand. Further in this thesis the divisions the Netherlands or Malaysia are both referred to as client.

The client cooperates with Seacon Logistics and an ocean carrier, to arrange and execute transport. Seacon Logistics books containers based on the 'Container Ready Date' (CRD) on a vessel of the ocean carrier. The client provides the CRD, which is an estimation based on the pre-calculated planning in the first step of the supply chain 'order management'. The CRD is an intern time interval of four days in which the containers need to be loaded and completed for transport. With the booking of the containers next to the CRD Seacon Logistics also need to consider the 'Container Closing Date' (CCD). The CCD is a deadline in which the containers need to be in the port set by the ocean carrier. If the containers, based on this deadline, are late the containers are not loaded on the vessel. Figure 5 shows the order of steps, in relation to the receipt of the customer order and the start of production, which initiates the booking process of Seacon Logistics.

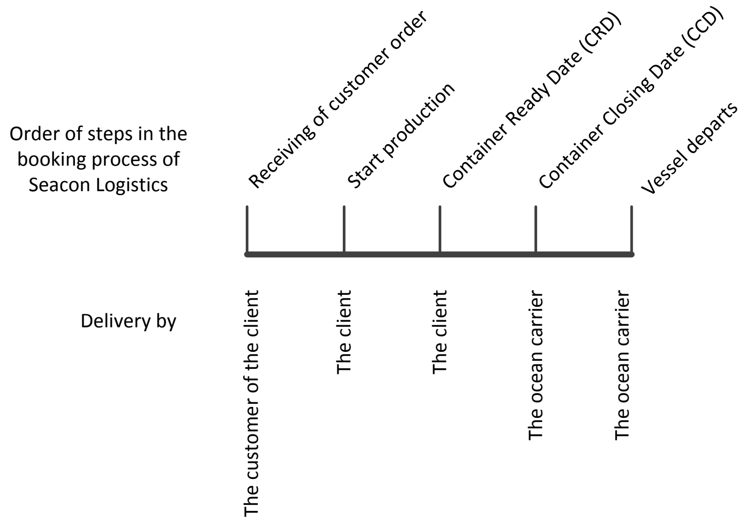

Figure 5: Order of steps in booking process of Seacon Logistics

The booking process for batches to Malaysia and Thailand differs and is therefore discussed in the following paragraphs. A common aspect of the booking process is that containers which contain dangerous goods are booked individually and without the rest of containers belonging to the same batch, these containers are called IMO[1] containers. Seacon Logistics also provides the shipping instructions to the ocean carrier. These include booking number, parties and roles, cargo characteristics, equipment, and route. The role of Seacon Logistics is to act as an intermediary party between the client and the ocean carrier; all communication takes place via Seacon Logistics.

Based on the booking of the containers, the ocean carrier executes the transportation and composes the related transport documents. The main transport documents are the Bill of Lading (B/L), the export declaration, and the arrival note. The B/L is based on the booking instructions for both batches, which are combined on one B/L. Note that also the booking for the IMO containers should be included. The B/L is used as input for the arrival note, which is sent to the customer and customs in country of destination. The arrival note is also created by the ocean carrier. The export declaration is compulsory to export containers; this document is set up by the client.

[1] IMO stands for International Maritime Organisation, which represents the global standard-setting authority for the safety, security and environmental performance of international shipping.

3.3 Malaysia

The data which is used to determine the lead-times is obtained from 2014 and the first period of 2015. Four different routes are used to transport the 51 batches, containing 455 containers, to Port Klang. In Figure 6 these different routes of containers are visualized and appendix 3 illustrates the statistical information about the routes to Malaysia.

As mentioned earlier, the batches from Sweden and the Netherlands need to arrive simultaneously at Port Klang. The reason behind this aligned arrival is the financial advantage in import taxes. If the containers arrive together, the import tariff is 12% lower than if the batches with containers arrive separately. The average price for a product is €77.000, so the aligned arrival of a batch saves €9.240 per product. On average 350 products per year are transported to Malaysia, so this can result in a saving of €3.234.000 per year. These are substantial savings in relation to the total transportation costs of these containers. Unfortunately the percentage of savings relative to the total transportation costs is unknown. The containers from both batches need to be sequenced physically and administratively during the transportation leg. The physical sequencing occurs in the port of Rotterdam, Singapore, or Tanjung Pelepas.

The administrative sequencing requires combining the booking information from the both batches to one B/L, this administrative sequencing is an exceptional process for shipping companies. The booking information is sent to the ocean carrier by Seacon Logistics. The starting process of the booking is the CRD of the batch from Sweden because the transit time for this batch is seven days longer than for the batch from the Netherlands. Each week a vessel departures from the port to Gothenburg, the 'Cargo Closing Date' (CCD) is two days earlier. If the containers do not enter the port before the CCD the containers are not accepted and need to wait for the next vessel. The booking of the batch from Sweden is made on the first available vessel; both the CRD and the CCD are taken into account. The booking of the batch from the Netherlands depends on the moment of sequencing along the transportation leg. For example, if the batches are sequenced in the port of Rotterdam, the batch from the Netherlands is booked on the same vessel as the batch from Sweden. Sometimes the batch from Sweden is discharged in the port of Rotterdam; this typically occurs when the batch from Sweden is shipped on a short sea vessel to the port of Rotterdam. The ocean vessel from the port of Rotterdam also departs once a week, with again a CCD of two days. In the port of Singapore and Tanjung Pelepas the feeder to Port Klang departs every four days, in these ports there is a CCD of one day.

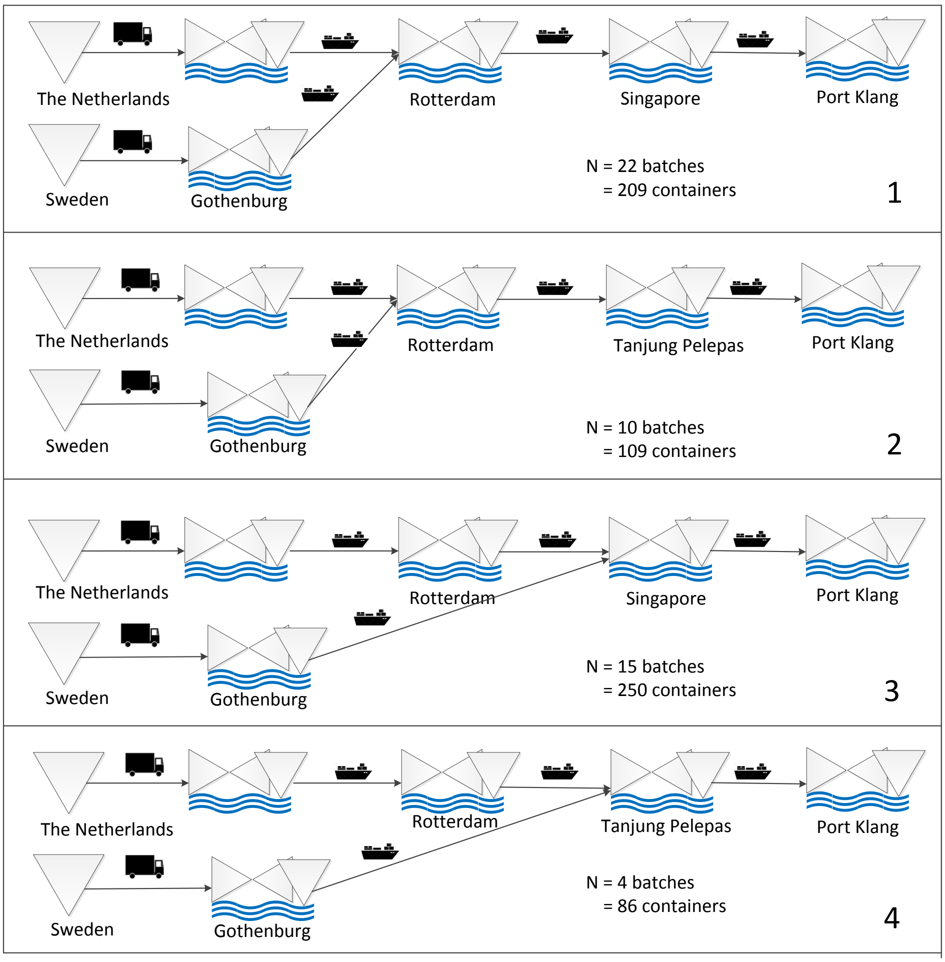

Figure 6: Four routes to Malaysia

The information system of the ocean carrier is not equipped for the alignment of bookings and therefore errors occur in the transport documents. Three bookings need to be combined on one B/L; the batch from Sweden, the batch from the Netherlands and the IMO container. Unfortunately, this process is error-prone and time consuming for both the ocean carrier and Seacon Logistics. Most errors occur in combining the bookings, replication of the number of the containers and the related content, and changing the port of departure to the port where the containers are physical sequenced. This last aspect, changing the port of loading to the port where the containers are sequenced, is problematic if the containers are sequenced in Tanjung Pelepas, route 4. If the containers are sequenced in Tanjung Pelepas this need to be stated on the B/L, however, Tanjung Pelepas is located in Malaysia and then it give the impression that the containers originates from Malaysia. Unfortunately, the Malaysian customs does not accept this and therefore the port of loading should always be Rotterdam or Singapore. To avoid other inaccuracies in the final B/L Seacon Logistics first checks the draft B/L and when errors are found sends the corrections back to the ocean carrier. If Seacon believes the B/L is correct, the B/L is sent to the client. Subsequently, the client also checks the B/L for inaccuracies. When both Seacon and the client approve the final B/L can be released by the ocean carrier. Unfortunately, this process is time consuming due to the numerous mistakes by the ocean carrier and the circuitous checking procedure.

If the containers belonging to one batch do not arrive simultaneously in Port Klang the containers are denied by the Malaysian customs. The containers are denied because the B/L states that the containers belong to one batch with the same arrival date. If the containers are denied a statement is required which states that the containers belong to one batch. In other words, this statement confirms that the information flow is correct. This statement should be confirmed by both the client and the ocean carrier. There is also a clarification required, why the goods arrived separately. Before this statement and clarification are set up by the ocean carrier and approved by the Malaysian customs, the lead-time is extended, with additional paperwork and extra costs as consequences. Another reason for denying the containers is an incorrect information flow; the B/L and the arrival note. In this case also a statement and clarification need to be provided to the Malaysian customs. Like the situation with the partial arrivals, an incorrect B/L also causes delays, additional paperwork and extra costs.

3.4 Thailand

The data which is used to determine the lead-times is obtained from 2014 and the first period of 2015. Seven different transportation legs are used to transport 35 batches, containing 194 containers, to Laem Chabang. These seven routes are combined into four routes to make the statistical data more aggregated. The routes are based on the last transhipment port; Singapore or Tanjung Pelepas. In Figure 7 the four routes of containers are visualized. Appendix 4 illustrates the original seven routes and the statistical information about the four routes to Thailand.

To import the goods in Thailand it is beneficial for the client to have at least four days between the arrivals of both batches. The order in which the batches arrive first is not important. If the actual arrival date of both batches is within the four day interval, 30% extra import duties need to be paid. Because then the goods are recognised by the Thai customs as complete product, instead of parts. For example, the cost price of product is around €77.000 and the batches arrive within four days; per product extra duties of €23.100 need to be paid. On average 200 products are transported to Thailand, when the containers arrive outside the four-day interval it can save €4.620.000 tax claims per year. These are substantial savings in relation to the total transportation costs of these containers. Unfortunately the percentage of savings relative to the total transportation costs is unknown.

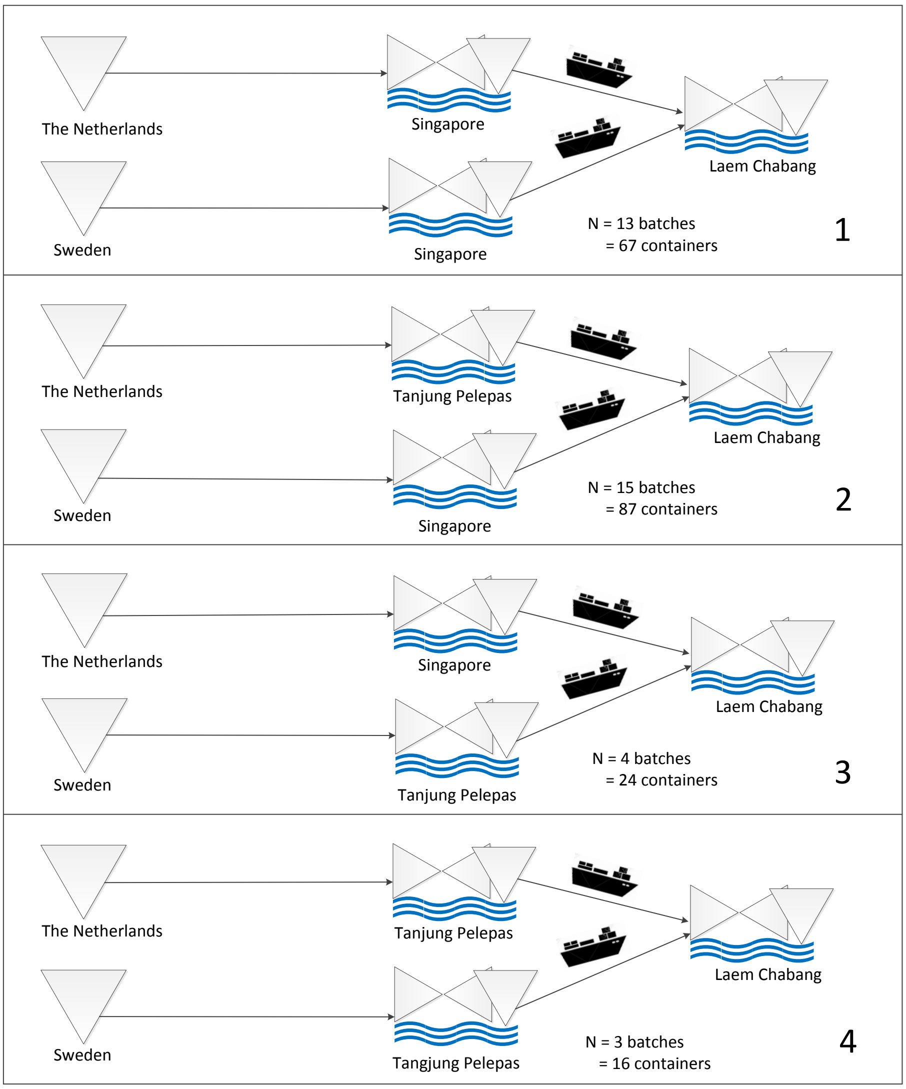

Figure 7: Four routes to Thailand

The containers from each batch can be considered as a separate flow, because only the moment of arrival is important. Therefore the booking of both batches is done parallel. The transit time of the batch from Sweden is seven days longer than the batch from the Netherlands; therefore, both batches are booked based on their CRD. During the booking the arrival interval of four days between of the batches is established. Difficulties in this lane occur due to the transhipment ports in the transportation leg. For example, if the first batch is delayed it is possible that this batch misses the feeder to Laem Chabang and therefore needs to wait for the next feeder. If in the meantime the second batch also arrives in the transhipment port, it is possible that both batches are transported on the same feeder to Laem Chabang. The requirement of a four day interval between arrivals is well-known to the ocean carrier; however, Seacon Logistics and the client track the containers during transportation to alert the ocean carrier if the actual arrival for both batches can be within the four day interval. The arrival of the batches is checked based on the track and trace information on the website of the ocean carrier.

4. Results and analysis

This chapter provides the results of the data analysis. First the lead-times of both transportation legs are examined in order to identify the high variances in the transportation leg. The transportation legs to Malaysia and Thailand are considered separately, because the requirements for sequencing are opposite to each other. Subsequently, the routes are modelled with the aid of Bayesian Networks. Before the results are provided, the Bayesian Network theory is explained.

4.1 Malaysia

Appendix 3 illustrates the routes to Malaysia and the statistical information. Table 2 summarises this statistical data of the total flow of containers to Port Klang. A striking result is the high variance of waiting time in the ports, namely 73 days. The containers pass three or four ports based on the route (Gothenburg, Rotterdam, Singapore or Tanjung Pelepas, and Port Klang). The inland terminal is not included because no data is available about entering the port, and therefore this waiting time is included into the transit time. The variance of the waiting time is 73 days, which occupies a large part of the variance of the total lead-time. The variance of the total waiting time is principally caused by waiting time in Port Klang, because if the waiting time for this port is excluded the variance diminishes from 73 to 19.2 days. Appendix 5 illustrates the frequency tables of the waiting times in all the ports, and the related distribution is also provided.

Malaysia	Mean	Variance	St. deviation	Minimal	Maximum	Range	Median	Mode
Total lead-time	57,6	93,7	9,7	40,0	98,0	58,0	56,0	64,0
Total waiting time	19,1	73,0	8,5	5,0	59,0	54,0	18,0	17,0
Waiting time minus WT in Port Klang	10,0	19,2	4,4	2,0	29,0	27,0	9,0	7,0
Total transit time	38,4	28,5	5,3	27,0	54,0	27,0	38,0	37,0
Tansit time minus pre-haulage	32,7	14,7	3,8	27,0	50,0	23,0	32,0	32,0

Table 2: Malaysia - Summarised statistical data

The transit time experiences a variance of 28.5 days, and therefore has less impact on the variance of the total lead-time. The variance in transit time is primarily caused by the first part; pre-haulage. Part of this pre-haulage includes the buffer time which is required to smoothing the sequencing process. For example, the containers from the Netherlands are ready for transport but the containers from Sweden not yet, than the containers are buffered at the client to avoid long waiting times in the port of Rotterdam. Unfortunately, no data is available to split the pre-haulage time in buffer time and actual transit time. The result is that the pre-haulage time ranges from zero to twenty-one days, where of twenty-two batches experience pre-haulage longer than ten days. If pre-haulage is excluded from the total transit time, the variance diminishes from 28.5 to 14.7 days.

The transit time from the transhipment port (Singapore or Tanjung Pelepas) to Port Klang also experiences high variance in some routes. This variance is caused by disruptions in the transhipment port and ensures that the containers arrive simultaneously. If, for instance, one container from a batch is left behind in the transhipment port the other containers on the feeder are not discharged in Port Klang but stay on the feeder. The containers are transported back to the transhipment port where the container that was left behind is re-united with the other containers from the batch. Therefore, the transit time for the containers that made an extra trip is between seven to eleven days. The containers that have a transit time of eleven days probably were not re-united the first time but the second time. Four batches run through this process batch 5, 28, 39, and 50. They cause a high variance in this last part because the average transit time is around two days.

The high variance of the waiting time is caused by several disruptions in combination with sequencing which emphasize the importance of correct execution and management of the sequencing process. The data analysis aims to find insights in the causes and consequences of the waiting time in the port of Gothenburg, Rotterdam, Singapore, Tanjung Pelepas, and Port Klang.

4.2 Thailand

As described before, the routes to Thailand are combined from seven to four routes to make the results more aggregate. Appendix 4 illustrates the original routes and the statistical information about the four routes to Thailand. Table 3 summarises the statistical data of all the containers to Thailand.

Thailand	Mean	Variance	St. deviation	Minimal	Maximum	Range	Median	Mode
Total lead-time	48,8	84,8	9,2	36,0	88,0	52,0	49,0	50,0
Total waiting time	11,1	19,5	4,4	2,0	24,0	22,0	10,0	8,0
Waiting time minus WT in Laem Chabang	7,8	14,4	3,8	1,0	19,0	18,0	7,0	5,0
Total transit time	38,6	83,5	9,1	25,0	79,0	54,0	38,0	39,0
Tansit time minus pre-haulage	31,6	17,2	4,1	24,0	39,0	15,0	31,0	30,0

Table 3: Thailand - Summarised statistical data

A striking result is the high variance for the total transit time; 83.5 days. This variance is caused by the long pre-haulage of a few batches; pre-haulage is equal measured for Thailand as for Malaysia. The maximum pre-haulage contains 45 days for several batches. The high variance of this pre-haulage time is not related to sequencing in the same way as the transportation leg to Malaysia because the containers do not need to be aligned during transportation. Probably the variance is caused by buffer time, unfortunately both Seacon Logistics and the client are not aware of the exact cause and nothing is reported in the related documents. If the pre-haulage is excluded from the total transit time it results in a reduced variance from 83.5 to 17.2 days.

Sequencing does not influence the transportation leg to Thailand as much as it influences the transportation leg to Malaysia; the batches from both Sweden and the Netherlands can be seen as separate flows in which only the moment of arrival is important. As long as the containers stick to the planned route and arrival times, no delays occur in the transportation leg. If one of the two batches is delayed, the other batch can continue as long as the arrival of both batches does not fall into the four day interval. If the delay causes extra time between arrivals, additional to the four days, it can cause extra inventory carrying cost or planning problems in the follow-up stage in the supply chain but it does not result in higher import taxes. Of the investigated batches it has occurred seven times that the batches arrived within the four-day interval. For these batches the import taxes are 30% higher than the standard import taxes.

Despite reducing the routes from seven to four, the number of batches is still limited for a representative data analysis. For instance, route 3 and 4 represent four and three batches respectively. Unfortunately, the track and trace information for the remainder batches of 2014 or earlier is not available. Conserving these limitations, the transportation leg to Thailand is excluded from the data analysis; the available data is limited and the available data shows limited impact of sequencing on the lead-time of the transportation leg.

4.3 Bayesian Networks

Bayesian Networks (BNs) are directed acyclic graphs that graphically describe dependencies between variables. BNs are constructed based on a directed graph and the parameters. The nodes represent the variables while the connectors link the dependent variables. Absences of connectors signify independency between the nodes. If node A influence node B; node A is called to be the parent of B. If node A is related to both nodes B and C, three types of connections are possible; convergent, serial, and divergent connections (Nadkarni and Shenoy, 2001; Fenton and Neil, 2013). The parameters are defined after constructing the directed graph and contain two important steps. First the step is to define the states for each variable and constructing the probability table (Nadkarni and Shenoy, 2004). The nodes in the BNs can have different states; depending on the node these states are discreet or continuous. Second, each node has an associated probability table, this is the probability distribution of A given the parents of A. If a variable has no parents it is defined as an input node and is the NPT simply the probability distribution of A (Fenton and Neil, 2013).

The Bayes' Theorem enables the BNs to update probability based on new evidence. The Bayes' Theorem allows revising and changing predictions and diagnoses based on new data and information. With new information the likelihood of events in the past can be calculated. This backward inference is called explaining away or non-monotonic reasoning. The Bayes' Theorem is based on formula 1, which relies on three axioms; the probability of an event is between zero and one; the cumulative probability of the event is one; and for mutually exclusive events (events which include the whole sample size) the probability of occurrence is the sum of the probabilities of the individual events (Fenton and Neil, 2013).

$$P(A|B) = \frac{P(A|B)xP(B)}{P(B)} \quad 1)$$

According to Fenton and Neil (2013) BNs have multiple benefits. The first benefit is the possibility of non-monotonic reasoning and to make what-if analysis. Second the BNs explicitly model causal factors, which is not possible in classical statistics which are developed by purely data-driven approaches. A BN is modular and compact whereby a BN will require fewer probability values and parameters. It is also possible to make predictions with incomplete data. The model determines the probability distributions for all the unknown nodes when new evidence is not entered for all nodes. Evidences entered in the model can be both subjective belief and objective data, which facilitates in the way the probabilities tables are defined. Lastly, the BN reviews decisions based on a visible, auditable reasoning; there are no hidden nodes and the deduction is based on the Bayes' Theorem. These benefits together with the explicit quantification of uncertainty and the distinct visibility of the dependencies make BNs a powerful solution for risk assessment (Fenton and Neil, 2013).

The graphical representation of BNs is based on the four routes identified for Malaysia. The nodes represent the waiting times in the ports, and the connectors between nodes represent the routes. The waiting time in the ports is identified as a non-elementary event, which implies that the result can contain multiple outcomes. Subsequently it is important to define the possible states after which the NPs can be calculated (Nadkarni and Shenoy, 2004). Paragraph 4.4 illustrates the possible states for waiting time in the ports. AgenaRisk is used as software to model the routes as BN; this software is also used by Fenton and Neil (2013) to explain BNs. In appendix 9 the used program AgenaRisk is explained, and needed assumptions and decisions are clarified.

4.4 Possible states for waiting time in the ports

The waiting time in the ports is measured from the date the containers enter the port, or are discharged from the vessel, until the containers are loaded on the vessel. However, part of this waiting time is compulsory and is part of the transit time; this is defined as 'minimal' waiting time. This part is caused by the obligation to deliver the goods before the 'Cargo Closing Date' (CCD). The CCD is a deadline for containers to be on the terminal, if the containers arrive after this deadline the containers will be transported on the next vessel. The CCD is to ensure that vessels depart on time, and that shipping companies, together with their terminal operators, have sufficient time to load the booked containers on the vessel. Waiting time related to CCD occurs mainly in the port of departure (Gothenburg and Rotterdam). The CCD is determined by the shipping company and can be different for each port. These CCDs also result in minimal waiting times which are visualized in Table 4. The 'minimal' waiting time in the port of Gothenburg is three days; two days due to the CCD and the containers are delivered one day earlier to meet the CCD. In the port of Rotterdam the minimal waiting time is split up for the batches from Sweden and the Netherlands. The batch from Sweden, passes Rotterdam in route 1 and 2, and has a minimal waiting time of five days. These days are required to sequence the batches smoothly. The minimal waiting time for the batches from the Netherlands is three days; two days due to the CCD and the containers are delivered on day earlier to meet the CCD. The minimal waiting time is also the desired waiting time; these times are included in the total lead-time and therefore do not cause any additional lead-time in the transportation leg.

[days]	Gothenburg	Rotterdam	Singapore	Tanjung Pelepas	Port Klang
Minimal WT	≤ 3	NL≤3; SE≤5	≤5	≤5	≤5
Acceptable WT	≤ 7	≤ 7			
Tardy	> 7	> 7	>5	>5	>5

Table 4: States in waiting time in the ports [these are accepted limits in the practice]

Next to 'minimal' waiting time, there is also 'acceptable' waiting time. This waiting time is defined as acceptable because the waiting time does not cause any additional charges. For the port of Gothenburg, Rotterdam and Port Klang agreements are made about the number of days the containers are allowed to stay in the port without paying any additional charge; this is called free time. In the port of Gothenburg and Rotterdam the free time is seven days, while in Port Klang the free time is five days. In the transhipment ports no agreements are made about the free time. In these ports the acceptable waiting time depends on the schedule of feeders to Port Klang; the feeder departures from both ports every four days to Port Klang. The acceptable waiting time, which is agreed with the ocean carrier, is four days plus one additional day for the CCD in the port of Singapore and Tanjung Pelepas. For the transhipment ports and Port Klang the acceptable waiting time is equal to the minimal waiting time because no distinction can be made. If waiting times are longer than the acceptable waiting times, the containers are considered as tardy. Due to the missing literature no official terminology is defined for long unacceptable waiting times, therefore, unacceptable and undesired waiting times are defined in this thesis as tardy waiting times.

Every day a container is tardy has consequences for both time and cost factors. The time factor represents delays in the transportation leg; this can be caused by different disruptions. The cost factor can be split up in direct and indirect costs. Direct costs are charges for waiting on the terminal after free time expires; demurrage costs. This charge differs per port, per time period and per type of equipment; the charges are visualized in appendix 6. Indirect costs are inventory carrying costs for cargo in transit, a rate of six percent is applied (Seacon Logistics, May 2015).

Figure 8 illustrates the BNs for the four routes to Port Klang. The states are adopted from Table 4, and N represents the number of containers. A direct method is used to provide the likelihood of the different states. The probabilities are calculated based on the track and trace information provided by Seacon Logistics and the ocean carrier. In appendix 7 the disruptions which cause acceptable and tardy waiting time are specified in more detail. The causes that occur in appendix 7 are explained in detail in appendix 8.

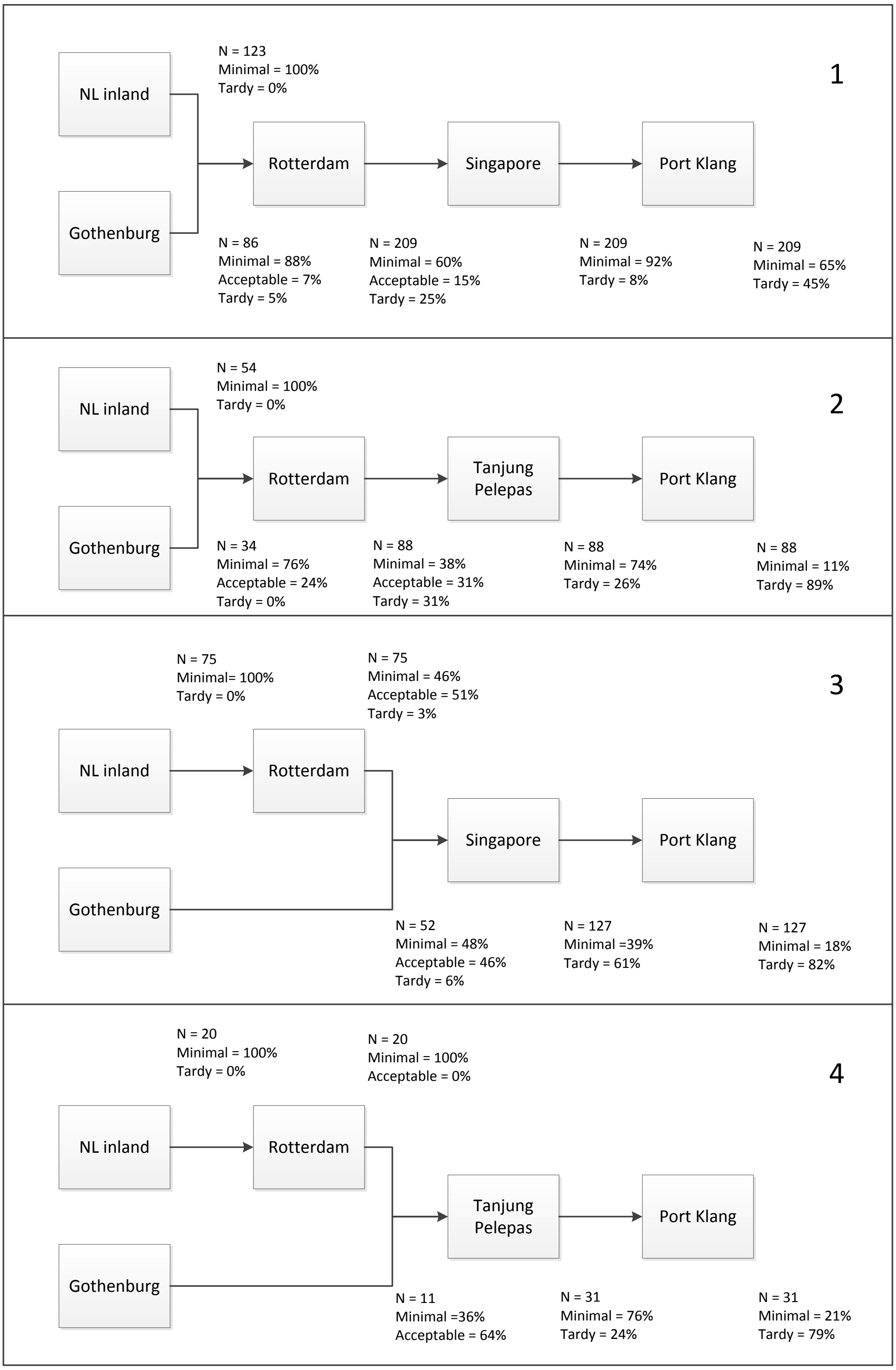

Figure 8: Routes of visualised in Bayesian Networks Malaysia

4.5 Analysis of the transportation leg

Appendix 7 confirms that sequencing is one of the causes of tardy waiting times in the transportation leg to Malaysia. All the batches with tardy waiting times related to sequencing are specified in appendix 10 and summarised in Table 5. The batches which are illustrated in bold are complete batches with tardy waiting times, while for the other batches it is either the batch from Sweden or the Netherlands which experiences tardiness. The last two columns of Table 5 illustrate the percentages of the tardy containers compared to the route they accomplished and to the total flow of containers. In other words, the percentages are calculated by dividing the number of tardy containers by the number of containers per route (see Figure 8) or by the total number of containers (455 containers).

Batch number	Route	Number of tardy containers	Port	Causes	Min. waiting time [days]	Max. waiting time [days]	% of route	% of total
44	1	3	SGSCT	Missing shipping instructions	10	10	1,4%	0,7%
51	**1**	**8**	**NLRTM**	**Vessel network change**	**8**	**20**	**3,8%**	**1,8%**
27	2	7	NLRTM	Vessel network change	8	8	8,0%	1,5%
29	2	6	NLRTM	Vessel capacity limited	8	8	6,8%	1,3%
30	2	4	NLRTM	Vessel capacity limited	8	8	4,5%	0,9%
31	2	2	NLRTM	Vessel capacity limited	8	8	2,3%	0,4%
32	2	3	NLRTM	Vessel capacity limited	8	8	3,4%	0,7%
38	2	4	NLRTM	Vessel network change	8	8	4,5%	0,9%
5	**3**	**10**	**SGSCT**	**Vessel cut and run**	**6**	**13**	**7,9%**	**2,2%**
9	3	9	SGSCT	Port omitted by vessel	6	6	7,1%	2,0%
16	3	2	SGSCT	Unforeseen contingency	8	8	1,6%	0,4%
18	**3**	**10**	**SGSCT**	**Vessel network change**	**7**	**8**	**7,9%**	**2,2%**
10	4	4	MYTPP	Cargo ETA earlied/advanced	8	9	12,1%	0,9%
								15,8%

Table 5: Tardy waiting times related to sequencing

Tardiness caused due to sequencing occurs in almost 16% of the transported containers. Except for batch 44 in route 1 all tardy waiting time related to sequencing occurs in the port where the sequencing process is planned. All the disruptions that cause waiting time related to sequencing, except for the 'Missing shipping instructions' and the 'Unforeseen contingency,' are events initiated by decisions made by the ocean carrier. These decision cause for 93% (14.7/15.8 *100) of the containers tardy waiting times. These decisions result in changed schedules for the containers, which leads to additional waiting time of approximately eight days. In case of the 'Missing shipping instructions', Seacon logistics is responsible because it is their task to provide them. However, the shipping instructions were according to the mail communication tardy because the client was late with sending the product details which is required for setting up the instructions. The event 'unforeseen contingency' is cannot avoided and is part of general risk related to ocean transportation. Table 6 represents the conditional probabilities of the causes of sequencing the total flow of containers. This table confirms that the likelihood of tardiness due to decisions of the ocean carrier is 93%. The conditional probabilities of tardy waiting time are calculated with formula 2 while the conditional probabilities of the acceptable waiting times are calculated with formula 3.

$$P(Cause\ X | Tardiness\ due\ to\ sequencing\ in\ NLRTM, SGSCT\ and\ MYTTP) = \frac{\#\ of\ containter\ with\ tardy\ WT\ related\ to\ sequencing\ due\ to\ cause\ X}{\#\ containers\ with\ tardy\ WT\ due\ to\ sequencing\ in\ NLRTM, SGSCT\ and\ MYTTP} \quad 2)$$

$$P(Cause\ X | Accptable\ WT\ due\ to\ sequencing\ in\ NLRTM, SGSCT, and\ MYTTP) = \frac{\#\ of\ containter\ with\ acceptble\ WT\ related\ to\ sequencing\ due\ to\ cause\ X}{Total\ \#\ containers\ with\ acceptable\ WT\ due\ to\ sequencing\ in\ NLRTM, SGSCT\ and\ MYTTP} \quad 3)$$

Probability of sequencing in the transportation leg sorted by cause						
	Number of containers		Number of batches		Conditional probabilities	
	Acceptable WT	Tardy WT	Acceptable WT	Tardy WT	Acceptable WT	Tardy WT
Vessel network change	9	29	3	2	26%	40%
Limited vessel capacity	10	15	4	4	29%	21%
Unknown	16	0	3	2	46%	0%
Vessel cut and run		10		1	0%	14%
Omitted port		9		1	0%	13%
Cargo ETA earlied/advanced		4		1	0%	6%
Missing shipping instructions		3		1	0%	4%
Unforeseen contingency		2		1	0%	3%
Total	35	72	10	13	100%	100%

Table 6: Conditional probabilities of tardiness related to sequencing

Based on the occurrence of sequencing in the routes, the impact of the sequencing on the rest of the transportation leg is visualised in figures 9, 10 and 11. In Figure 9 the conditional probabilities are visualised for tardy waiting times due to sequencing in the port of Rotterdam, route 1 and 2. In other words, the probabilities show the causes and consequences if the sequencing process results in tardy waiting times in the port of Rotterdam. If sequencing occurs in route 1 it is caused by a 'vessel network change' in the port of Gothenburg. In route 2 the waiting time in the port of Gothenburg is acceptable, the waiting time is probably avoided by holding the containers longer at the

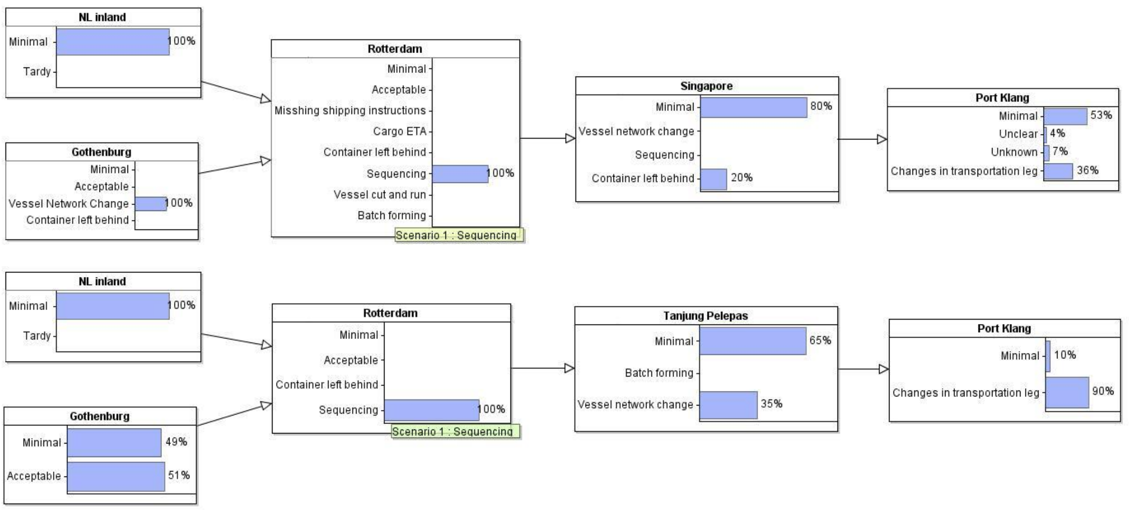

Figure 9: Disruptions in the sequencing process in the port of Rotterdam (route 1 & 2)

manufacturer in Sweden. Overall it did not result in tardy waiting time in the transhipment ports; the tardiness in these ports is not related to the sequencing process. The probability of waiting time in Port Klang is 47% and 90%, respectively for route 1 and 2. If sequencing in route 1 occurs in the port of Singapore, instead of the port of Rotterdam, the tardiness is caused by missing shipping instructions for the batch from the Netherlands in the port of Rotterdam, see Figure 11. The consequence is tardy waiting times in Port Klang.

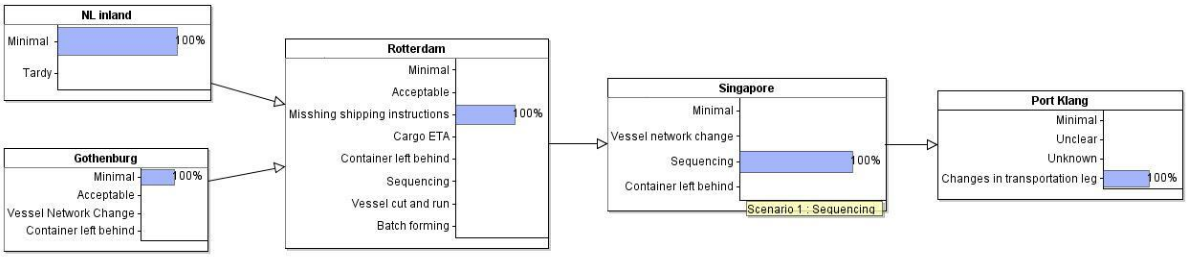

Figure 11: Disruptions in the sequencing process in the port of Singapore (route 1)

Figure 10 shows the conditional probabilities for tardy waiting times due to sequencing in the transhipment ports, route 3 and 4. A striking result is that if tardy waiting time occurs due to sequencing neither tardy waiting times occurred in the NL inland terminal or the port of Gothenburg nor Rotterdam. For batch 16, a container was left behind in the port of Rotterdam but the tardiness due to sequencing occurred due to an 'unforeseen contingency' between the port of Rotterdam and Singapore. If tardy waiting time occurs due to sequencing the probabilities of tardy waiting time in Port Klang is 86% and 0%, respectively for route 3 and 4. The consequences for route 3 match with route 1 and 2, while route 4 shows the opposite result. Unfortunately, route 4 only consists of three batches and therefore the probabilities shown in Figure 10 reflect only one batch.

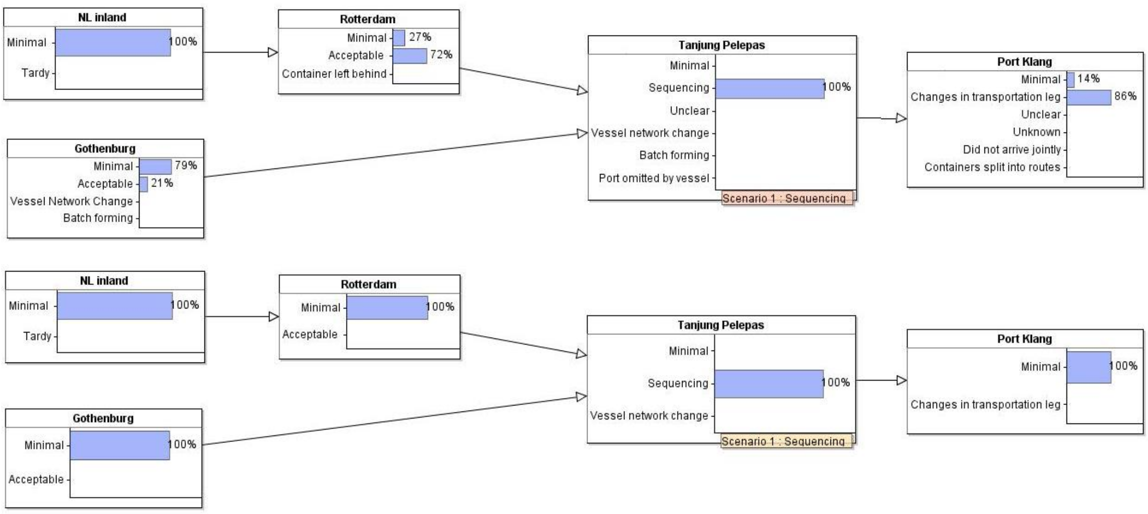

Figure 10: Disruptions in the sequencing process in the port of transshipment (route 3 & 4)

Figure 9, 10, and 11 show the causes and consequences of tardy waiting time in the different routes. However, these figures do not show information about the length of the total lead-time. In order to gain more insight in the lead-time, Table 7 shows three different average lead-times for the batches that dealt with tardy waiting time due to sequencing, and the average lead-times of the accompanying route. The first lead-time (type 1) is measured from the moment the containers enter the port of departure until the moment of discharge in Port Klang. This lead-time represents the part where the ocean carrier has custody over the containers. The lead-time of type 1 is inconsistently higher or lower compared to the average lead-time of the total flow of containers; the coloured lead-times represent the lead-times longer than the route averages. The second lead-time (type 2) is measured from the moment the containers enter the port of departure until the containers leave Port Klang. This lead-time adds up the waiting time in Port Klang to the lead-time of type 1. The average lead-times of the batches are again inconsistently higher or lower compared to the average lead-times of the related routes. The third lead-time (type 3) is measured from the moment the goods are loaded in the container until the containers leave Port Klang. This lead-time includes the lead-time of type 2 and also the pre-haulage to the port of departure. Again, the average lead-times of the batches are inconsistently higher or lower compared to the average lead-times of the route.

		Gate in - discharge	**Gate in - gate out**	**Loading date - gate out**
		Type 1	**Type 2**	**Type 3**
Route	**Batch**	**Average lead-time [days]**		
1	44	45,2	50,8	59,8
1	51	49	54,4	53,5
1	*Average*	*42,4*	*48*	*54,78*
2	27	47,5	56,5	58,8
2	29	40,8	61,6	67,6
2	30	39,5	49,7	56,6
2	31	39,6	57,6	64,2
2	32	39,4	47	52,8
2	38	40	43	49,3
2	*Average*	*41,9*	*56,7*	*62,8*
3	5	48,2	61,5	69,5
3	9	36,4	44	46,8
3	16	41,2	46,2	50,8
3	18	44,2	55,2	63,7
4	*Average*	*41,9*	*52,4*	*59*
4	10	44,3	48,7	54,7
4	*Average*	*38,8*	*49,6*	*55,29*

Table 7: Lead-times of batches related to tardiness due to sequencing [Coloured lead-times indicate that these are longer than the average lead-time]

The inconsistently lead-times can be the result of the average measurement of the two sequenced batches. Therefore, in order to verify this, the containers are split up based on country of destination; Sweden or the Netherlands in Table 8. In this table the averages lead-times of the batches compared to the average lead-time of the total flow of containers transported to Port Klang. The averages of the total number of containers are used instead of the averages per route because these lead-times are more aggregate. Also the lead-time per route is not important as long as the containers arrive in time. The three types of waiting time used are equal to the types in Table 7. Every type shows a different type of delay in the transportation leg caused by sequencing. If only the lead-time of type 1 is longer it indicates that additional waiting time due to sequencing took place. If only the lead-time of type 2 is longer, it implies that additional waiting time occurred in Port Klang.

			Gate in - discharge	Gate in - gate out	Loading date - gate out
			Type 1	Type 2	Type 3
Route	**Batch**		**Average lead-time [days]**		
1	44	SE	48	53,5	57
		NL	43,3	49	61,7
1	51	SE	49	55	57
		NL	49	54	55
2	27	SE	50	58	59,3
		NL	46	55,6	58,6
2	29	SE	43	63,7	64,7
		NL	39,1	60,2	69,8
2	30	SE	40,2	52,5	62,5
		NL	39	47,6	52
2	31	SE	40,5	58,5	69
		NL	39	57	61
2	32	SE	40	48,5	58,5
		NL	39	46	49
2	38	SE	38	44	53
		NL	41	41	47,5
3	5	SE	53	64,5	71,5
		NL	45	59,7	68,2
3	9	SE	38,8	46,8	52
		NL	34,8	42,2	43,3
3	16	SE	43	48	49
		NL	40	45	52
3	18	SE	48	58	68
		NL	52	53,3	60,8
4	10	SE	46	50,3	60,3
		NL	43	47,5	50,5
Total	**Average**	**SE**	**44,2**	**53,2**	**59,2**
		NL	**40,4**	**49,5**	**56,4**

Table 8: Lead-times split in origin containers

If only the lead-time of type 3 is longer, it implies additional buffer time in pre-haulage to smooth the sequencing process. If multiple lead-times are longer than the average lead-times it is a combination of the three possible causes. Although the containers of the batches are split up in to country of destination the results still show inconsistently results. This implies that the waiting time occurred due to sequencing does not result in substantive longer waiting times compared to the average lead-times.

Possibly, this is caused due to high average lead-times, for instance, if next to sequencing also other disruptions in the transportation leg occurred the average lead-time is longer. To verify this Table 9 compares the average lead-time of the batches in Table 8 to the lead-time of all the containers to Port Klang. Also the expected lead-times of the client and the ocean carrier are included to which represent the difference between the expected lead-times to the actual performance.

		Gate in - discharge	***Difference T2 - T1***	**Gate in - gate out**	***Difference T3 - T2***	**Loading date - gate out**
		Type 1		**Type 2**		**Type 3**
Expected LD of the client [days]	SE					46
	NL					38
Expected LD of the ocean carrier [days]	SE	38				
	NL	31				
Average LD of containers with tardy waiting times due to sequencing [days]	SE	44,4	*9,5*	53,9	*6,2*	60,1
	NL	42,3	*8,3*	50,6	*5,5*	56,1
Average LD of all containers transported to Port Klang [days]	SE	44,2	*9*	53,2	*6*	59,2
	NL	40,4	*9,1*	49,5	*6,9*	56,4

Table 9: Averages lead-times compared to the expectation of the client and the ocean carrier

By comparing the lead-times in Table 9 it can be concluded that the lead-times obtained from the entire data are higher than expected by the client and the ocean carrier. The lead-times derived from the ocean carrier are officially 35 (SE) and 28 (NL) days. The waiting time in the port of departure is not included by the ocean carrier and therefore the minimal waiting time (three days) is added to be able to compare the lead-times to each other. To deal with pre-haulage and sequencing the client adds seven to eight days to the expected lead-time of the ocean carrier to be able to plan the latter activities of the supply chain more accurate. However, these extra days are not enough to compensate for additional delays compared to the lead-times calculated from the data. The determined total lead-times are on average thirteen to sixteen days longer than the expectation of the client. These differences suggest that the client is not up to date about the actual lead-time of the shipments.

The lead-time of type 1 obtained from the data is six to nine days longer than the expectation of the ocean carrier. This difference between the lead-times seems explicable because if containers experience additional waiting time it is approximately eight days, because the ocean vessel departs once a week. Therefore the other batch needs to wait at least one week before the containers can be sequenced. Waiting time in the batch from Sweden due to sequencing often occurs in a transhipment port, where the feeder departs every four days which decreases the average waiting time compared to the batch from the Netherlands. Table 5 supports these tardy waiting times in batches related to sequencing. Nevertheless, some containers wait much longer than eight days, probably these containers experienced additional disruptions.

The differences in lead-times between type 1 and 2 are caused due to waiting time in Port Klang. For both the containers from Sweden and the Netherlands the additional lead-time is nine days, ea. the average additional waiting time is nine days in Port Klang, while the free time in Port Klang is five days. The difference for batches from Sweden and the Netherlands is equal because both batches arrive and leave the port as one batch. The total average lead-time from the data (type 3) includes, next to lead-time type 2, pre-haulage. This lead-time is on average six to seven days longer, which seems explicable as buffer time in pre-haulage. Buffer time is needed to smooth the sequencing process, for instance, if the batch from Sweden is delayed they will arrive seven days later because the ocean vessel departures once a week.

The three types of lead-times related to sequencing are on average longer than the averages of the total data. This confirms that disruptions related to sequencing in the transportation legs cause additional delays in the transportation leg. However, the differences between the averages of batches related to sequencing and the total batch are minimal; the difference between the averages is less than 5%. This implies that next to delays related to sequencing, also other disruption influences average lead-time in the transportation leg.

Unfortunately, no causes can be found for the tardy waiting time of nine days in Port Klang. In total 455 containers are investigated in this thesis, whereof in total 301 containers experienced a waiting period over five days in Port Klang. These containers represent 37 of the 51 investigated batches. Table 10 shows the conditional probabilities of the causes of the tardy waiting times in Port Klang, the conditional probabilities are calculated with formula 4. A few containers encountered multiple events; resulting in a sum of conditional probabilities higher than 100%.

$$P\left(Cause\ X \middle| Tardiness\ in\ Port\ Klang = \frac{\#\ of\ containers\ with\ tardy\ WT\ due\ to\ cause\ X}{\#\ of\ containers\ with\ tardy\ WT\ in\ Port\ Klang}\right) \qquad 4)$$

For 12% of the containers the cause of waiting time is unknown and for 9% of the containers the cause is unclear. This indicates that 79% of the containers experienced a change along the transportation leg.

Causes	Number of containers	Number of batches	Conditional probabilities
Sequencing	69	9	23%
Vessel network change	59	7	20%
Container left behind	56	5	19%
Vessel capacity limited	38	4	13%
Unknown	35	5	12%
Batch forming	34	4	11%
Cargo ETA earlied/advanced	26	3	9%
Vessel cut and run	24	2	8%
Unforeseen contingency	22	3	7%
Unclear	26	4	9%
Vessel omitted port	15	2	5%
Missing shipping instructions	13	2	4%
Separate arrival	7	1	2%

Table 10: Probability of causes based on tardiness in Port Klang

Nevertheless, these disruptions are not the actual cause of the tardy waiting time in Port Klang. It only shows that the probability of tardiness in Port Klang is higher if disruptions change the transportation leg. However, the actual cause of tardy waiting times in Port Klang cannot be explained by the sequencing process of by the available data. Not all containers mentioned in Table 10 experienced disruptions due to sequencing, therefore, another cause need to cause the waiting time in Port Klang. To confirm this, appendix 11 shows the conditional probabilities if no tardy waiting time occurs due to sequencing.

The conditional probabilities depicted in appendix 11 are compared in Table 11 with the probabilities that tardiness occurs due to sequencing (Figure 9 and Figure 10). For both route 1 and 2, the waiting time in Port Klang improves if the sequencing process run smoothly. Conditional probabilities for minimal waiting time improve from 53% to 66% and from 10% to 16%. For route 3 the likelihood for the minimal waiting time decline from 14% to 12%, while for route 4 the probability of minimal waiting time in Port Klang deteriorates from 100% to 13%. But still in every route tardy waiting times occur, which confirms that next to sequencing other problems cause tardy waiting time in Port Klang.

Route	Waiting time in in Port Klang	Conditional probability	
		Tardiness due to sequencing	No tardiness due to sequencing
1	Minimal	53%	66%
	Unclear	4%	5%
	Unkown	7%	8%
	Changes in the transportation leg	36%	22%
2	Minimal	10%	16%
	Changes in the transportation leg	90%	84%
3	Minimal	14%	12%
	Unclear	0%	18%
	Unkown	0%	45%
	Changes in the transportation leg	86%	24%
4	Minimal	100%	13%
	Changes in the transportation leg	0%	87%

Table 11: Conditional probabilities of waiting times in Port Klang

Chapter 5: Discussion and conclusions

This chapter starts with a discussion about the results provided in chapter 4. Subsequently the conclusion provides an answer to the research question. Finally, the limitations, possibilities for future research, and recommendations are provided.

5.1 Discussion

The aim of this thesis is to provide insights on the sequencing process in the international transportation leg. Sequencing aims to align two or more flows smoothly in order to enhance the efficiency of the process. Traditionally, sequencing occurs in the internal logistics and material management, while this thesis focuses on sequencing in the external logistics. Therefore, this thesis investigates an undiscovered field of research. Sequencing in the transportation leg deals with additional complexity due to multiple partners and governmental regulations and controls. Higginson (2013) confirms that extra complexity occurs in the supply chain due to governmental regulations and taxes when the movement of goods crosses borders. The transportation legs investigated in this thesis include the sequencing process to prevent high tax rates and to enhance the efficiency. However, the sequencing mainly increases the complexity for the client. Complexity can result in unreliable and inconsistent lead-times (Hausman et al., 2005).

The sequencing process in the transportation leg to Malaysia leads to unreliable and inconsistent lead-times for the client; the average lead-time is almost 58 days and its variance is almost 94 days. The impact of the sequencing process is limited for the containers transported to Thailand. The flows of containers from Sweden and the Netherlands to the port of Laem Chabang can be considered as parallel flows in which only the moment of arrival is important. Also the available data is limited for this the transportation leg, therefore the transportation leg to Thailand is not included the data analysis.

The delayed lead-times experienced by the containers as result of the sequencing process in the transportation leg to Malaysia are for 93% caused by decisions of the ocean carrier. These decisions result in changing the booked vessel or changing the departure and arrival details of the containers. The decisions of the ocean carrier results in a tardy waiting time of at least eight days in the port of Rotterdam because the vessel in the port of Gothenburg and Rotterdam departs only once a week. If the sequencing occurs in a transhipment port the waiting time is at least five days because the feeder to Port Klang for both ports departs every four days. This delayed lead-time includes the waiting time for the next vessel additional to the days required for the Container Closing Date (CCD).

The consequences of sequencing mainly have impact on the waiting time. The average lead-time of 58 days includes 19 days of waiting time with a variance of 73 days. These high variances in the transportation leg of the client result in higher transportation costs and missed tax advantages for the client. The variance in the waiting time is caused by tardy waiting time in the port where the sequencing process of the containers is planned and in the port of destination (Port Klang). The waiting time in the port of sequencing, is a direct consequence of the sequencing process; to align the containers waiting time occurs. If the sequencing is planned in the port of Rotterdam it is possible to avoid tardy waiting times by buffering the containers at the client, but if the sequencing occurs in a transhipment port the containers need to wait until the sequencing take places and the departure of the next feeder to Port Klang. This buffer time is included in the pre-haulage time of the containers, because no data is available of the steps between the loading of the containers and departure of the barge in the inland terminal. Therefore, the buffer time is part of the transit time instead of the waiting time. This buffer time also contributes to the variance of the total lead-time because if the pre-haulage time is excluded from the transit time the variance reduces from 28.5 to 14.7 days.

The waiting time in Port Klang is not directly related to the sequencing process. However, this waiting time is the main cause of the high variance of the waiting time; by excluding the waiting time in Port Klang the variances of the total waiting time reduces from 73 to 19.2 days. The waiting time in Port Klang is not directly related to sequencing because not only containers that experiences disruptions in the sequencing process have tardy waiting times in Port Klang, in total 301 containers encounter waiting time over five days in Port Klang. Unfortunately, the available data does not provide insights in the actual causes of the tardy waiting time in Port Klang. Both the client and Seacon Logistics presume that these containers encounter problems with the Malaysian customs, which causes the tardy waiting times. Not the physical sequencing process induces these problems but probably the administrative sequencing process, except for the batch of the containers which did not arrive simultaneously. Problems with the administrative flow can be the result of incorrect documentations or a late release of the required documentations. Unfortunately, no evidence is found for both possible problems by checking the documentation for all batches with tardy waiting times. The tardy waiting times can also be the consequence of inefficiency in the Port Klang or in the pick-up of process of the Malaysian client, though, no evidence for these possible causes can be found in the available data.

Remarkable is the unawareness of both the client and Seacon Logistics about the waiting time in Port Klang. Officially, the client is responsible until the containers are discharged in Port Klang, the applied incoterm is 'Delivery At Place' (DAP), and the specified place is Port Klang. Seacon Logistics' job is to arrange this transportation for the client which implies that their responsibility is also until the discharge of the containers in Port Klang. Even the ocean carrier, who executes the transportation, is responsible until delivery in Port Klang. Despite the fact that the real cause for tardy waiting times in Port Klang is unknown, it seems reasonable that there is a relationship between waiting time in Port Klang and tardiness along the transportation leg. This relationship is confirmed by Table 11 which shows that for 35 containers (12%) the cause of tardiness is unknown while for the other 266 containers disruptions occurred during the transportation. However neither the client, ocean carrier, nor Seacon Logistics are responsible for the activities in Port Klang, therefore, the Malaysian client need to deal with it while they are not aware of the proceedings along the transportation leg.

5.2 Conclusion

In order to manage the sequencing process in the transportation leg it is important to control the logistic indicator 'time'. Sequencing aims to align two or more flows in order to create efficiency which affects especially the lead-times of the transportation leg. Nevertheless, sequencing activities in the transportation leg is an undiscovered field of research. Traditionally, sequencing lies at the core of assembly planning in the built-to-order production environment (Jiménez, 2011). Assembly aims to increase efficiency in the process due to minimizing lead-times and inventories (Hopp and Spearman, 2008). The influence of inventories is irrelevant for the transportation leg; nevertheless, extra complexity occurs due to governmental regulations and taxes when the movement of goods crosses borders (Higginson, 2013). The investigated case study wherein sequencing takes place is a transportation leg in which the containers originate from two different manufacturing locations and need to be sequenced during transportation. Sequencing is beneficial for Malaysia because the import taxes are 12% lower if containers that belong to one batch arrive simultaneously in Port Klang. For Thailand the import taxes are even 30% lower if the containers that belong to one batch arrive at least four days from each other. The client cooperates with Seacon Logistics to realise these tax advantages. Seacon logistics is responsible for arranging the transportation for the client. The ocean carrier executes the ocean transport.

The research question of this thesis is "*How can Seacon Logistics manage the sequencing process in the international transportation leg?"* The first step for Seacon Logistics is to reduce the variance of the total lead-time, which is mainly caused by the variance of the waiting times in the ports. The importance of reducing variance is confirmed by Christensen et al. (2007), who found a positive relationship between reducing lead-time variance and increasing financial performance. The variance in waiting times in the ports along the transportation leg is mainly (93%) caused by decisions of the ocean carrier. These decisions often result in re-planning the containers on the next available vessel which causes at least eight days waiting time in the port of Gothenburg and Rotterdam and at least five days waiting in the port of Singapore and Tanjung Pelepas. The consequences of these scheduling changes are, due to the sequencing process, larger than for individual flows. This is confirmed by the data from the transportation leg to Thailand in which scheduling changes have limited impact on the total lead-time.

Seacon Logistics and the client need to present the consequences of the decisions made by the ocean carrier, in such a way that it defines the need for the ocean carrier to adhere to the planned bookings. Based on this representation, agreements can be made on how to avoid the scheduling changes made by the ocean carrier. If in the long term the ocean carrier is unable to adhere to the planned bookings of Seacon Logistics, it seems reasonable to look for another ocean carrier. As long as the ocean carrier cannot fulfil the booking requests it is impossible for Seacon to manage the sequencing process.

The second step is to book the sequencing process in the port of Rotterdam. First of all, if the flow of containers from Sweden is delayed it is possible to buffer the containers at the client which avoids demurrages charges in the port of Rotterdam. These charges cannot be avoided if the containers are sequenced in the transhipment ports. Secondly, the sooner the sequencing process takes places in the transportation leg, the more time is available to solve possible problems. For example, if the containers are sequenced in Singapore and unfortunately part of the batch is left behind, than only one or two days remain to correct the sequencing process before the containers are discharged in Port Klang. Besides this possible problem, sequencing in the port of Tanjung Pelepas is not allowed by the Malaysian customs, due to the incorrect administrative flow. Also the variance of the lead-time of route 3, in which the containers are sequenced in the port of Singapore, is the highest of the four routes. Therefore this route is the most unreliable and inconstant flow of the routes. Finally, if the sequencing occurs early in the transportation leg it is more likely that a delay occurs in the total batch, instead of in one of the two batches, which does not endanger the simultaneous arrival of the containers in Port Klang. Ensuring the simultaneous arrival of the containers, in which the import tax is 12% lower, is the main reason for applying the sequencing in the transportation leg.

5.3 Limitations and future research

Although the thesis provides insights on how to manage the sequencing process in the international transportation leg, there are some limitations. First of all, the available data of the batches to Malaysia and Thailand is limited. The lead-time in the case study is measured based on 455 containers to Malaysia and 194 containers to Thailand. These containers represent respectively 52 and 35 batches which signify that the containers are transported in batches with an average of nine and six containers. Besides, the batches are transported over four different routes for Malaysia and seven routes, which are combined to four routes, for Thailand, which limits the available data per route. If more data would be incorporated in this case study, it would be possible to verify the causes and consequences of sequencing more conclusively. When there is more data available, also the transportation leg to Thailand can be used to define the causes and consequences of sequencing.

Second, due to the limited available time, only one transportation leg is investigated to provide insights on how to manage sequencing in the international transportation leg. This subject is not explored before and thus it is not possible to verify the results with the outcomes of other investigations. Therefore, in order to generalise the results of this thesis, multiple other transportations legs should be explored first.

Thirdly, the possibilities for applying the Bayesian Network (BNs) should be discovered. In this thesis the BNs are used as a tool to provide insights in the causes and consequences of sequencing, with the aid of the freely accessible version of AgenaRisk. However, more extended models are possibly, for example including the time aspect of the waiting time into the model. In order to include a more complex model a more extended or comprehensive software should be applied because the freely accessible version of AgenaRisk has limited possibilities.

5.4 Recommendations

Although Seacon Logistics is not responsible for problems related to sequencing, they can enhance their control in the sequencing process in the transportation leg. First of all, the control can be enhanced by booking the sequencing process in the port of Rotterdam. Second, the control can also be enhanced by investigating the causes of the other disruptions in the transportation leg, which are not related to sequencing. Especially, disruptions related to the tardy waiting times in Port Klang. Currently, the responsibility of Seacon Logistics is until the discharge of the containers; however, their business strategy is to be active as chain director. In order to provide that service the responsibility should cover the entire transportation leg, from pick-up at the client until delivery at the Malaysian client. However, managing the total transportation leg is more complicated by requirements of clients, e.g. in this case a fixed choice for the ocean carrier. Still, if Seacon Logistics manages the entire leg the causes and consequences can be made more transparent and it is easier to intervene if disruptions occur.

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Appendix 1: Search options

The search options used to filter for relevant literature is:

- Assembly- to- order
- Barriers in international transport
- Bayesian Networks
- Control theories
- Cross- border management
- Cross- docking
- Decoupling point
- Globalization
- Incoterms
- International trade
- Merging physical and information flow
- Oversee freight transport
- Production logistics
- Regulations
- Risk and uncertainties in supply chains
- Risk management (in supply chains)
- Sequencing
- Supply chains
- Supply chain disruptions
- Supply chain mapping
- Trade compliance
- Trade facilitation
- Trusted trade lane

Appendix 2: Additional information about data

First all point of measurements in the data are provided. Subsequently the data characteristics of the data of the containers to Malaysia and Thailand are explained.

In order to measure the lead-time of the transportation legs it is important to define the points of measurements. Table 12 shows all points of measurements per container and who provided the information. Most of the points of measurement are provided by the ocean carrier. This data is available by the track and trace webpage of the ocean carrier. Due to confidential issues the identity if the ocean carrier is kept anonymous.

Point of measurement	Abbreviations	Provided by	Explanation
Loading date		Client	Before this date the containers need to be loaded
Container Ready Date	CRD	Client	Before this date the container need be ready for transport
NL Inland port Out	NU	Seacon	This date is the final moment the containers need to leave the NL inland port
Expected Time of Departure	ETA	Seacon	This is the expected date of departure of the planned vessel
Actual Time of Departure	ATA	Client	This is the actual date of departure of the containers from the port of departure
Expected Time of Arrival	ETA	Seacon	This is the expected date of arrival of the planned vessel
Actual Time of Arrival	ATA	Client	This is tha actual date of arrival of the containers in the port of destination
Gate out empty		Ocean carrier	On this date the empty container is picked up in the port of departure
Gate in Gothenburg		Ocean carrier	On this date the container entered the port of Gothenburg
Load Gothenburg		Ocean carrier	On this date the container is loaded on the vessel in the port of Gothenburg
Departure vessel Gothenburg		Ocean carrier	On this date the vessel containing the containers departures in Gothenburg
Gate in/Discharge Rotterdam		Ocean carrier	On this date the container entered the port of Rotterdam
Load Rotterdam		Ocean carrier	On this date the container is loaded on the vessel in the port of Rotterdam
Departure vessel Rotterdam		Ocean carrier	On this date the vessel containing the containers departs in Rotterdam
Discharge Bremerhaven		Ocean carrier	On this date the container is discharged in the port of Bremerhaven
Load Bremerhaven		Ocean carrier	On this date the container is loaded on the vessel in the port of Bremerhaven
Discharge Singapore		Ocean carrier	On this date the container is discharged in the port of Singapore
Load Singapore		Ocean carrier	On this date the container is loaded on the vessel in the port of Singapore
Discharge Tanjung Pelepas		Ocean carrier	On this date the container is discharged in the port of Tanjung Pelepas
Load Tanjung Pelepas		Ocean carrier	On this date the container is loaded on the vessel in the port of Tanjung Pelepas
Discharge Port Klang		Ocean carrier	On this date the container is discharged in Port Klang
Gate out Port Klang		Ocean carrier	On this date the container is loaded on the vessel in Port Klang
Discharge Laem Chabang		Ocean carrier	On this date the container is discharged in the port of Laem Chabang
Gate out Laem Chabang		Ocean carrier	On this date the container is loaded on the vessel in the port of Laem Chabang
Delayed (#days)		Ocean carrier	This is the number of days the container is delayed in the port of destination
Early (#days)		Ocean carrier	This is the number of days the container arrived earlier in the port of destination
Reason delay/early		Ocean carrier	This is the reason why the container is early or late in the port of destination

Table 12: Points of measurement per container

Malaysia

The data for Malaysia consist of 51 batches; one batch contains the containers from Sweden and the Netherlands. Most batches originate from 2014, but also three batches originate from 2015. These batches represent 455 containers and 748 complete products, which are delivered in Malaysia. In order to control the containers, Seacon Logistics, the client, and the ocean carrier keep track of the containers. However, their information per individual container is not totally complete. Batches which were too incomplete to make reasonable estimations about are excluded for this research. Seacon books the containers at ocean carrier and keep track of the estimated information at moment of booking until the containers are loaded for transport to their port of departure. The client receives the booking information from Seacon and updates this information with the ATD and ATA of the vessel. Both the client and Seacon, keep track of the batches to control the actual moment of arrival.

Points in the transportation leg	Missing	Filled in by estimation	Missing after estimations
Date of loading container	1	1	0
Container Ready Date	0	0	0
NL Inland terminal Out	17	1	16
Estimated Time of Arrival	1	1	0
Estimated Time of Departure	0	0	0
Pick-up empty container	365	-	Excluded
Gate in Gothenburg	14	14	0
Load in Gothenburg	14	14	0
Departure vessel Gothenburg	0	0	0
Gate in/ Discharge Rotterdam	15	15	0
Load in Rotterdam	3	3	0
Departure vessel in Rotterdam	0	0	0
Discharge Singapore	4	4	0
Load in Singapore	3	3	0
Discharge Tanjung Pelepas	3	3	0
Load in Tanjung Pelepas	3	3	0
Discharge in Port Klang	3	3	0
Gate out Port Klang	3	3	0

Table 13: Missing points of measurement for Malaysia

Table 13 shows the missing data points in the data for Malaysia. The second column depicts the number of missing track and trace information of specific containers. Missing implies that the track and trace website of the ocean carrier does not show the information about particular points of the transportation leg. The missing data mentioned in the third column are filled up with estimations; these estimations are based on information from other containers from the same batch. For example, if a batch consists of five containers and for one container the information is missing about the moment of discharge in SP, although, the container is loaded on the same date in Rotterdam and Singapore. Then it is assumed that this container has the same moment of discharge in SP, like the other four containers. If the other containers differ in date of discharge, which deviates maximum one day of each other, the earliest moment is chosen. The third row represents the number of estimations which are filled in to make the data more complete.

The data for the moment of the pick-up of an empty container is excluded for the analysis. Too much data is missing; therefore it is not possible make reasonable assumptions. All other points in the transportation leg can be complemented due to reasonable estimations. The data of Seacon consist some missing data of “NL inland terminal out (NU)” which represents the moment the containers are leaving the client in the Netherlands, for three batches (batch 26, seven containers; batch 38, four containers; batch 51, five containers) the actual NU is unknown. This does not have a high impact on the analyses because it does not influence the total lead-time. Naturally, it impacts the average time between loading and departure in the NL inland terminal, but for this part these three batches will be excluded for the analysis. The data of the client is complete and therefore does not need any assumptions.

Thailand

The data of Thailand consist of 35 batches. Most batches originates from 2014, nevertheless, also six batches originates from 2015. These batches represent 194 containers. The tracking information is obtained in the same manner as for the batches to Malaysia. Unfortunately, much data about the batches to Thailand was not available on the website of the ocean carrier whereby these are excluded for this research. Table 14 represents the missing data for the transportation leg to Thailand. The NU date is missing for batch 38, from 2014; no estimations are made to fill up these data because no reasonable assumptions could be made and the impact of the missing information is limited; it does not impact the total lead-time. After a few estimations and excluding 'Pick-up empty container' the data is complete.

Points in the transportation leg	Missing	Filled in by estimation	Missing after estimations
Date of loading container	2	2	0
Container Ready Date	0	0	0
NL inland port out	4	0	4
Estimated Time of Arrival	0	0	0
Estimated Time of Departure	0	0	0
Pick-up empty container	163	-	Excluded
Gate in Gothenburg	1	1	0
Load in Gothenburg	1	1	0
Departure vessel Gothenburg	0	0	0
Gate in/ Discharge Rotterdam	4	4	0
Load in Rotterdam	2	2	0
Departure vessel in Rotterdam	0	0	0
Discharge Singapore	0	0	0
Load in Singapore	0	0	0
Discharge Tanjung Pelepas	1	1	0
Load in Tanjung Pelepas	1	1	0
Discharge in Port Laem Chabang	1	1	0
Gate out Port Laem Chabang	1	1	0

Table 14: Missing points of measurement for Thailand

Appendix 3: Statistical facts about the transportation leg to Malaysia

This appendix shows the statistical information about the four routes to Malaysia. The statistical information is based on 455 containers which are transported from the port of Gothenburg or Rotterdam to Port Klang.

Malaysia

Route 1 represents the biggest flow of containers which are sequenced in the port of Rotterdam, where after the containers are jointly transported via Singapore to Port Klang. All the parts of the transportation leg are numbered; these numbers correspond with the numbers in the histogram and the table. The histogram visualizes the average duration and its variance in days. The table shows the statistical details for all parts. The structure of visualisation is equal for all routes. The containers are loaded in the Netherlands and Sweden, these locations also serve as buffer place to align the containers efficiently and minimize the waiting time in the ports, in this case the moment of sequencing. Figure 12 shows route 1. In this route the containers are sequenced in the port of Rotterdam, where after the containers jointly are transported via Singapore to Port Klang.

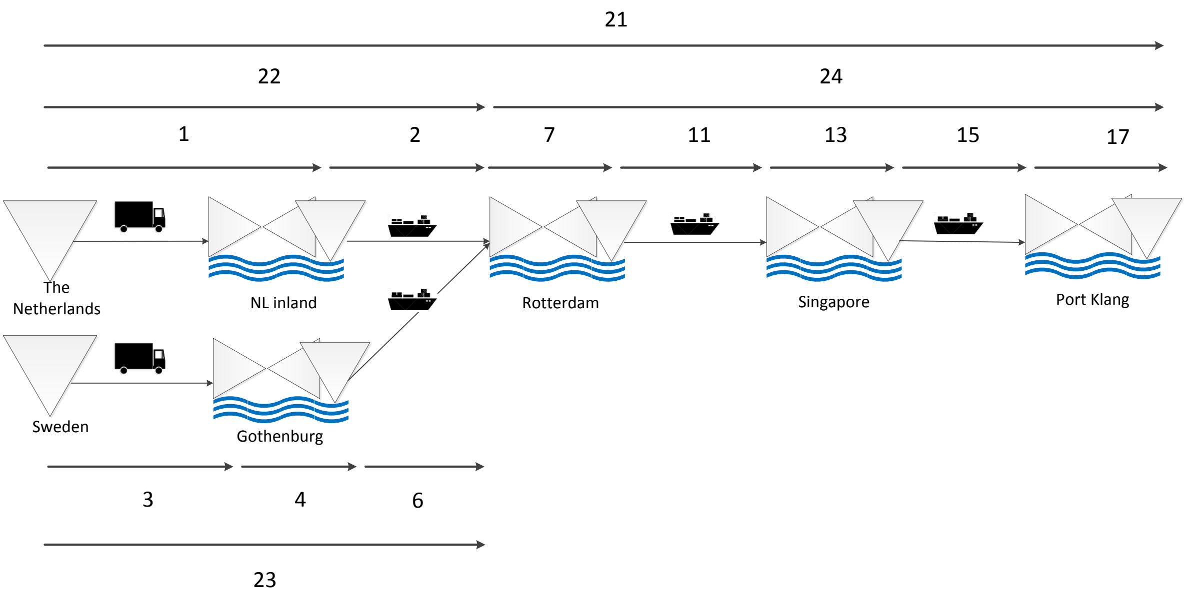
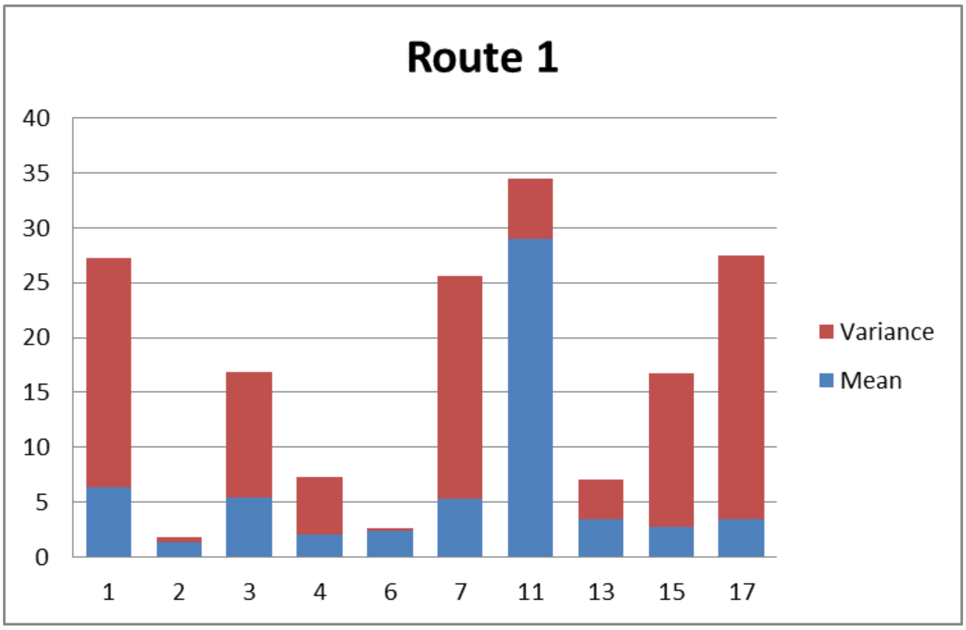


Figure 12: Malaysia - route 1

The statistical information of all the numbered parts is shown in Graphics 1 and Table 15. The variances for part 1, 3, 4, 7, 15 and 17 are higher than the mean of these parts. In chapter 3 these high variances are explained



Graphics 1: Malaysia - route 1

Part	Type	N	Mean	Variance	St. Dev.	Minimal	Maximal	Range	Median	Mode
1	LD	123	6,37	20,87	4,57	0	21	21	5	12
2	LD	123	1,37	0,43	0,66	0	2	2	1	2
3	LD	86	5,44	11,45	3,38	0	14	14	4	4
4	WT	86	2,06	5,28	2,30	0	17	17	1	1
6	LD	86	2,37	0,31	0,56	2	5	3	2	2
7	WT	209	5,35	20,29	4,50	0	20	20	3	2
11	LD	209	28,99	5,45	2,33	24	40	16	30	30
13	WT	209	3,44	3,56	1,89	1	10	9	4	4
15	LD	209	2,76	13,98	3,74	0	17	17	1	1
17	WT	209	3,44	23,99	4,90	0	20	20	5	1
21	Total	209	54,78	79,06	8,89	40	79	39	52	49
22	1+2	123	7,75	20,98	4,58	0	22	22	7	8
23	3+4+6	86	9,87	14,04	3,75	5	24	19	8	7
24	7+..+17	209	46,19	82,5	9,08	33	68	35	43	40

Table 15: Statistical data - MY route 1

Route 2 represent the flow of containers which are sequenced in the port of Rotterdam, where after the containers are jointly transported via Tanjung Pelepas to Port Klang. Figure 13 shows route 2.

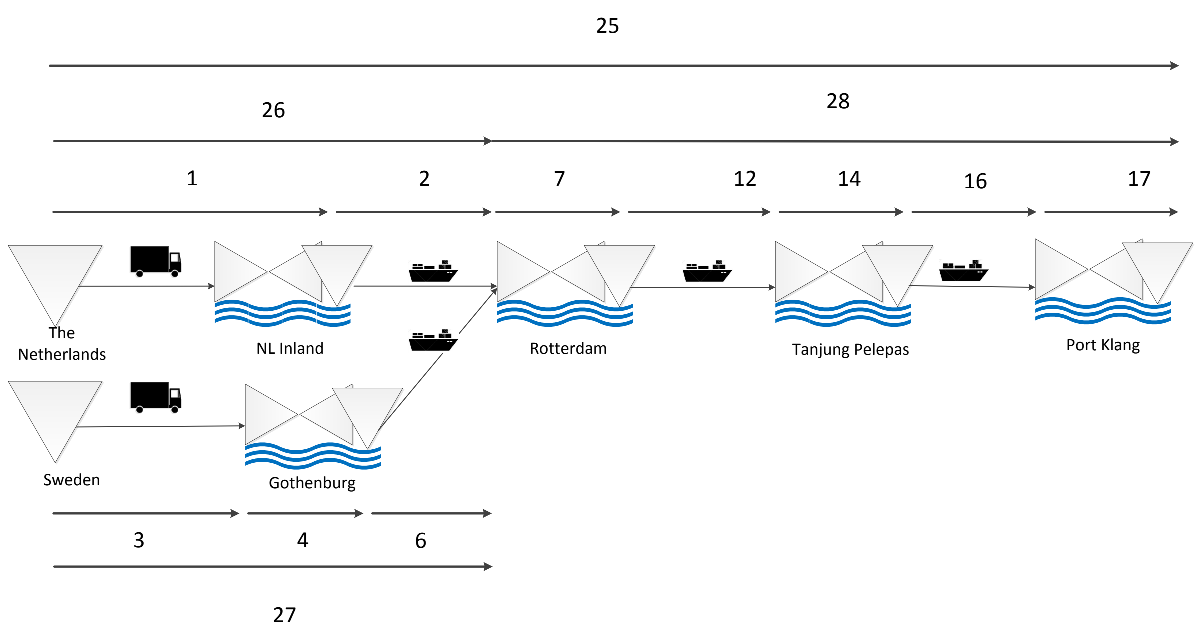
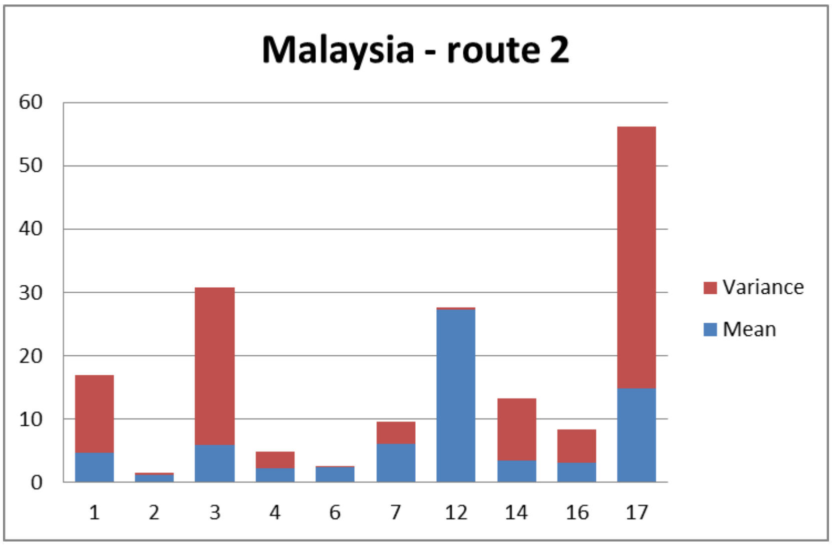


Figure 13: Malaysia - route 2

The statistical information of all the numbered parts is shown in Graphics 2: Malaysia - route 2Graphics 2 and Table 16. The variances for part 1, 3, 14, 16, and 17 are higher than the mean of these parts. In chapter 3 these high variances are explained.



Graphics 2: Malaysia - route 2

Part	Type	N	Mean	Variance	St. Dev.	Minimal	Maximal	Range	Median	mode
1	LD	54	4,74	12,2	3,49	0	11	11	4	3
2	LD	54	1,19	0,3	0,55	0	2	2	1	1
3	LD	34	6,03	24,82	4,98	0	14	14	6	10
4	WT	34	2,32	2,59	1,61	1	5	4	1,5	1
6	LD	34	2,41	0,25	0,50	2	3	1	2	2
7	WT	88	6,16	3,4	1,84	3	11	8	6	5
12	LD	88	27,28	0,48	0,69	23	28	5	27	27
14	WT	88	3,44	9,79	3,13	1	9	8	2	2
16	LD	88	3,16	5,31	2,30	2	10	8	2	2
17	WT	88	14,83	41,48	6,44	0	29	29	15	20
25	Total	88	62,83	55,87	7,47	43	74	31	64	64
26	1+2	54	5,93	13,54	3,68	0	13	13	5	3
27	3+4+6	34	10,76	14,85	3,85	6	17	11	9,5	14
28	7+..+17	88	54,88	44,23	6,65	39	66	27	56	56

Table 16: Statistical date - MY route 2

Route 3 represent the flow of containers which are sequenced in the port of Singapore, where after the containers are jointly transported to Port Klang. Figure 14 shows route 3.

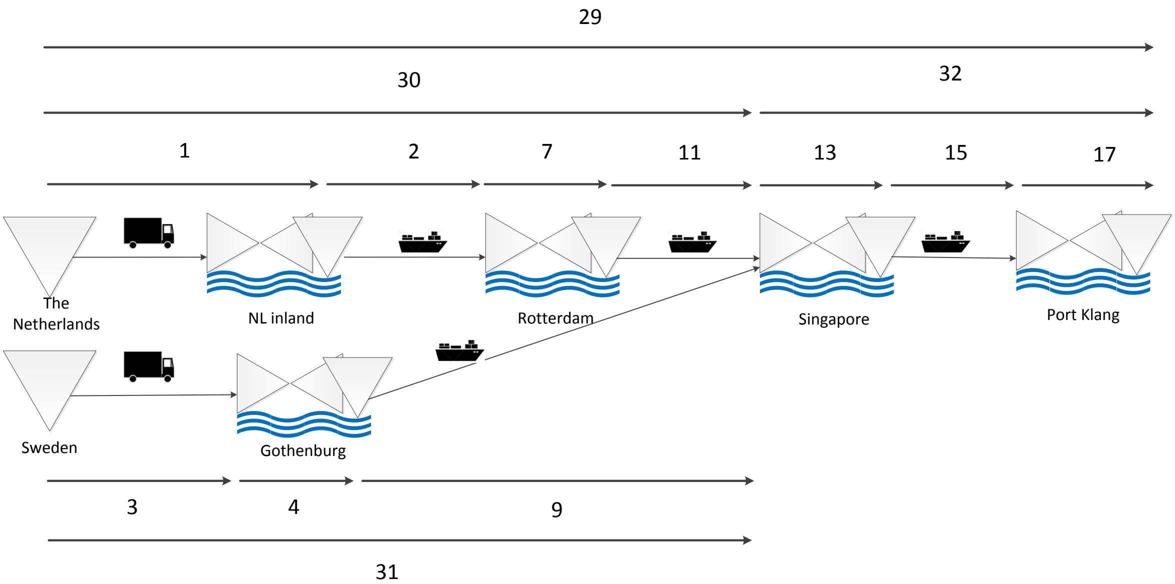
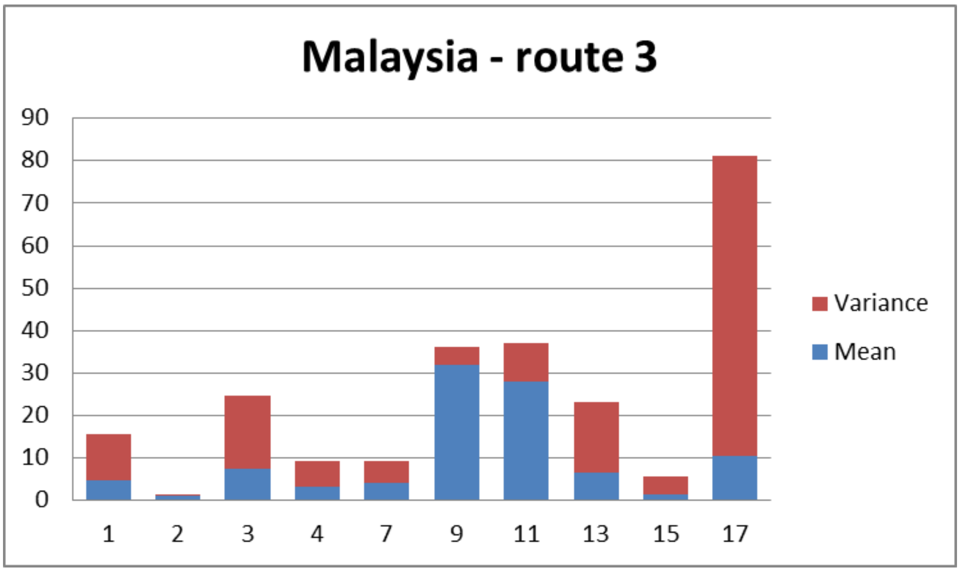


Figure 14: Malaysia - route 3

The statistical information of all the numbered parts is shown in Graphics 3 and Table 17. The variances for part 1, 3, 4, 7, 13, 15, and 17 are higher than the mean of these parts. In chapter 3 these high variances are explained.



Graphics 3: Malaysia - route 3

Part	Type	N	Mean	Variance	St. Dev.	Minimal	Maximal	Range	Median	mode
1	LD	75	4,84	10,76	3,28	0	12	12	5	5
2	LD	75	1,23	0,26	0,51	1	3	2	1	1
3	LD	52	7,54	17,23	4,15	0	17	17	7	7
4	WT	52	3,23	6,14	2,48	0	11	11	4	1
7	LD	75	4,13	5,25	2,29	1	17	16	4	5
9	WT	52	31,98	4,25	2,06	28	37	9	32	30
11	LD	75	27,95	9,16	3,03	22	37	15	28	28
13	WT	127	6,61	16,59	4,07	0	18	18	6	6
15	LD	127	1,57	4,14	2,03	0	11	11	1	1
17	WT	127	10,43	70,58	8,40	1	54	53	10	15
29	Total	127	59,01	129,39	11,37	42	98	56	58	58
30	1+2+7+11	75	38,15	22,99	4,79	29	51	22	39	39
31	3+4+9	52	42,75	31,92	5,65	35	56	21	42,5	38
32	13+15+17	127	18,61	93,38	9,66	5	56	51	17	13

Table 17: Statistical data - MY route 3

Route 4 represent the flow of containers which are sequenced in the port of Tanjung Pelepas, where after the containers are jointly transported to Port Klang. Figure 15 shows route 4.

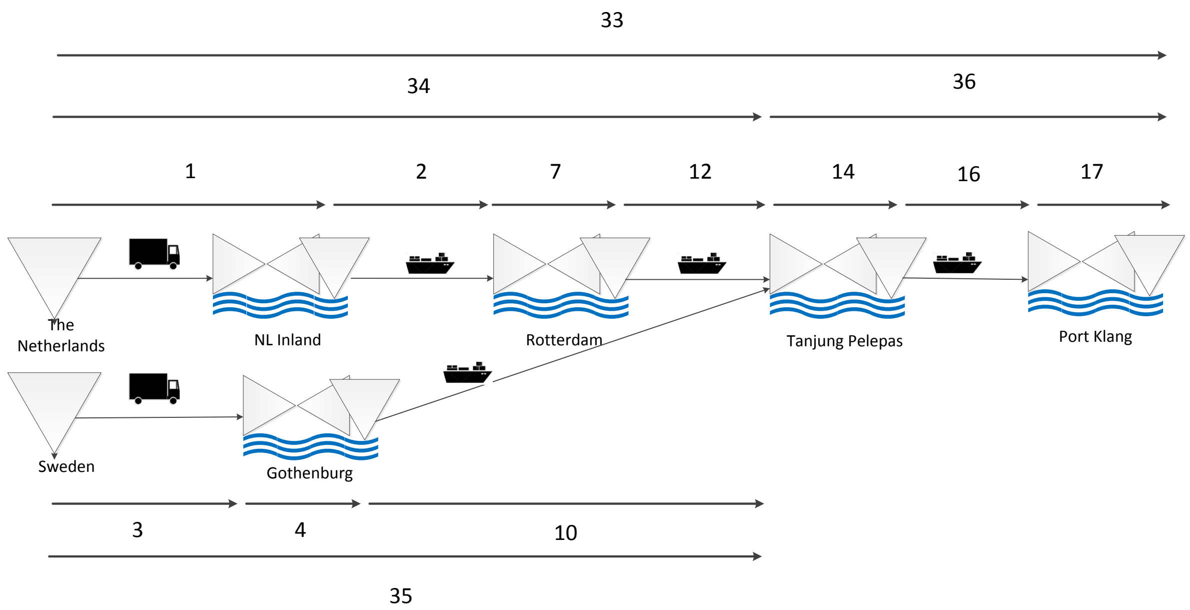
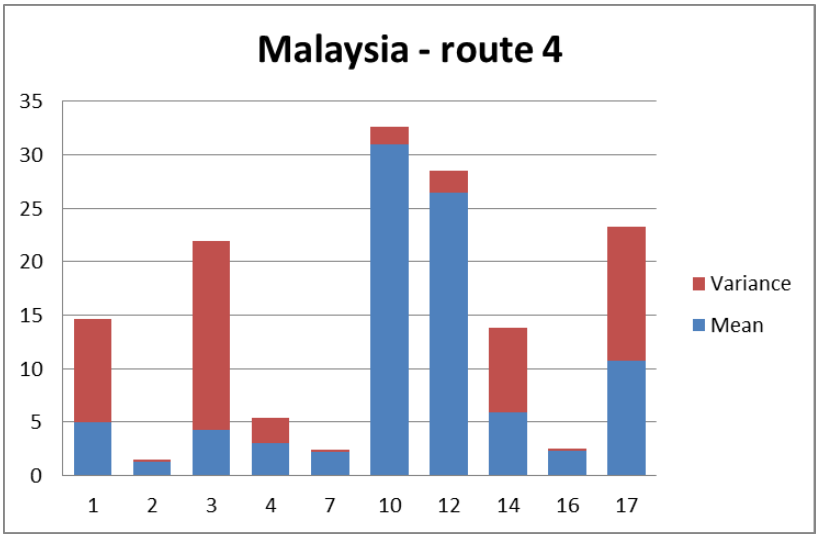


Figure 15: Malaysia - route 4

The statistical information of all the numbered parts is shown in Graphics 4 and Table 18. The variances for part 1, 3, 4, 7, 13, 15, and 17 are higher than the mean of these parts. In chapter 3 these high variances are explained.



Graphics 4: Malaysia - route 4

Part	Type	N	Mean	Variance	St. Dev.	Minimal	Maximal	Range	Median	mode
1	LD	20	4,95	9,65	3,11	0	8	8	7	8
2	LD	20	1,3	0,22	0,47	1	2	1	1	1
3	LD	11	4,27	17,62	4,20	0	16	16	4	4
4	WT	11	3,09	2,29	1,51	1	5	4	4	4
7	WT	20	2,2	0,27	0,52	1	3	2	2	2
10	LD	11	31	1,6	1,26	29	32	3	32	32
12	LD	20	26,45	2,05	1,43	23	29	6	26	26
14	WT	31	5,94	7,86	2,80	1	12	11	5	5
16	LD	31	2,29	0,21	0,46	2	3	1	2	2
17	WT	31	10,77	12,45	3,53	3	18	15	11	14
33	Total	31	55,29	15,21	3,90	48	64	16	55,5	55
34	1+2+7+12	20	35,15	4,24	2,06	31	37	6	36	37
35	3+4+10	11	38,36	19,45	4,41	31	46	15	40	40
36	14+16+17	31	19	25,6	5,06	7	33	26	18	18

Table 18: Statistical data - MY route 4

Appendix 4: Statistical facts about the transportation leg to Thailand

The original seven routes to Thailand are visualized in Figure 16. Route 4 is the frequent most used flow (twelve batches), followed by route 3 (seven batches), route 1 and 6 (both four batches), route 5 and 7 (both three batches) and route 2 (two batches). To make the statistical facts more aggregate the seven routes are combined into four main routes. The routes are based on the last transhipment port; Singapore or Tanjung Pelepas. The flows of containers to Thailand can be considered as two sequential flows whereby the time of arrival is importation; the flows should arrive at least four days from each other. Like in the routes to Malaysia, all the parts of the transportation leg are numbered; these numbers correspond with the numbers in the histogram and the table. The structure of visualisation is equal for all routes.

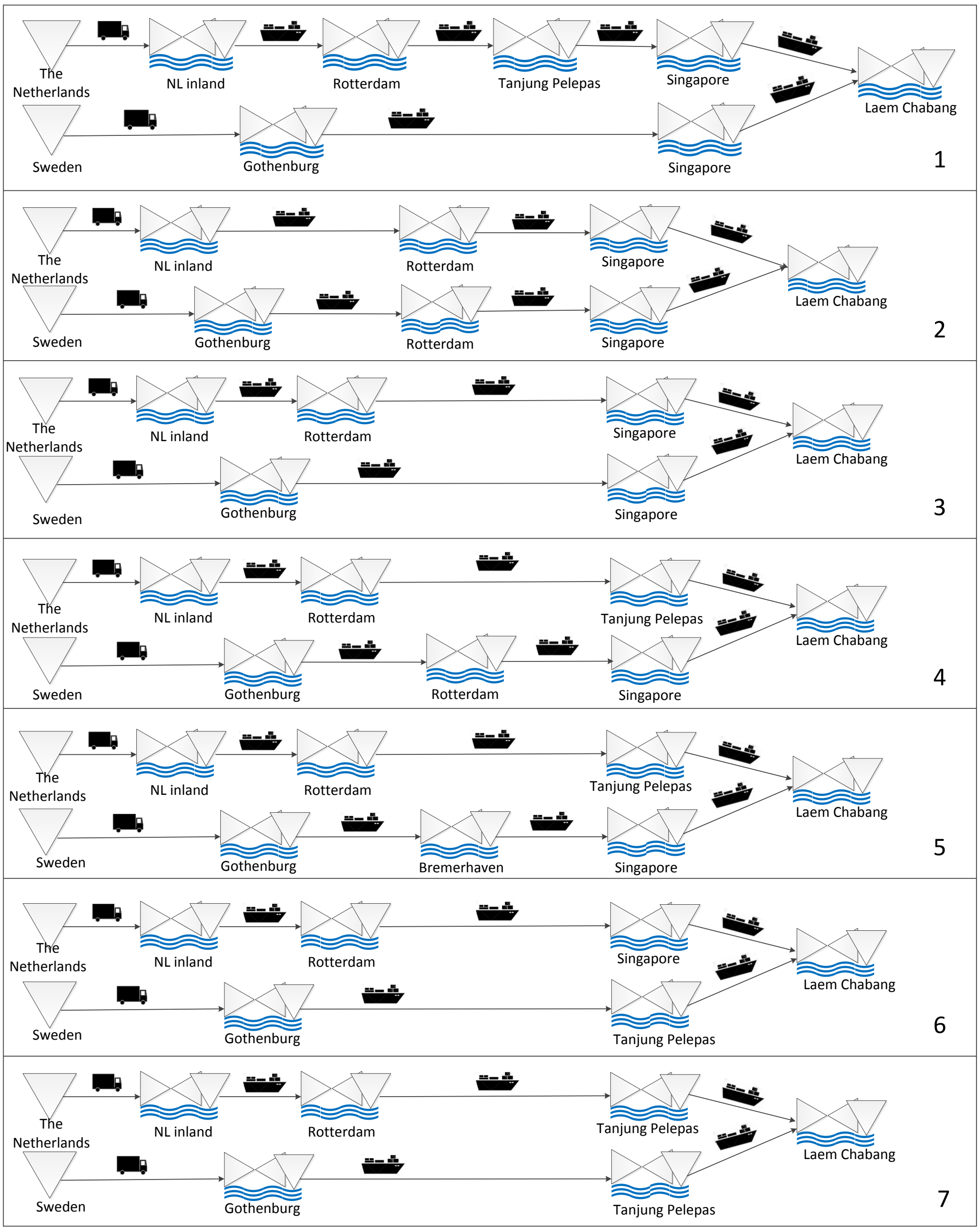


Figure 16: Original seven routes to Thailand

The first main route represents the flows of containers which both go via the port of Singapore to Laem Chabang. Figure 17 shows route 1.

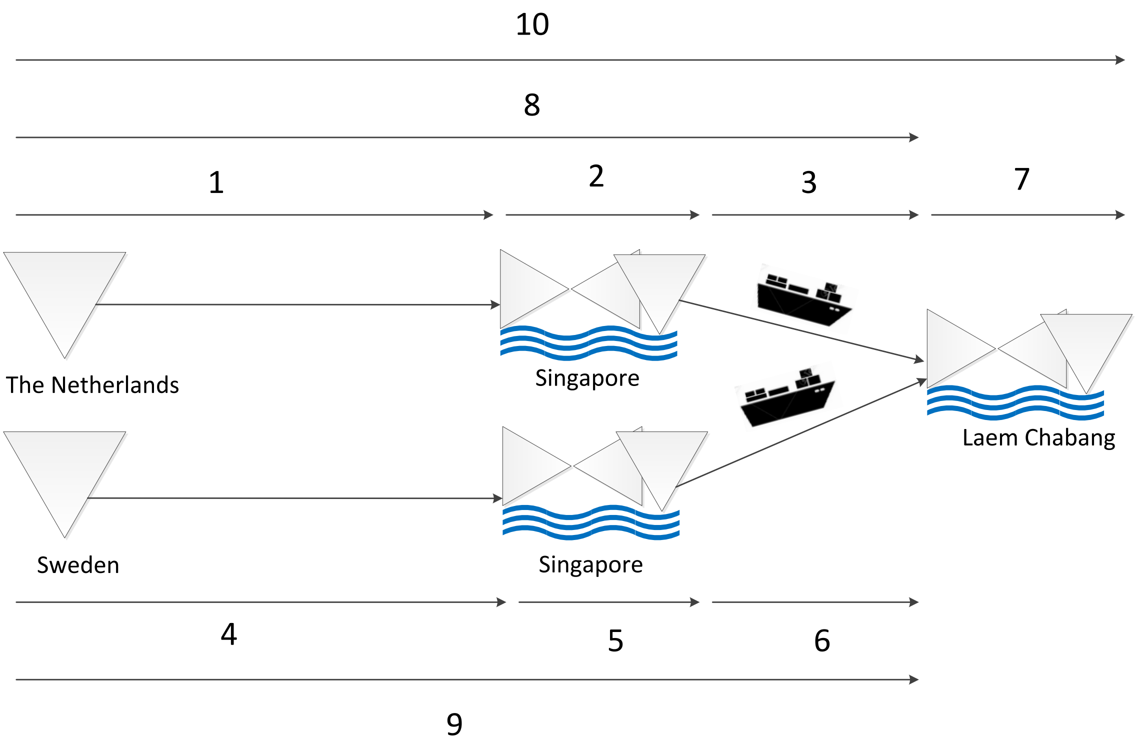
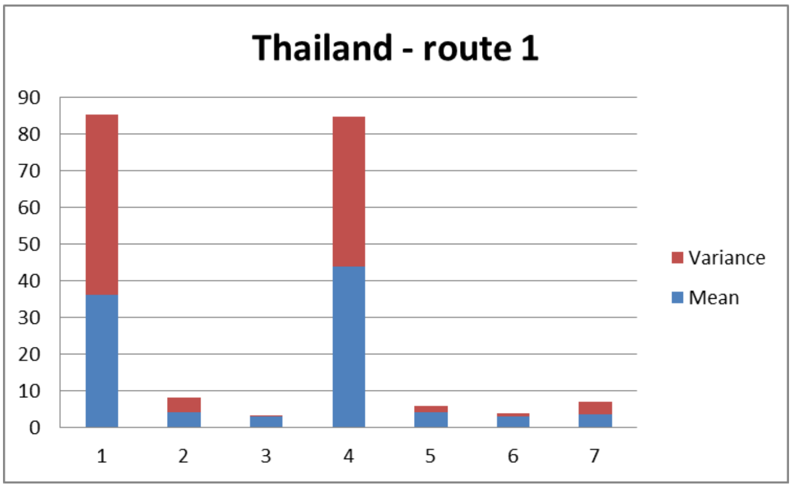


Figure 17: Thailand - route 1

The statistical information of all the numbered parts is shown in Graphics 5Graphics 2: Malaysia - route 2 and Table 19. The variances for part 1 and 4 are higher than the mean of these parts. These high variances are caused because these parts contain multiple steps in the transportation leg.



Graphics 5: Thailand - route 1

Part	Type	N	Mean	Variance	St. dev	Min	Max	Range	Median	Mode
1	LD	45	36,02	49,43	7,03	27	48	21	38	28
2	WT	45	4,16	3,91	1,98	2	7	5	3	3
3	LD	45	3,09	0,13	0,36	2	4	2	3	3
4	LD	22	43,77	40,95	6,40	33	56	23	41	41
5	WT	22	4,18	1,58	1,26	2	7	5	4	4
6	LD	22	3,05	0,71	0,84	2	4	2	3	4
7	WT	67	3,55	3,43	1,85	1	10	9	3	3
8	1+2+3	45	43,27	68,34	8,27	32	55	23	46	34
9	4+5+6	22	51,00	31,33	5,60	41	61	20	49	49
10	Total	67	49,36	55,26	7,43	36	65	29	51	57

Table 19: Statistical data - TH route 1

The second main route represents the flows of containers whereby the containers from the Netherlands are transported via Tanjung Pelepas, and the containers from Sweden are transported via Singapore to Laem Chabang. Figure 18 shows route 2.

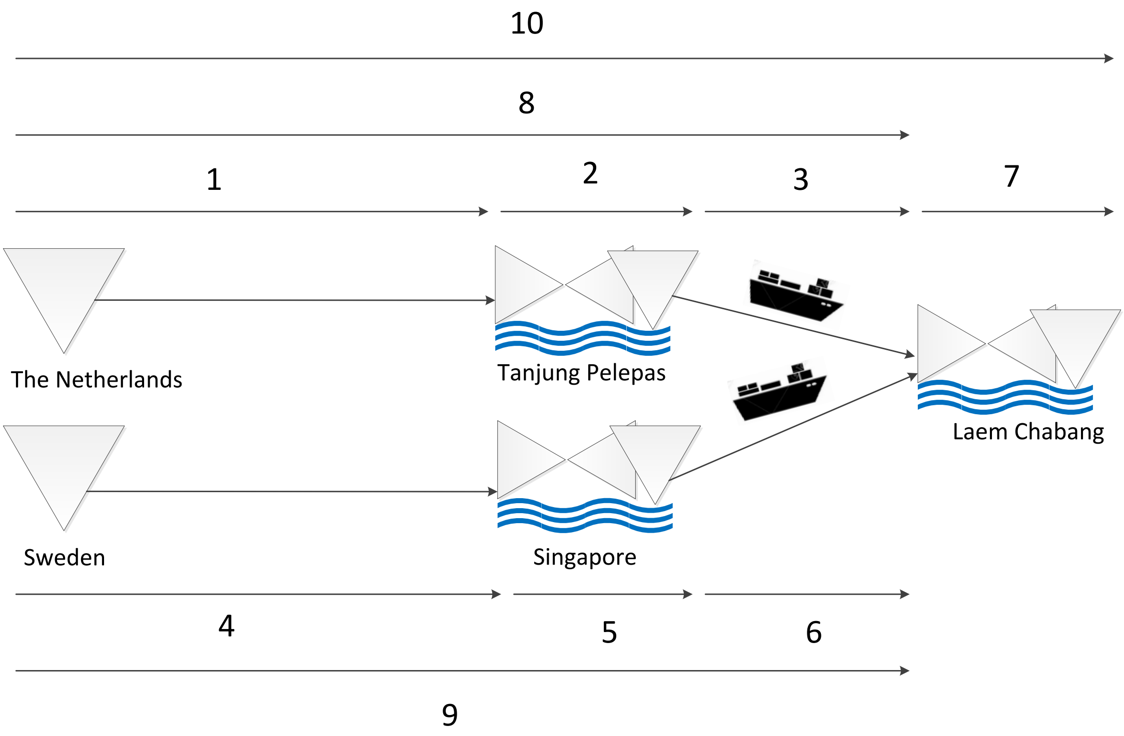
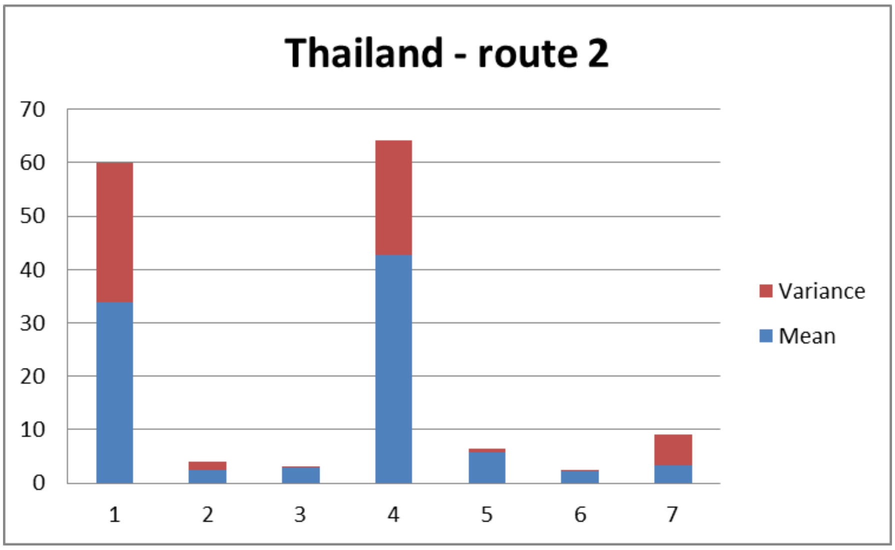


Figure 18: Thailand - route 2

The statistical information of all the numbered parts is shown in Graphics 6 and Table 20. The variance for part 1, 4, and 7 are higher than the mean of these parts. These high variances are caused because these parts contain multiple steps in the transportation leg.



Graphics 6: Thailand - route 2

Part	Type	N	Mean	Variance	St. dev	Min	Max	Range	Median	Mode
1	LD	58	33,79	26,27	5,13	29	50	21	32	32
2	WT	58	2,38	1,68	1,30	0	8	8	2	2
3	LD	58	2,81	0,23	0,48	2	4	2	3	3
4	LD	29	42,79	21,46	4,63	32	51	19	40	40
5	WT	29	5,66	0,81	0,90	2	7	5	6	6
6	LD	29	2,28	0,28	0,53	2	4	2	2	2
7	WT	87	3,31	5,68	2,38	0	11	11	3	3
8	1+2+3	58	38,98	28,30	5,32	34	55	21	37	37
9	4+5+6	29	50,72	19,28	4,39	41	58	17	49	48
10	Total	87	46,21	63,56	7,97	36	66	30	43	42

Table 20: Statistical data - TH route 2

The third main route represents the flows of containers whereby the containers from the Netherlands are transported via Tanjung Pelepas, and the containers from Sweden are transported via Singapore to Laem Chabang. Figure 19 shows route 3.

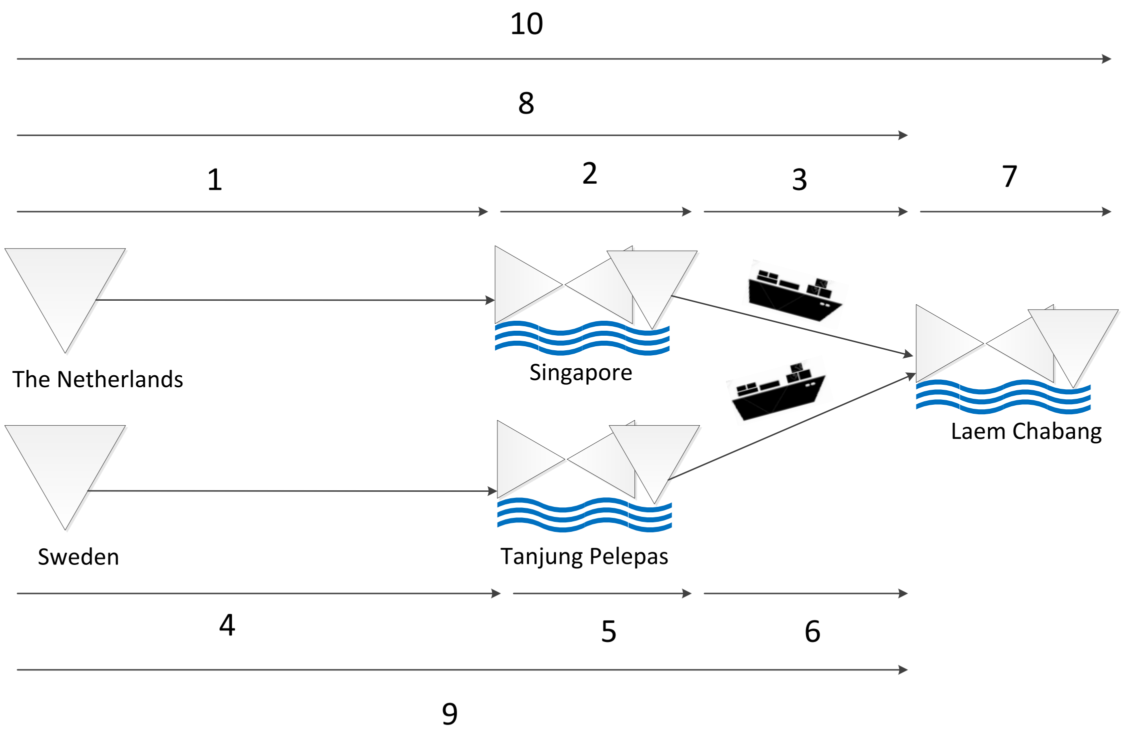
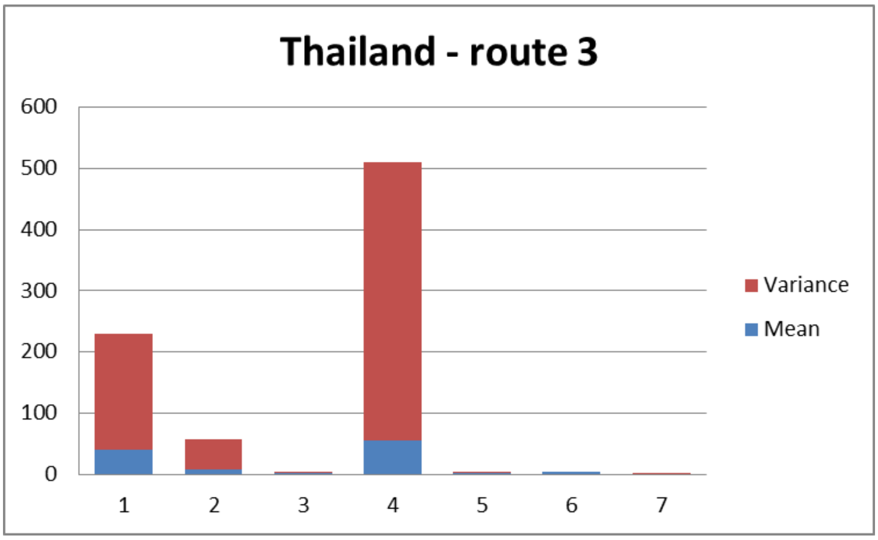


Figure 19: Thailand – route 3

The statistical information of all the numbered parts is shown in Graphics 7 and Table 21. The variance for part 1 and 4 are higher than the mean of these parts. These high variances are caused because these parts contain multiple steps in the transportation leg.



Graphics 7: Thailand - route 3

Part	Type	N	Mean	Variance	St. dev	Min	Max	Range	Median	Mode
1	LD	16	40,81	189,10	13,75	25	55	30	41,5	25
2	WT	16	8,31	49,30	7,02	0	17	17	4	17
3	LD	16	2,81	0,70	0,83	0	4	4	3	3
4	LD	8	55,00	454,29	21,31	37	80	43	44,5	37
5	WT	8	2,75	1,07	1,04	2	4	2	2	2
6	LD	8	3,00	0,00	0,00	3	3	0	3	3
7	WT	8	0,50	0,29	0,53	0	1	1	0,5	0
8	1+2+3	16	51,94	70,46	8,39	44	62	18	45	45
9	4+5+6	8	60,75	498,21	22,32	42	87	45	49,5	42
10	Total	24	57,38	194,33	13,94	42	88	46	50	50

Table 21: Statistical data - TH route 3

The fourth main route represents the flows of containers which are both transported via Tanjung Pelepas to Laem Chabang. Figure 20 shows route 4.

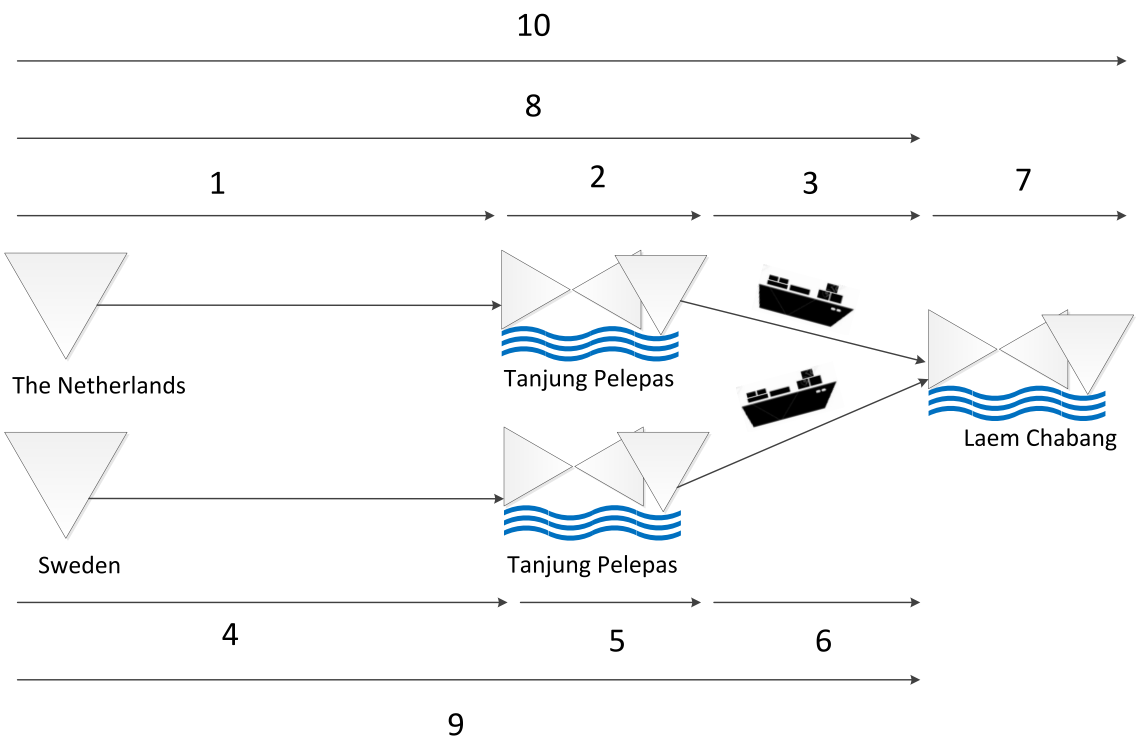
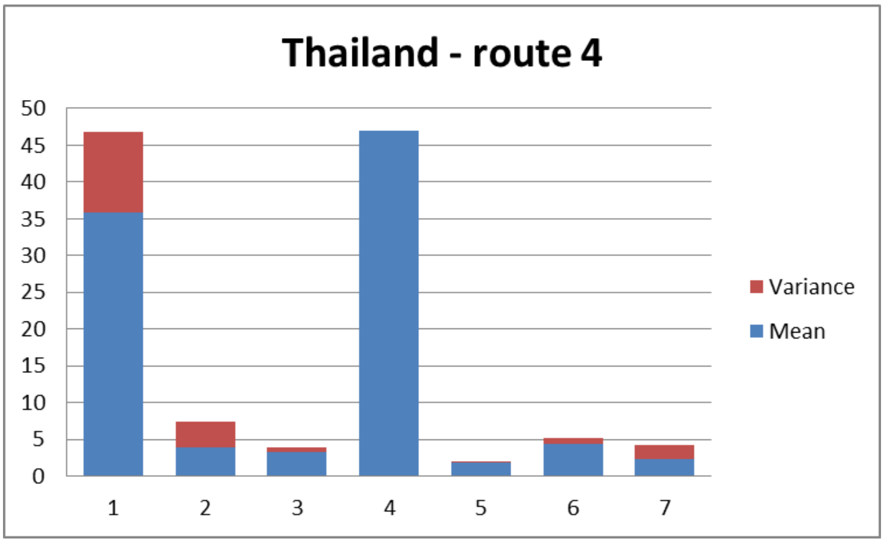


Figure 20: Thailand – route 4

The statistical information of all the numbered parts is shown in Graphics 8 and Table 22. The variance for part 1 is higher than the mean of this part. These high variances are caused because these parts contain multiple steps in the transportation leg.



Graphics 8: Thailand - route 4

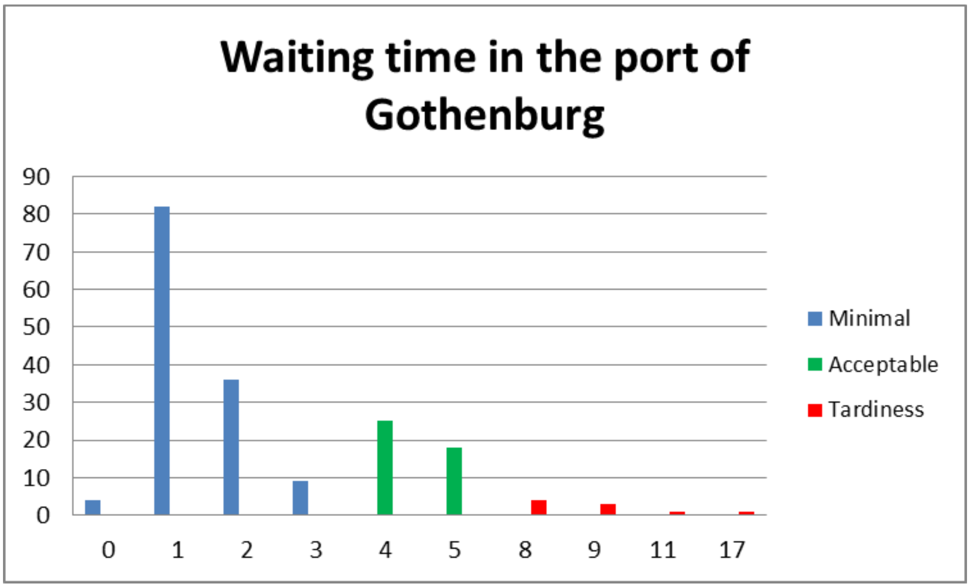
Part	Type	N	Mean	Variance	St. dev	Min	Max	Range	Median	Mode
1	LD	11	35,82	10,96	3,31	31	40	9	36	36
2	WT	11	3,82	3,56	1,89	2	7	5	3	2
3	LD	11	3,18	0,76	0,87	2	5	3	3	3
4	LD	5	47,00	0,00	0,00	47	47	0	47	47
5	WT	5	1,80	0,20	0,45	1	2	1	2	2
6	LD	5	4,40	0,80	0,89	3	5	2	5	5
7	WT	16	2,31	1,83	1,35	0	5	5	3	3
8	1+2+3	11	42,82	17,76	4,21	36	46	10	45	45
9	4+5+6	5	53,20	1,20	1,10	52	54	2	54	54
10	Total	16	48,00	20,27	4,50	39	53	14	48	48

Table 22: Statistical data - TH route 4

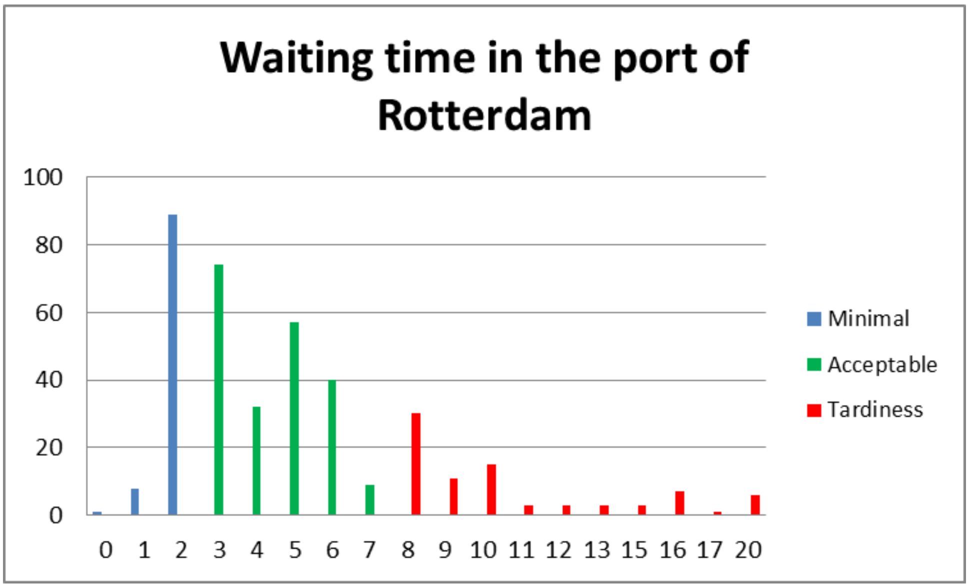
Appendix 5: Waiting time in the transportation leg to Malaysia

In this appendix the frequency tables of the waiting time are provided for the port of Gothenburg, Rotterdam, Singapore, Tanjung Pelepas and Port Klang. Also the related distributions are provided in Table 23. The waiting time in the frequency tables is determined from moment of arrival in the port until the moment of loading on the vessel. This deviates for Port Klang, which is the final port, in this port the waiting time is determined from moment of discharge until the containers leave the port.

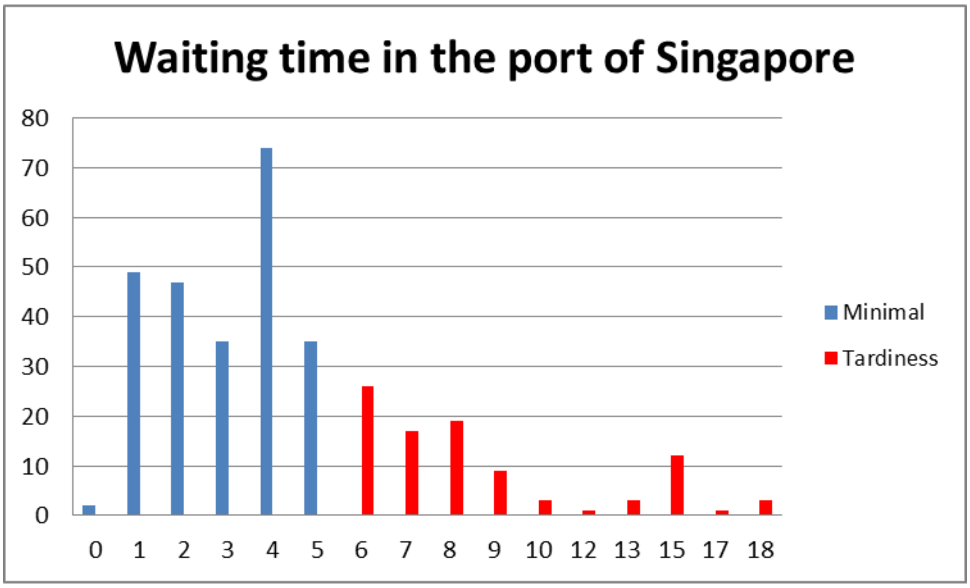
The used states in the frequency tables match the defined states in paragraph 4.5.



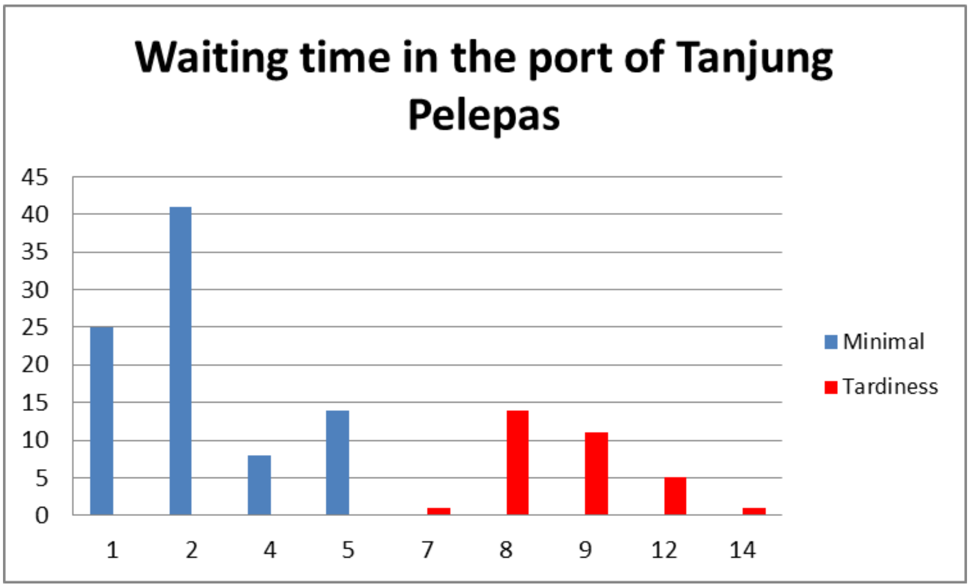
Graphics 10: Frequency table of waiting time in the port of Gothenburg



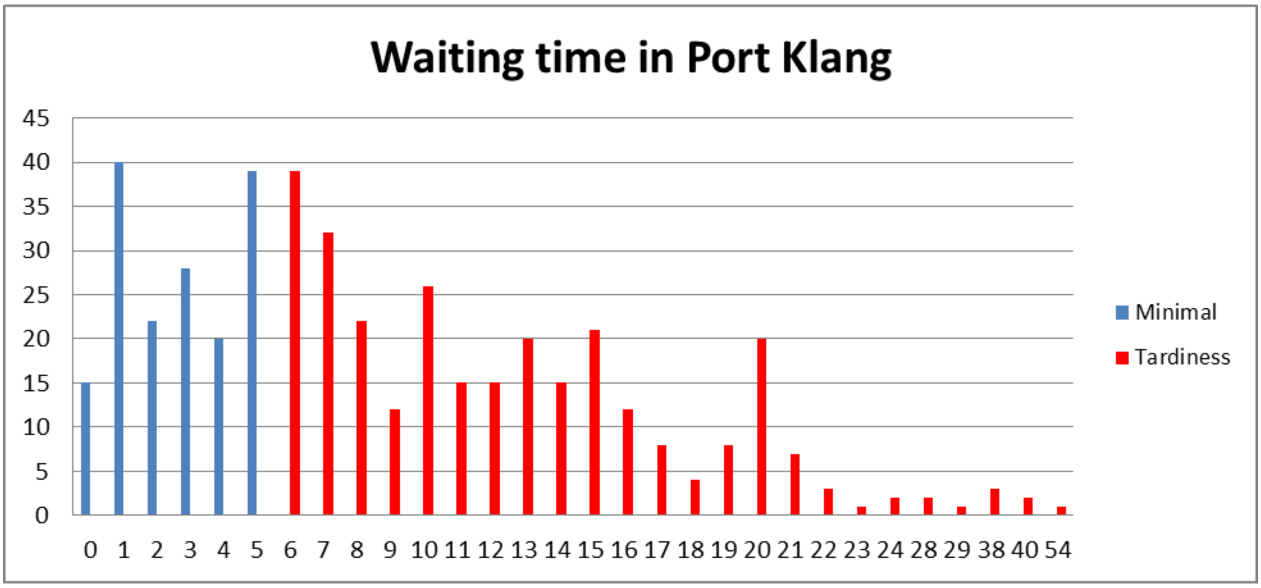
Graphics 9: Frequency table of waiting time in the port of Rotterdam



Graphics 11: Frequency table of waiting time in the port of Singapore



Graphics 12: Frequency table of waiting time in the port of Tanjung Pelepas



Graphics 13: Frequency table of waiting time in Port Klang

Table 23 represents the distributions for the waiting time in the different ports. The length of the waiting time is described in the table in the column. The distributions are determined with the software StatAssist 5.6.

Waiting time in	Length	Malaysia
Rotterdam	Discharge - Load	Lognormal
Rotterdam	Gate in - Departure	Normal
Gothenburg	Gate in - Load	Exponential
Gothenburg	Gate in - Departure	Log-logistics
Singapore	Discharge - Load	Johnson SB
Tanjung Pelepas	Discharge - Load	Log-logistics
Final port	Discharge - Gate out	Weibull

Table 23: Distributions of the waiting time in the ports of the transportation leg to Malaysia

Appendix 6: Demurrage charges

This appendix shows information about the demurrage charges. The term demurrage is defined by the ocean carrier as: "Penalty charged by holding carrier for storage of property beyond allowed free time for removal or unloading (import) and delays attributed to the shipper or his nominated forwarder in delaying the loading of the cargo or when the container has been delivered in before the given free time (export)" (webpage ocean carrier, consulted on 1/7/15). Due to confidential issues the identity if the ocean carrier is kept anonymous. By interest in these charges the name of the ocean carrier can be obtained from the author.

The demurrage charges on the website of the ocean carrier are in the national currency and for simplicity are converted to Euro, with the aid of www.valuta.nl/calculator. The currencies are converted on 1/7/15.

Equipment	Demurrage charges - Gothenburg			
	7 to 11 days	12 to 21 days	22 to 30 days	31 + days
20' dry	€ 27,08	€ 75,84	€ 86,67	€ 97,50
40' dry	€ 48,75	€ 146,26	€ 157,09	€ 167,93
20' IMO	€ 54,17	€ 102,92	€ 113,76	€ 124,59
40' IMO	€ 75,84	€ 173,34	€ 184,18	€ 195,01

Table 24: Demurrage charges - Gothenburg

Equipment	Demurrage charges- Rotterdam	
	7 to 11 days	8 + days
20' dry	€ 50,00	€ 80,00
40' dry	€ 70,00	€ 110,00
20' IMO	€ 140,00	€ 200,00
40' IMO	€ 140,00	€ 200,00

Table 25: Demurrage charges - Rotterdam

Equipment	Demurrage charges - Singapore		
	5 to 10 days	11 to 20 days	21 + days
20' dry	€ 36,64	€ 49,97	€ 49,97
40' dry	€ 56,63	€ 66,62	€ 83,28
20' IMO	€ 67,29	€ 97,94	
40' IMO	€ 99,94	€ 111,26	

Table 26: Demurrage charges - Singapore

Equipment	Demurrage charges - Tanjung Pelepas & Port Klang			
	5 to 10 days	11 to 14 days	15 to 20 days	21 + days
20' dry	€ 16,43	€ 21,49	€ 25,28	€ 31,60
40' dry	€ 27,81	€ 32,86	€ 40,45	€ 50,56
20' IMO	€ 53,09			
40' IMO	€ 98,59			

Table 27: Demurrage charges - Tanjung Pelepas & Port Klang

Appendix 7: Detailed information about causes acceptable and tardy waiting times

This appendix shows detailed information on the causes of acceptable and tardy waiting times. These causes are specified for all the ports in the four routes. The batch number matches with the order number used by the client to identify the batches. The total number of containers shows the summation of both batches into the total number of containers related to that particular batch. For example, for batch 52, five containers from Sweden plus seven containers from the Netherlands represent together twelve containers. The number of containers shows the amount of containers which are related to the acceptable waiting times or to tardiness. For example batch 52; five containers have acceptable waiting times due to “early delivery”. The last column presents the percentage of containers, from the total containers in this port in this route. The information related to the causes of the acceptable and tardy containers are verified with the aid of the track and trace informative from both the client and the ocean carrier. The causes of the waiting time are also verified with the remarks of the related files kept by Seacon Logistics. All the different causes are explained in detail in appendix 8.

Route 1

	Batch number	Number of containers in batch	Number of tardy of containers	Waiting time [days]	Causes	%
					Gothenburg	
Acceptable	52	5 + 7 = 12	5	4	Early delivery	5,8%
	3 (15)	5 + 6 = 11	1	4	Early delivery	1,2%
Tardy	51	3 + 5 = 8	3	9	Vessel network change	3,5%
	3(15)	5 + 6 = 11	1	17	Container left behind (twice)	1,2%
					Rotterdam	
Acceptable	26	4 + 7 = 11	7	4	Early delivery MYT	3,3%
	40	5 + 6 = 11	6	6 or 7	Vessel network change	2,9%
	42	5 + 7 = 12	7	5	Vessel capacity limited	3,3%
	43	6 + 8 = 14	1	4	Early delivery MYT	0,5%
	52	5 + 7 = 12	7	6	Sequencing	3,3%
	1(15)	2 + 3 = 5	3	6	Sequencing	1,4%
Tardy	39	5 + 6 = 11	11	10 to 13	Missing shipping instructions for IMO, mistake ocean carrier (S)	5,3%
	44	2 + 3 = 5	2	10	Missing shipping instructions, mistake ocean carrier (S)	1,0%
	50	5 + 8 = 13	6	8	Cargo ETA is earlied due to weather conditions (hard wind)	2,9%
		5 + 8 = 13	2	20	Containers left behind (1x IMO)	1,0%
	51	3 + 5 = 8	8	8 to 20	Sequencing	3,8%
	2(15)	6 + 8 = 14	14	9 or 10	Vessel cut and run	6,7%
	3 (15)	5 + 6 = 11	10	15 or 16	Batch forming	4,8%
					Singapore	
Tardy	26	4 + 7 = 11	11	7	Vessel network change	5,3%
	44	2 + 3 = 5	3	10	Sequencing	1,4%
	50	5 + 8 = 13	2	9	Containers left behind (1x IMO)	1,0%
	51	3 + 5 = 8	1	9	Container left behind (IMO)	0,5%
					Port Klang	
Tardy	4	4 + 7 = 11	5	6 to 8	Unclear, some containers left terminal within five days	2,4%
	26	4 + 7 = 11	11	11 to 16	Changes in transportation leg/ vessel network change	5,3%
	36	4 + 7 = 11	11	7 to 9	Unknown	5,3%
	37	4 + 7 = 11	3	6 to 8	Unclear, some containers left terminal within five days	1,4%
	40	6 + 6 = 12	12	6 or 7	Changes in transportation leg/ vessel network change	5,7%
	44	2 + 3 = 5	3	6	Changes in transportation leg/ missing shipping instructions	1,4%
	47	2 + 2 = 4	1	6	Unknown	0,5%
	48	2 + 3 = 5	5	6 or 7	Unknown	2,4%
	50	5 + 8 = 13	13	7 to 12	Changes in transportation leg/ vessel network change + containers left behind	6,2%
	51	3 + 5 = 8	7	6	Changes in transportation leg/cargo ETA earlied/advanced	3,3%
	1(15)	2 + 3 = 5	4	9	Changes in transportation leg/ extra WT due to sequencing	1,9%
	2(15)	6 + 8 = 14	14	18 to 20	Changes in transportation leg / vessel cut and run	6,7%
	3(15)	5 + 6 = 11	4	6	Changes in transportation leg, some containers left terminal within five days	1,9%

Table 28: Causes of acceptable and tardy waiting times for route 1

Route 2

	Batch number	Number of containers in batch	Number of tardy of containers	Waiting time [days]	Causes	%
Gothenburg						
Acceptable	27	4 + 7 = 11	4	4 or 5	Early delivery MYT [weekend]	11,8%
	29	6 + 8 = 14	4	5	Early delivery MYT	11,8%
Rotterdam						
Acceptable	28	4 + 7 = 11	7	5	Early delivery MYT [weekend]	8,0%
	29	6 + 8 = 14	2	7	Sequencing MYT	2,3%
	30	6 + 8 = 14	4	7	Sequencing MYT	4,5%
	31	2 + 3 = 5	1	7	Sequencing MYT	1,1%
	32	2 + 3 = 5	3	7	Sequencing MYT	3,4%
	33	6 + 4 = 10	4	6	Sequencing due to transfer to another vessel	4,5%
	34	4 + 3 = 7	3	6	Sequencing due to transfer to another vessel	3,4%
	35	2 + 3 = 5	2	6	Sequencing due to transfer to another vessel	2,3%
	38	4 + 2 = 6	1	6	Sequencing MYC	1,1%
Tardy	21	0 + 1 = 1	1	11	Container left behind (mistake Seacon)	1,1%
	27	4 + 7 = 11	7	8	Sequencing MYT	8,0%
	29	6 + 8 = 14	6	8	Sequencing (MYC late due to limited vessel capacity)	6,8%
	30	6 + 8 = 14	4	8	Sequencing (MYC late due to limited vessel capacity)	4,5%
	31	2 + 3 = 5	2	8	Sequencing (MYC late due to limited vessel capacity)	2,3%
	32	2 + 3 = 5	3	8	Sequencing (MYC late due to limited vessel capacity)	3,4%
	38	4 + 2 = 6	4	10 or 11	Sequencing MYT	4,5%
Tanjung Pelepas						
Tardy	21	0 + 1 = 1	1	12	Batch formation [batch split up]	1,1%
	27	4 + 7 = 11	11	7 to 9	Vessel network change	12,5%
	28	4 + 7 = 11	11	7 to 9	Vessel network change	12,5%
Port Klang						
Tardy	21	0 + 1 = 1	1	7	Changes in transportation leg/ different routes	1,1%
	27	4 + 7 = 11	11	5 to 14	Changes in transportation leg /extra WT due to sequencing	12,5%
	28	4 + 7 = 11	11	12 to 16	Changes in transportation leg / vessel network change	12,5%
	29	6 + 8 = 14	14	20 to 23	Changes in transportation leg / extra WT due to sequencing	15,9%
	30	6 + 8 = 14	14	8 to 13	Changes in transportation leg, one container left terminal on time	15,9%
	31	2 + 3 = 5	5	16 to 20	Changes in transportation leg / extra WT due to sequencing	5,7%
	32	2 + 3 = 5	5	7 to 9	Changes in transportation leg / extra WT due to sequencing	5,7%
	33	6 + 4 = 10	10	17 to 20	Changes in transportation leg / extra WT due to sequencing	11,4%
	34	4 + 3 = 7	7	20 to 22	Changes in transportation leg / extra WT due to sequencing	8,0%

Table 29: Causes of acceptable and tardy waiting times for route 2

Route 3

	Batch number	Number of containers in batch	Number of tardy of containers	Waiting time [days]	Causes	%
				Gothenburg		
Acceptable	11	4 + 7 = 11	4	4	Early delivery	8%
	12	3 + 5 = 8	3	4 or 5	Early delivery	6%
	13	3 + 4 = 7	3	4 or 5	Early delivery	6%
	15	4 + 6 = 10	1	5	Early delivery	2%
	16	2 + 3 = 5	2	4	Early delivery	4%
	17	3 + 4 = 7	2	5	Early delivery	4%
	18	4 + 6 = 10	4	5	Early delivery	8%
	19	2 + 4 = 6	2	5	Early delivery	4%
	20	2 + 2 = 4	2	4	Early delivery	4%
Tardy	10	0 + 3 = 3	3	8	Vessel network change	6%
	17	3 + 4 = 7	1	11	Batch forming	2%
				Rotterdam		
Acceptable	5	4 + 6 = 10	6	5 or 6	Missing shipping instruction - missed consolidation	8%
	7	4 + 6 = 10	6	5 or 6	Early delivery	8%
	8	2 + 3 = 5	3	5 or 6	Early delivery	4%
	11	4 + 7 = 11	3	6	Early delivery	4%
	12	3 + 5 = 8	5	5	Early delivery	7%
	13	3 + 4 = 7	4	5	Early delivery	5%
	15	4 + 6 = 10	5	4	Early delivery	7%
	18	4 + 6 = 10	6	4	Early delivery	8%
Tardy	15	4 + 6 = 10	1	17	Container left behind (IMO)	1%
	16	2 + 3 = 5	1	10	Container left behind	1%
				Singapore		
Tardy	5	4 + 6 = 10	10	6 to 13	Sequencing - Cut and run vessel	8%
	7	4 + 6 = 10	8	6	Unclear	6%
	8	2 + 3 = 5	3	6	Unclear	2%
	9	4 + 6 = 10	9	6	Sequencing - Port omitted by vessel	7%
	11	4 + 7 = 11	11	8	Vessel network change - capacity problems in TP	9%
	15	4 + 6 = 10	9	15	Batch forming	7%
	16	2 + 3 = 5	2	8	Sequencing - unforeseen contingency	2%
	17	3 + 4 = 7	7	7 to 15	Port omitted by vessel	6%
	18	4 + 6 = 10	10	7 or 8	Sequencing - changed feeder	8%
	21	4 + 6 = 10	9	9 to 18	Batch forming [batch split up]	7%
				Port Klang		
Tardy	5	4 + 6 = 10	10	8 to 17	Changes in transportation leg / cut and run	8%
	6	4 + 7 = 11	11	7 to 11	Unknown	9%
	7	4 + 6 = 10	10	6 to 7	Unclear, not all late	8%
	9	4 + 6 = 10	11	6 to 11	Changes in transportation leg/ port omitted by vessel	9%
	11	4 + 7 = 11	11	13 to 16	Changes in transportation leg/ vessel network change	9%
	12	3 + 5 = 8	8	10 to 12	Unclear, not all late	6%
	13	3 + 4 = 7	7	11 to 16	Unknown	6%
	17	3 + 4 = 7	7	15 to 54	Did not arrive jointly	6%
	18	4 + 6 = 10	10	9 to 13	Changes in transportation leg/ changed feeder	8%
	19	2 + 4 = 6	6	15	Changes in transportation leg/ Cargo ETA is earlied/advanced	5%
	20	2 + 2 = 4	4	13 to 16	Changes in transportation leg/ port omitted by vessel	3%
	21	4 + 6 = 10	9	3 to 8	Containers shipped via different routes	7%

Table 30: Causes of acceptable and tardy waiting times for route 3

Route 4

	Batch number	Number of containers in batch	Number of tardy of containers	Waiting time [days]	Causes	%
				Gothenburg		
Acceptable	23	4 + 7 = 11	4	4 or 5	Unforeseen contingency	36%
	24	3 + 5 = 8	3	4	Unforeseen contingency	27%
				Tanjung Pelepas		
Tardy	10	4 + 0 = 4	4	8 a 9	Sequencing	12%
	22	2+2 = 4	4	12	Vessel network change	12%
				Port Klang		
Tardy	22	2 + 2 = 4	4	14 to 18	Changes in transportation leg / vessel network change	12%
	23	4 + 7 = 11	11	10 to 13	Changes in transportation leg / unforeseen contingency	33%
	24	3 + 5 = 8	8	12 to 14	Changes in transportation leg/ unforeseen contingency	24%
	25	2 + 1 = 3	3	7 to 10	Changes in transportation leg/ unforeseen contingency	9%

Table 31: Causes of acceptable and tardy waiting times for route 4

Appendix 8: Explanation of causes acceptable and tardy waiting times

In this appendix the causes for acceptable and tardy waiting times are explained. Also the responsibilities and consequences are shortly explained.

Early Delivery

Explanation: the acceptable waiting times due to early delivery only occurs in the Port of Gothenburg and Rotterdam, because both ports are port of departure. Most containers have an early delivery because the vessel departures on Monday, Tuesday or Wednesday and in order to meet the CCD (of two days) the containers are delivered already on Thursday or Friday. Another reason for early deliveries can be due to holidays, for example, containers are delivered just before New Year's Eve because on New Year's Day companies are closed but containers need to be on time for the CCD of the booked vessel. Early deliveries in Gothenburg can also occur due to the "reconnection system" for containers. This system implies that if the client picks up an empty container on the terminal a full container need to be returned, which can cause additional waiting time for individual containers. Early delivery in the port of Rotterdam can be related to sequencing, because if the containers from Gothenburg have a delay the containers from NL inland terminal need to wait to sequence the containers in the port of Rotterdam. Instead of stocking the containers in the port of Rotterdam, often the containers are buffered in the NL inland terminal.

Responsibility: the decision to deliver containers early is taken by the Seacon Logistics for the containers from the Netherlands, and by the client for the containers in Sweden.

Consequences: no consequences, because it prevents late delivery.

Vessel Network Change

Explanation: the official explanation by ocean carrier for this delay is "As a result of an unforeseen operational constraint, your shipment has now been re- planned to the next available vessel". A vessel network change leads to acceptable and tardy waiting times. First of all the containers need to wait for the next vessel, which is seven days for the containers in the port of Gothenburg and Rotterdam, and four days for containers in the port of Singapore or Tanjung Pelepas. It can also induces additional delay due to sequencing in the next port, for instance, if the containers are re-planned on another vessel in Gothenburg the containers from the Netherlands need to wait in the port of Rotterdam to sequence with the containers from Sweden. But this also occurs in Singapore or Tanjung Pelepas if one batch is delayed in the port of Rotterdam or Gothenburg.

Responsibility: the responsibility for this type of delay is for the ocean carrier, because they make the decision to change the network of the vessel.

Consequences: the consequence is additional waiting time until the next vessel departures. This implies at least seven days for the containers waiting in the port of Gothenburg and Rotterdam, and at least four days for the containers in the transhipment ports.

Container left behind

Explanation: If a container is left behind in the port, tardy waiting times occur. The reason that a container is left behind can have multiple causes. Some will be discussed individually in this chapter because they have a clearly recognizable explanation. If not, it is possible that the ocean carrier or one of their terminal operators left behind a container on the terminal because it was unknown that the container belongs to the same booking. This is often the case for the IMO containers; these containers contain dangerous goods and therefore have a unique booking number. The bookings which belong to one batch are administrative consolidated after the departure of the vessel, therefore, indistinctness can occur. However, the ocean carrier is informed about this situation and should arrange that the containers leave together on the same vessel.

Responsibility: the responsibility for this type of delay is for the ocean carrier, because they are aware that the bookings belong to each other.

Consequences: if a container is left behind this leads to additional waiting time for the container which is left behind; at least seven days in the port of Gothenburg of Rotterdam, and four days for Singapore and Tanjung Pelepas. The remainder containers belonging to the same batch also need to wait in the port until the missing containers arrived; this phenomenon is called 'batch forming'.

Vessel Capacity Limited

Explanation: the official explanation by the ocean carrier for this delay is "Due to limitations on vessel capacity, it was not able to load all cargo as planned. Your shipment has been re-planned to the next available vessel". If the vessel capacity is limited it causes mainly to tardy waiting times. First of all the containers need to wait for the next vessel, which is seven days for the containers in the port of Gothenburg and Rotterdam, and four days for containers in the port of Singapore or Tanjung Pelepas. It can also induces additional delay due to sequencing in the next port, for instance, if the containers are re- planned to another vessel in Gothenburg the containers from the inland terminal need to wait in the port of Rotterdam to sequence the containers. But this also occurs in Singapore or Tanjung Pelepas if one batch is delayed in the port of Rotterdam or Gothenburg.

Responsibility: the responsibility for this type of delay is for the ocean carrier, because the booking of the containers is conformed on that particular vessel

Consequences: the consequence is additional waiting time of at least four to seven days until the next vessel departures.

Sequencing

Explanation: tardy waiting time occurs if one of the flows is delayed or disrupted. The related containers need the wait until the containers can be sequenced. Table 29 shows the causes of tardy waiting time related to sequencing in the transportation leg. These disruptions are explained in this appendix and can cause acceptable or tardy waiting times. More information on this table can be found in paragraph 4.5.

Responsibility: different parties can be responsible, depends on the type of disruption.

Consequences: sequencing leads to acceptable and tardy waiting time.

Probibility of sequencing in the transportation leg due to							
Causes	# of containers		# of batches		Cond. probabilities		
	Acceptable	Tardy	Acceptable	Tardy	Acceptable	Tardy	Total
Vessel network change	9	18	3	2	14%	27%	41%
Unknown	16	11	3	2	24%	17%	41%
Limited vessel capacity	10	15	4	4	15%	23%	38%
Vessel cut and run		10		1	0%	15%	15%
Omitted port		9		1	0%	14%	14%
Cargo ETA earlied/advanced		4		1	0%	6%	6%
Missing shipping instructions		3		1	0%	5%	5%
Unforeseen contingency		2		1	0%	3%	3%

Table 32: Causes of tardy waiting times related to sequencing

Missing shipping instructions

Explanation: the official explanation by the ocean carrier for this delay is “Since shipping instructions for this shipment was not received prior to documentation cut- off, it can therefore not be loaded on the original vessel. Please submit the shipping instructions so that we can re- plan loading your shipment”. Due to missing shipping instructions for a total batch, or for one container, the container(s) leave behind in the terminal. After receiving the correct documentation the containers can be re-planned on the next vessel. During the transportation leg three times delay exist due to missing instructions, however, two times Seacon Logistics claims that the documentation was sent before the cut- off date. Nevertheless, the containers were delayed because they were not loaded on the planned vessel.

Responsibility: the responsibility for this type of delay is on Seacon Logistics, because it is their task to send the shipping instructions before the cut-off.

Consequences: missing shipping instructions leads to sequencing and batch forming, and therefore to tardy waiting times. The containers need to wait on the next vessel which implies at least seven days for the containers waiting in the port of Gothenburg and Rotterdam and at least four days for the containers in the transhipment ports.

Cargo ETA earlier/advance

Explanation: the official explanation by the ocean carrier for this delay is “Your shipment has been moved to an earlier vessel in the transhipment port to avoid a long layover. Your shipment has been re-planned to an earlier vessel”. If the ETA of one of batches is earlier than planned, this batch probably has to wait in the next ports to be sequenced with the related batch. For example, if two batches are planned to be sequenced in Singapore but on batch depart earlier additional waiting time occurs in Singapore to align the containers before the containers departures to Port Klang.

Responsibility: the responsibility for this type of delay is on the ocean carrier, because they make the decision to change the ETA.

Consequences: changed cargo ETA results in sequencing if it concerns one of the two flows and tardy waiting times. If it concerns both flows the consequences is an earlier delivery.

Vessel cut and run

Explanation: the official explanation by the ocean carrier for this delay is “Unfortunately the vessel has been forces to leave the port prior to completing operations. Your shipment had to be re-planned to the next available vessel”. If a vessel cut and run occurs for one of the batches additional waiting times occur also additional waiting time occurs for the related containers.

Responsibility: the responsibility for this type of delay is on ocean carrier, because they make the decision to plan the containers on the next vessel.

Consequences: the consequence is additional waiting time until the next vessel departures. This implies at least seven days for the containers waiting in the port of Gothenburg and Rotterdam, and at least four days for the containers in the transhipment ports.

Port omitted by vessel

Explanation: the official explanation by the ocean carrier for this delay is “As a result of an unforeseen operation constraint the vessel has been forces to omit this port. All cargo will be re-planned to the next available vessel”. If a port is omitted in Gothenburg or Rotterdam it relates to one of the two batches, in which it causes tardiness related to sequencing. Otherwise it causes delays in the lead-time of the total batch.

Responsibility: although the cargo is re-planned due to unforeseen operational constraint the responsibility for this type of delay is on ocean carrier, because it is part of their business to and if they face operational problems it is part of their risk.

Consequences: the consequence is additional waiting time until the next vessel departures. This implies at least seven days for the containers waiting in the port of Gothenburg and Rotterdam, and at least four days for the containers in the transhipment ports.

Batch forming

Explanation: If one or multiple containers is left behind the containers need to be re-united. This is required because the containers are booked on one B/L and if they arrive separately, the customs in the country of destination will not accept the containers. Batch forming is caused if one or multiple containers are left behind in the port. The containers are left behind due to missing documents or by operational mistakes by the terminal operator.

Responsibility: the responsibility for batch forming is depending on who causes the split up of the containers. Both causes are explained individually.

Consequences: the consequence is additional waiting time until the next vessel departures. This implies at least seven days for the containers waiting in the port of Gothenburg and Rotterdam, and at least four days for the containers in the transhipment ports. If it happens in the last transhipment port it results in extra transit time because the containers have to be re-united before the containers can be discharged in the port of destination.

Unclear

Explanation: In this case the reason for tardy waiting time is undefined. However, part of the containers experience minimal waiting times. The tardy waiting time can be caused by inefficiencies in the port or by the client who needs to pick up the containers. But the actual cause cannot be determined based on the available data.

Responsibility: is unknown.

Consequences: Tardiness in the ports. The waiting time is up to twelve days in Port Klang.

Unknown

Explanation: In this case the reason for tardy waiting times is undefined. Compared to the previous cause; all containers that belong to one batch experiences tardy waiting times. The actual cause cannot be determined based on the available data.

Responsibility: is unknown.

Consequences: Tardiness in the ports. The waiting time is up to sixteen days in Port Klang.

Did not arrive jointly

Explanation: if the containers did not arrive jointly in Port Klang somewhere along the transportation leg a disruption occurs that separate the containers from one batch.

Responsibility: different disruptions can cause that containers do not arrive simultaneously and there different parties can be responsible.

Consequences: the consequence is problems with the Malaysian customs because the administrative and physical flows do not match. These problems result in tardy waiting times and probably also higher tax rates for the goods.

Unforeseen contingency

Explanation: the official explanation by the ocean carrier for this delay is "As a result of an unforeseen operational constraint, your shipment has now been re-planned to the next available vessel". Unforeseen contingency can be related to weather conditions, political situations, and etcetera.

Responsibility: the partners in this transportation leg are not responsible for this type of disruptions. However, the ocean carrier can take precautions to limit the impact of some contingencies.

Consequences: the consequences differ per the situation of the contingency. If the contingency occurs in one of the flows of containers the other containers need to wait before the containers are sequenced. Otherwise the total batch of containers is delayed.

Appendix 9: AgenaRisk

This appendix provides insights in the structure of the model flows in AgenaRisk. First the program AgenaRisk is short introduced. Subsequently the taken steps are visualised which makes it possible to reproduce the models. The steps are visualised with as example the port of Gothenburg from route 1. Also decisions and assumptions to model in AgenaRisk are clarified.

AgenaRisk is software program recommended by Fenton and Neil (2013) to model BNs. This software is freely accessible, http://www.agenarisk.com/products/free_download.shtml. This software provides the basic options to model a BN; an updated version of the software is not free accessible but provides several improvements. However, the BNs are used as a tool to model the routes and therefore the freely accessible software is sufficient. If the BNs were more incorporated in this thesis it would not satisfy the requirements. Unfortunately, the free software has it shortages and therefore the probabilities calculated from the data change slightly after implementing them in the software. However, these changes do not deviate more than 5% from each other whereby it does not have impact on the results of the BNs.

To model de flows in AgenaRisk the node details, states, and the node probability table need to be updated for every port. Figure 21 shows the node details of the port of Gothenburg of route 1. The unique identifier is provided by AgenaRisk. The required node type is 'labelled' to make use of multiple states which can be labelled manually. In order to apply labelled node type it is assumed that waiting time are discrete variables. Waiting time are numeric values which can be measured in fractions of a second and therefore continuously; however, in this thesis the waiting times are measured in days. Days are distinct countable values without any grey area in between, and only whole days are counted. For example, if a container is discharged and loaded on the same day the waiting time is counted as zero days. Therefore the assumption of discrete variables instead of continuous variables is plausible. Subsequently, by checking the box 'visible' the node is visual in the model. Also the box 'input node' is checked because this node has no parents is this model. The 'output node' should be checked if the node does not have any children.

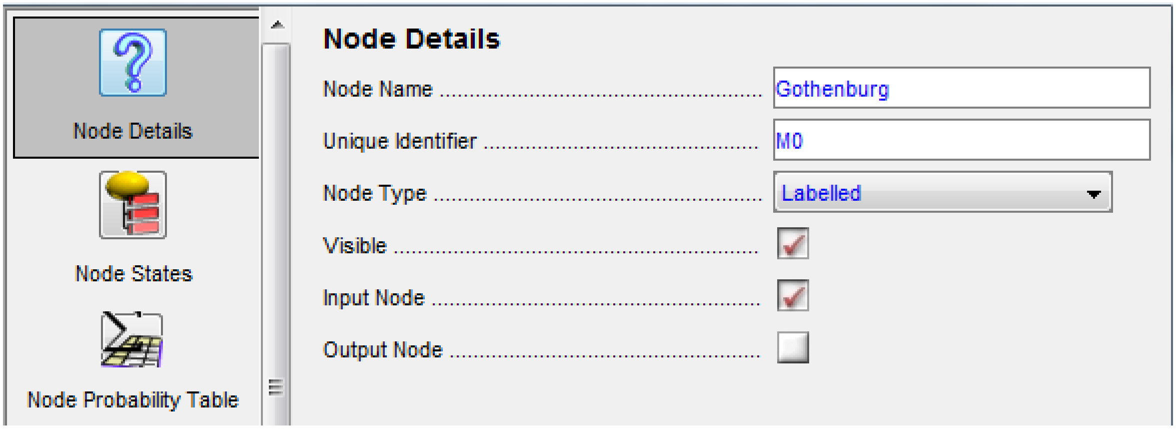


Figure 21: Node details of the port of Gothenburg - route 1

The next step is to include the node states, see Figure 22. For the port of Gothenburg this are four states; Minimal, Acceptable, Vessel Network Change, and Container left behind. These states are explained in paragraph 4.4. In appendix 8 these causes are explained, and responsibilities and consequences are clarified. In other ports the tardy states can be defined by other causes than the ones for the port of Gothenburg.

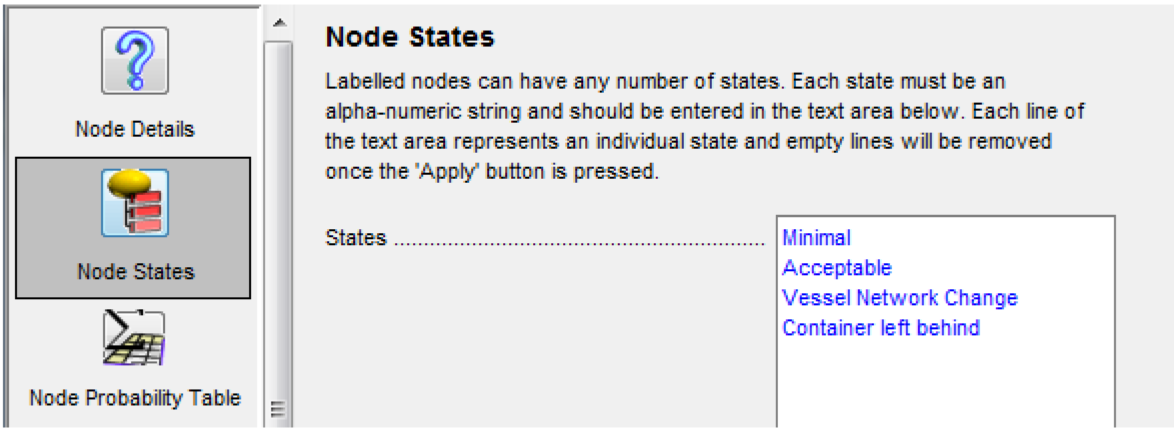
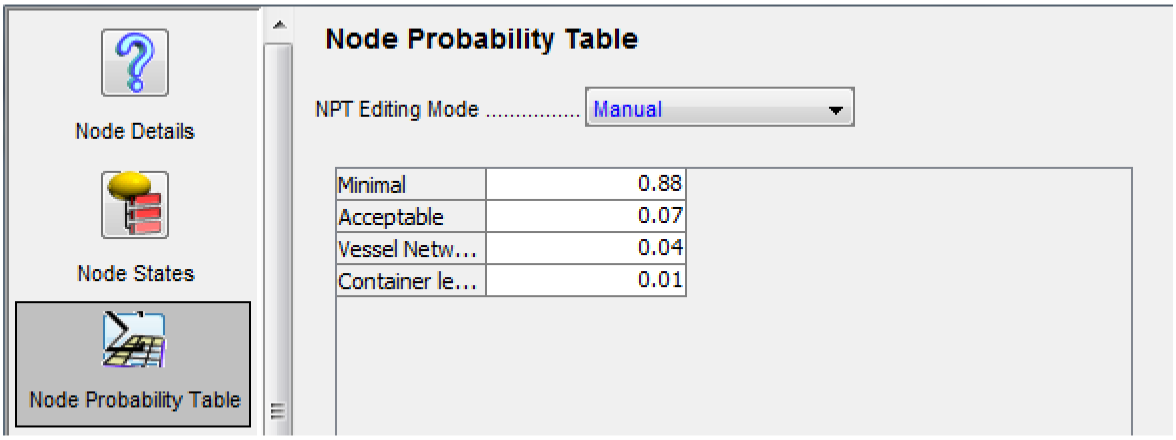


Figure 22: Node states for the port of Gothenburg - route 1

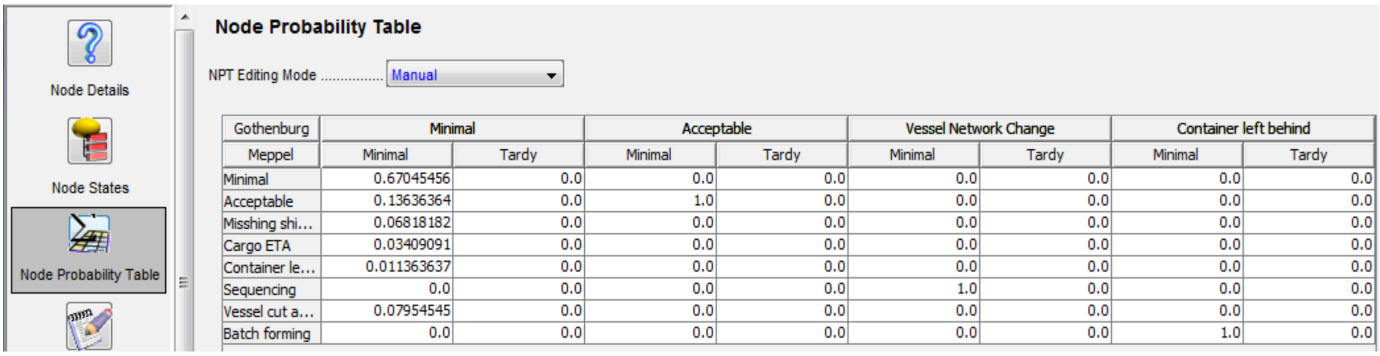
The third step is to define the node probability table. The likelihood of the states is determined in appendix 8 and filled manually in the node probability table, see Figure 23. In this example the probabilities sum up to 100%. In case the probabilities are not summed up to 100%, AgenaRisk normalises the probabilities.



Minimal	0.88
Acceptable	0.07
Vessel Netw...	0.04
Container le...	0.01

Figure 23: Node probability state for the port of Gothenburg - route 1

It is important connect the parent and children nodes before the node probability table is filled. The arcs define the dependences between the nodes and therefore the probabilities are based on these dependencies. For example, the probabilities for the port of Rotterdam deal with the probabilities of the parents nodes (Inland Port and Gothenburg). The node probability table of the port of Rotterdam is visualised in Figure 24. Note, the probabilities in this table are normalised. The normalisation ensures that the total probability in a column is one.



Gothenburg	Minimal		Acceptable		Vessel Network Change		Container left behind	
Meppel	Minimal	Tardy	Minimal	Tardy	Minimal	Tardy	Minimal	Tardy
Minimal	0.67045456	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acceptable	0.13636364	0.0	1.0	0.0	0.0	0.0	0.0	0.0
Misshing shi...	0.06818182	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cargo ETA	0.03409091	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Container le...	0.011363637	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sequencing	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
Vessel cut a...	0.07954545	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Batch forming	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0

Figure 24: Node probability table for the port of Rotterdam - route 1

Not all probabilities in the BN for the effect nodes do match with the determined probabilities from the historical data in Figure 8; this is caused by two reasons. First, AgenaRisk normalises the resulting distribution over the finite range between 0 and 1. Normalised probabilities allow quantifying the relationships between the variables. Second, the NPT for any node in the BN (except for nodes without parents) is intended to capture the strength of the relationship between the node and its parents. The relationship with the parent node is not included in the calculated probabilities in Figure 8. Despite the probabilities are not identical it is possible to use this model to asses risks. Models cannot totally match with reality and the probabilities of Figure 8 do not deviate more than 5% from the probabilities determined by AgenaRisk. The disruptions where no probability is shown, is because the probability is 1%.

Appendix 10: Batches with disruptions in the sequencing process

The first route is illustrated in Figure 25. As explained before, the minimal waiting time is required to smooth the activities in the port, and does not cause any delays because it is incorporated in the transit time. The acceptable waiting time is not split up in events because it does not result in demurrages costs and often it exist due to early delivery of the containers in the port of Gothenburg and Rotterdam. All other specifications are tardy waiting times, e.g. 5% of the containers were tardy in Gothenburg; 4% of these containers where tardy due to a vessel network change and 1% was tardy because a container was left behind on the terminal.

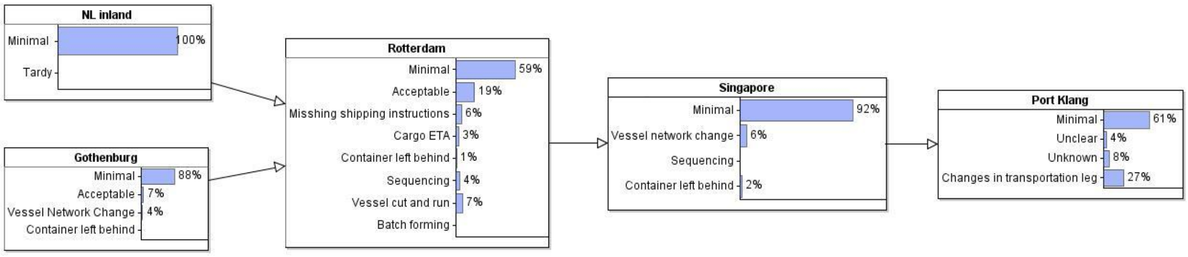


Figure 25: Malaysia – BN route 1

Tardy waiting time due to sequencing occurred both in the port of Rotterdam (batch 51) and Singapore (batch 44). The tardy waiting time of batch 51 is caused by a 'vessel network change' in the port of Gothenburg, hereby the related batch of containers needed to wait eight to twenty days in the port of Rotterdam to sequence the batches. Next to the 'vessel network change' also the IMO container is left behind in Rotterdam and therefore the waiting time mounted up to twenty days. The tardy waiting time of batch 44 is caused by 'missing shipping instructions' in Rotterdam for the batch of containers from the Netherlands. Therefore, this batch needed to wait for the next vessel, while in the meantime the shipping instructions were provided, and the batch from Sweden waited ten days in the port of Singapore. The tardiest waiting times occur in Port Klang, almost 40% of the containers have undesired waiting time. The cause of the waiting time in Port Klang is indistinct, however, in more than half of this waiting time a disruption occurred along the transportation leg. The remainder waiting time is unclear or unknown. The difference between these types is that the containers which wait due to an unknown reason have tardy waiting times equal for the entire batch while for the containers with an unclear reason some containers of the batch left Port Klang in time.

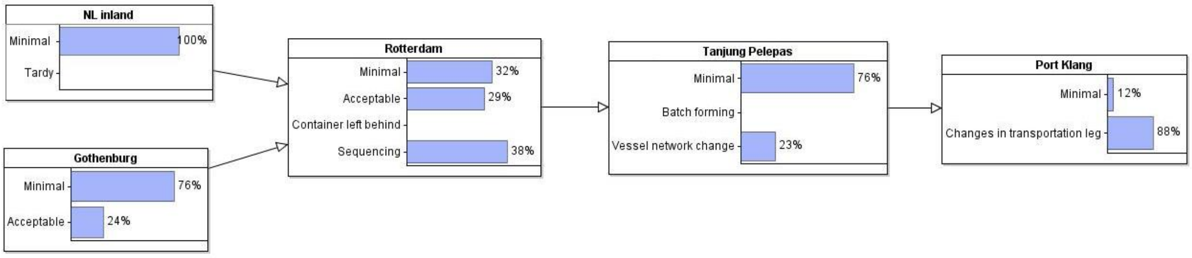


Figure 26: Malaysia – BN route 2

Figure 26 illustrates route 2. In this route the tardy waiting times take place in the port of Rotterdam, Tanjung Pelepas and Port Klang. In Rotterdam almost 40% of the tardiness is caused by sequencing, this implies that the batch from the Netherlands needs to wait for the batch from Sweden. In total six batches (batch 27, 29, 30, 31, 32, and 38) have tardy waiting times in the port of Rotterdam; batch 29 to 32 had to wait eight days because the 'vessel capacity was limited' in Gothenburg. This limited capacity did not cause tardiness in Gothenburg, because the containers are hold in at the client in Sweden to avoid tardy waiting times in the port of Gothenburg. The other two batches (batch 27 and 32) have tardy waiting time of eight days in the port of Rotterdam due to a 'vessel network change' in Gothenburg. Almost 90% of the containers in Port Klang needed to wait longer than five days; the cause is indistinct, however, for all containers a disruption occurred along the transportation leg. Only one batch left Port Klang in time, while the other nine batches had tardy waiting times.

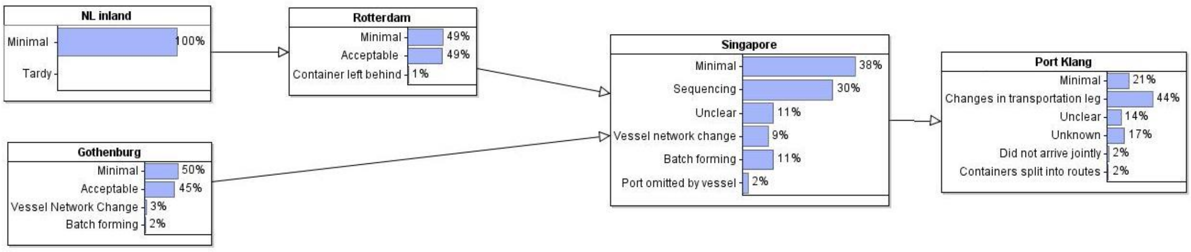


Figure 27: Malaysia – BN route 3

Figure 27 illustrates route 3. In this route the tardy waiting times take place in Singapore and Port Klang. In Singapore 30% of the tardy waiting time is caused by sequencing, this is initiated by four batches (batch 5, 9, 16, and 18). Batch 5 missed sequencing in the port of Rotterdam due to a 'vessel cut and run' which caused a waiting time of six to thirteen days. The tardy waiting time related to batch 9 is caused because the booked 'vessel omitted the port' of Gothenburg, whereby the containers were rescheduled to the next vessel, and the batch from the Netherlands waited six days in Singapore. The tardy waiting time in batch 16 is caused by 'unforeseen contingency' in de transit time of the batch from the Netherlands, whereby the batch from the Sweden needed to wait eight days in Singapore. In batch 18 the containers from the Netherlands need to wait seven or eight days in Singapore due to a 'vessel network change' in Gothenburg. In Port Klang almost 80% of the containers had tardy waiting times. The containers from batch 17 the containers did not arrive jointly in Port Klang, which caused a waiting time of 15 to 54 days in Port Klang. And for batch 21 one container was transported via Tanjung Pelepas is stead of Singapore which caused tardy waiting time until eight days. More than 40% of the containers have an indistinct cause, but disruptions occurred along the transportation leg. The cause of tardiness for the remaining containers is unclear or unknown.

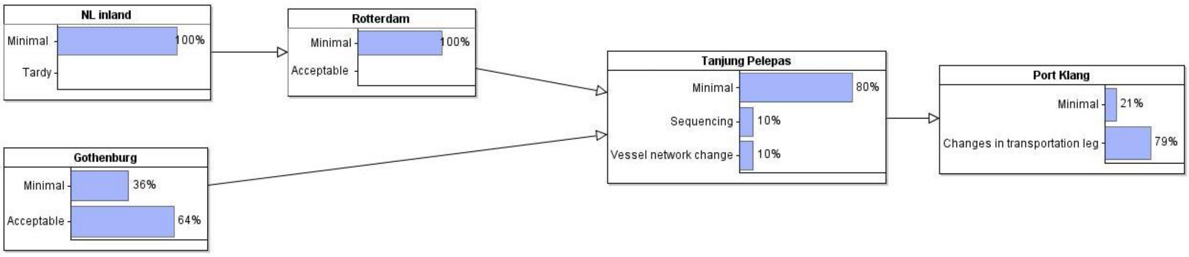


Figure 28: Malaysia – BN route 4

Figure 28 illustrates flow 4. In this route minimal disruptions occur along the transportation leg. Only one batch (batch 10) has tardy waiting time (eight to nine days) caused by sequencing in Tanjung Pelepas, due to 'cargo ETA earlied/advanced' of the batch from the Netherlands. Despite of the minimal disruptions along the transportation leg almost 80% of the containers have tardy waiting times in Port Klang. All these containers have changed departure and arrival times due to events along the transportation leg.

Appendix 11: BNs with minimal waiting time in the port of sequencing

This appendix shows the causes and probabilities of the scenario in which no tardiness occurs in the port where the physical sequencing takes place. In every port where the containers are supposed to be sequences the probability of minimal waiting time is set up 100%. Subsequently, the model calculates the probabilities of the causes and consequences of this requirement.

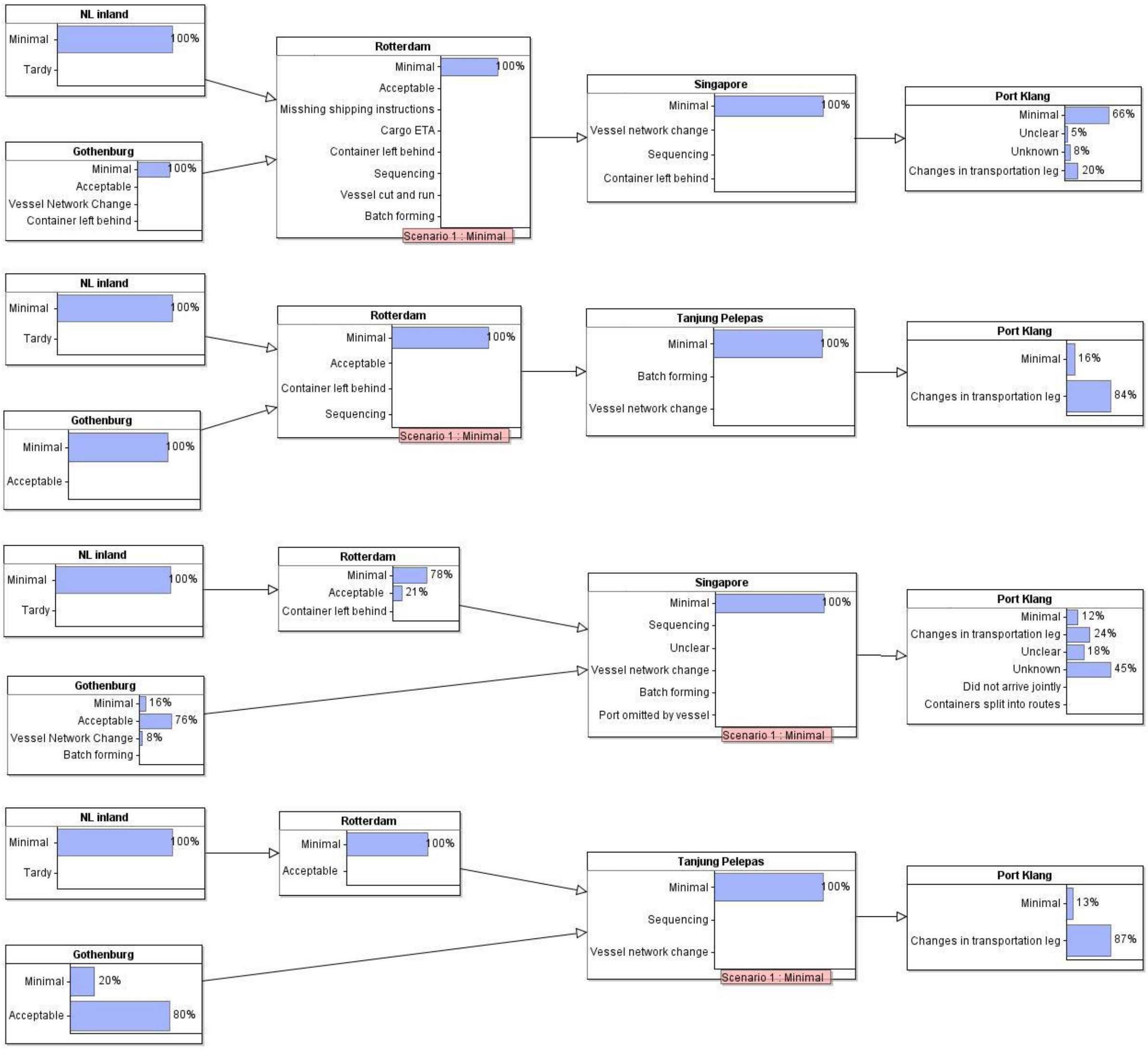


Figure 29: BN with minimal waiting time in the ports related to sequencing