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Decision support tool for pricing strategies in transportation networks

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Decision support tool for pricing strategies in transportation networks

Master Thesis

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Abstract

This study presents the design of a decision support tool for pricing strategies in transportation networks. Companies in the tank container industry are faced by imbalances in tank container flows. To overcome these, containers may be repositioned empty or pricing initiatives may be applied. Motivated by the latter, we propose a model that dynamically simulates the demand and repositioning flows, to determine the amount of profit that is generated within a transportation network, as a result of executing a specific demand scenario. By simulating several demand adjustments on multiple scenarios, we are able to determine the upstream effect of these demand adjustments, on the profit generated by the network. This enables us to determine and prioritise the strategies that are expected to improve the profit generated by the network, without the need to estimate or quantify the relationship between price and demand. We conduct a case study to illustrate the practical applicability of the proposed model.

Executive summary

The tank container industry is challenged by the imbalances within tank container flows. In regions where more tank containers are imported than exported, surpluses of tank containers arise. In the case more export than import occurs, the region is marked as a shortage. To overcome these imbalances, tank containers are either repositioned empty from surpluses to shortages or pricing tools to stimulate or destimulate demand are applied, such that less repositioning movements are required. Following the latter approach, we formulated the following research question:

How may companies in tank container industry benefit from the price elasticity of their demand to improve their profit by influencing tank container flows?

For feasibility of this study and applicability of the proposed model as a decision support tool, we do not aim to measure or estimate the impact of a price adjustment on the demanded quantity. Furthermore, we considered solely the demand flows on global level and monthly basis, to limit the amount of lanes to be incorporated.

We first conducted a survey at Den Hartogh Logistics, to analyse the demand and determine whether a pricing strategy would be effective. Results of the analysis confirmed the expectation that a pricing strategy should be able to influence the demand flows. The responses demonstrated that the sales rate of the transport service appears to be the most important criteria within a potential customers' LSP selection. Hence, we concluded that customers are indeed sensitive towards the rate of the service.

Next, we analysed the pricing model and profit structure, from which we concluded that not all elements are relevant to determine the effect of a demand adjustment on the profit generated by the network. In general, the gross profit margin of an order, the costs related to a repositioning of equipment, and the repositioning contribution charged on an order are required to determine the impact of a demand adjustment on the profit.

To determine which pricing strategies have a positive effect on the expected profit, we propose a simulation model. This model takes into account the upstream effect of a demand by simulating the laden and empty tank containers flows over a simulation horizon. Every period during the simulation horizon, the decision maker has to make a repositioning decision. To replicate this decision, we simulate a sequence of steps for each period of the simulation horizon. First, we simulate for each region whether the amount of tank containers available in the period, including the import of laden and empty tank containers during that period, is sufficient to fulfil the demand out of that region. If there are insufficient tank containers available to fulfil the demand, we apply an order acceptance rule that allocates the available tank containers to the demand. Thereafter, we simulate the state of the tank containers during a rolling horizon, defined as the repositioning decision horizon. During this horizon, we simulate whether there are sufficient tank containers in each region, taking into account already scheduled import and export of tank containers, to fulfil all potential demand during the horizon. If we have insufficient tank containers at the end of the

horizon in any of the regions, we determine the required repositioning movements by minimising the cost of the movements. Next, we simulate the tank container availability of the period again, taking into account the result of the repositioning decision. Hereby, we define the amount of available tank containers at the beginning of the next time period. This set of actions is repeated for each period during the simulation horizon. By formulating the demand as a stochastic variable and running the simulation multiple times, we established to incorporate uncertainty of the demand into the simulation. Based on the output of all runs, the model determines the expected profit generated by the network.

We concluded from the case study that we are able to identify and prioritise strategies that are expected to have a positive impact on the profit generated by the network, without quantifying the relationship between price and demand. We further conclude that the starting condition, the repositioning decision horizon, and constraints on repositioning lane capacities have a considerable impact on the outcome of the model.

Unfortunately, this research has some limitations due to assumptions and scoping:

1. The target group for the survey is considered to be too small to determine whether some of the differences in the data are statistically significant.
2. Most repositioning movements occur within the global regions and these costs are thus ignored by the scoping on the aggregation level.
3. We did not incorporate the stochastic nature of all input variables, the ability to back-order rejected demand, differences in tank container fleet, depot storing costs, and the portion of depots that do not offer cleaning facilities. As such, the model might not completely reflect the reality.
4. No validation of the model on its ability to simulate the tank container flows was possible using real data. Thus, the model is verified with face validity and an extreme condition test, but there is a chance that it does not completely reflect reality.
5. To illustrate the applicability of the model, we simulated a set of strategies that focused on a demand adjustment in one region at the time, though combinations are possible.

Based on the limitations, we identified the following possibilities for future research:

1. An extensive market analysis aimed at defining customer and/or demand characteristics, such that prices can be differentiated amongst customers or demands.
2. Reproducing the case study using smaller time units and a lower level of aggregation should improve the accuracy of the outcome.
3. Investigating the impact of elaborating the simulation with the ability to cope with multiple demand times, back-ordering demand, different tank container types, depot costs, and depots without cleaning facilities, to determine which level of detail improves the accuracy and robustness of the model outcome and the model applicability.
4. Development of a heuristic that matches the outcome of the simulation model, while still incorporating the dynamic aspect, to overcome the fallback of the time-consuming simulation model.

Finally, based on the case study, we identified some recommendations for Den Hartogh Logistics:

1. The results of the demand analysis show a possibility that different regions have a different sensitivity towards a market correction. An extensive market research could offer the possibility to incorporate these differences in prioritising the strategies recommended by the simulation model. Moreover, it offers the possibility to determine other characteristics to segment customers on their price sensitivity, as we expect that the differences between preferences are far more complex than spot versus tender. Finally, the demand analysis was performed using the estimate of the commercial department. Incorporating more sources into the analysis could improve the outcome.

2. The case study identified that the expected effect on the profit following a strategy can differ considerably for import and export lanes of the same region. Furthermore, we identified cases in which a strategy is recommended that increases the imbalance, instead of solving it. Thus, it is recommended that market corrections are set with the outcome of the simulation model in mind and that different price settings for each side of the imbalance are applied.

3. Different levels of aggregation should be tested to determine the optimum balance between incorporating all empty tank container flows and computational time.

4. It is recommended to follow-up on the research by investigating whether a heuristic could be applied or developed that provides with the same conclusions as the simulation model. This would significantly decrease the computation time and increases the level of aggregation that can be incorporated.

5. The model should be validated as soon as enough data is gathered on the new pricing model.

Preface

This report is the result of my graduation project undertaken at Den Hartogh Logistics, to obtain the masters degree in Operations Management & Logistics at Eindhoven University of Technology.

Hereby, I would like to express my gratitude towards a selection of people. First, I would like to thank dr. Zümbül Atan for her supervision on the thesis and patient advice. In addition, I would like to thank dr. Arun Chockalingam for his feedback, and dr. Murat Firat for taking a moment to evaluate my thesis. Furthermore, I would like to thank Sjoerd Groot and Luke van de Bunt for providing me with the opportunity to conduct my thesis project at Den Hartogh Logistics, and for their enthusiastic support throughout the entire thesis period. Finally, to all the other colleagues at Den Hartogh Logistics: a big shout-out to all of you, for your enthusiasm in helping me getting to know the company and your cooperation in answering all my questions.

Auke Holle,
February 2019

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Due to globalisation, quite some companies relocated to specific areas in the world, mostly for cost-efficient reasons. Ergo, a clear distinction can be drawn between predominantly production and consumption markets. In a production market, the transport activities consist mainly of export, whereas the transportation in a consumption market consists mainly of import (Suk Fung Ng, 2012). Within the containerised transportation industry, this so-called trade imbalance is classified as the main reason that imbalances occur within container flows (Song et al., 2005). To match the supply of containers with the demand for containerised transport in a region, containers may be transported empty. This is referred to as the repositioning of empty containers (Suk Fung Ng, 2012). Brito and Konings (2007) estimated that approximately 20% of the word wide container flows consist of empty containers. This repositioning is often seen as an inefficiency within the transportation industry (Zhou and Lee, 2009), as large amount of costs are involved. Song et al. (2005) estimated that the costs related to the repositioning of empty containers represent about 27% of the total world fleet running costs. According to Sanders et al. (2016), about 33% of the costs related to empty movements arise from company specific imbalances.

For this thesis, we focus on the impact of the container imbalances as faced by tank operators. A tank operator could be best described as a logistics service provider, offering transportation services for liquids, gasses and powders. To provide these services, they own and/or lease a fleet of tank containers and maintain contracts with a.o. trucking companies, railroads, port drayage companies and container steamship lines (Erera et al., 2005). A tank operator would ideally utilise a tank container imported into a region for export out of the same region, within a reasonable amount of time. Unfortunately, the imbalances prevent this ideal with a two-fold impact. First, in the mainly importing areas, a surplus of tank containers arises. This in turn leads to the down-time of tank containers and therefore costs of depreciation and storage arise. Secondly, in the mainly exporting areas, a shortage will occur. As the tank containers on down-time in one region cannot be used to fulfil demand in another, this results in lost sales and thus missed revenue. Overcoming this imbalance is one of the main challenges faced by tank operators. To cope with this challenge, two strategies are commonly applied. First, the empty tank containers may be repositioned from surplus to shortage areas. And secondly, pricing tools aiming to stimulate or destimulate the demand between certain regions could be applied, such that less repositioning movements are required.

1.1 Business opportunity

This thesis is motivated by a business opportunity of Den Hartogh Logistics, which is a logistics service provider offering worldwide transport services, mainly focused on the transport of chemicals. Prior and during the thesis project, Den Hartogh Logistics developed and implemented a Global Network Optimisation project. This project focused on four areas of improvement: Forecasting, Pricing, Stock Control and Repositioning. The overall goal of the Global Network Optimisation project is to improve the global network profitability, by providing strategic and tactical tools that complement the decision-making processes within each of those areas. One of the opportunities that arose from the project was the investigation into the potential of a pricing strategy based on the concept of price elasticity of demand. As such, this thesis aims to identify a manner in which the tank container industry may benefit from the price elasticity of their demand, to improve their global network profitability.

1.2 Literature review

This section contains a brief version of the literature review made as part of the thesis period. First, we discuss the selection criteria used by shippers' when selecting a logistics service provider or a carrier, to gain insight in the behaviour of the market. Thereafter, we discuss modelling approaches in freight transport pricing, which we benefited from during the development of the proposed model, as well as the methods for distribution fitting on demand and lead time data discussed next.

1.2.1 Selection criteria logistics service provider

The demand for a single logistics service provider (LSP) is not only depended upon economical and geographical considerations, but also on shippers' preferences. A large amount of studies aimed to identify the selection criteria that shippers use in their carrier or LSP selection, and the relative importance of those criteria. Based on a selection of these studies (Aguezzoul, 2014; Kent and Parker, 1999; Matear and Gray, 1993; McGinnis, 1979; McGinnis et al., 1995; Menon et al., 1998; Solakivi and Ojala, 2017; Whyte, 1993), we formulated a list of possible selection criteria and factor descriptions belonging to these criteria, as shown in Table 1.1.

Table 1.1: Selection criteria

Criteria	**Factor descriptions**
Rate	Rate, competitive rate, low rate, special offers, impact on other operational and inventory costs, rate changes, pricing flexibility, and value for money price.
Relationship	Reliability, truth, dependence, alliance, compatibility, reciprocity, and availability of top management. Often only described as relationship.
Services	Breadth and variety of services, specialisation of services, pre- and post-sales, value added services, service changes, special equipment, and ease of claim settlement.
Quality	Continuous improvement, ISO standards environmental issues, risk management and loss & damage, and superior error rates.
Information	Tracking/tracing possibility, information provided, accessibility, and technology capabilities (e.g. electronic data interchange).
Flexibility	Ability to meet future requirements, fast responsiveness, capability to handle specific business requirements, ability to meet or exceed promises, availability of equipment, scheduling flexibility, and responsiveness to unexpected problems and deliveries.
Delivery	Speed of the service, on-time performance, and delivery reliability.
Professionalism	Expertise, quality of personnel, competence, and experience.
Financial position	Regular upgrading of the equipment, and financial stability of the firm.
Location	Geographical coverage of the network, geographical specialisation, market coverage, and international scope.
Reputation	Opinion of customers, and strong competitive position.
Customer influence	Shippers' company policy, and customer influence.

The studies report somewhat contradictory conclusions to which selection criteria are most important. McGinnis (1979) indicated that the criteria speed & reliability, freight rates, and loss & damage are most important within a shippers' freight transportation choice. Later, Whyte (1993) identified service as the most important selection criteria, though he acknowledged that price had become an element of major importance. Contradictory, McGinnis et al. (1995) and Menon et al. (1998) reported that having the lowest price was seen as neither important nor unimportant, and that the LSP must meet performance and quality requirements prior to any negotiations on the rate. Later, Kent and Parker (1999) supported this claim as they identified the rate as not important, relative to other determinants. Of the in total 18 determinants identified, the sales rate was 12^{th} on the list in order of importance. Rate changes, on the other hand, were 4^{th} on the list, indicating that the amount of the sales rate is considerably less important than the variability within the sales rate. The literature studies performed by Aguezzoul (2014) and Solakivi and Ojala (2017) showed that even though previously mentioned studies do not classify it as most important, the rate of the service is the most incorporated criteria in all studies analysed.

1.2.2 Freight transport pricing

The literature study on freight transport pricing focused on management of fleet with some vehicle allocation problem incorporated in the decision making process. In general, we distinguished two different approaches to model the transportation flows: the classical transportation problem to determine the empty repositioning movements on a static input of demand and space/time networks to dynamically determine the upstream effect of demand and repositioning movements within the network.

Classical transportation problem

The classical transportation problem considers a network in which there are sources with a supply, and destinations with a demand. The aim of the transportation problem is to select the transportation movements between sources and destinations that fulfil the demand of the destinations using the supply of the sources, associated with the least amount of transportation costs related to the movements (Hillier and Lieberman, 2015). In the case of the empty repositioning movements, the sources are the locations that have an excess of fleet and the destinations are the locations that have a shortage of fleet. The repositioning problem is solved when all shortage is covered by the surplus, with the minimum amount of empty repositioning costs possible. Hence, the transportation problem can be used to determine the expected repositioning flows when imbalances in demand occur. Gorman (2001) implemented this approach in a model that provides price recommendations to achieve the optimum profit. He computed the network wide profitability based on the anticipated prices multiplied by the demanded quantities, minus the empty repositioning costs determined by the specified transportation problem. To achieve the optimum prices, Gorman (2001) defined demand as depended upon the price of the service, and formulated a price sensitivity factor and a base-level for the demand. According to Powell (1987), the downfall of using the classical transportation problem is the ignorance of the up- and downstream impact of the transportation flows.

Space/time model

This dynamic approach models the flows of a network on both a time and space dimension. Yan et al. (1995) developed such a model in which the following flows between the locations over time are defined: (1) holding links, associated with holding cost, that define the amount of fleet held on down-time in the same location for the time specified by the link, (2) empty movement links, associated with empty movement costs, that define the repositioning movements in the network, and (3) the loaded movement links that define the demand flows in the network, associated with costs to execute the movement and revenue generated by the movement. Topaloglu and Powell (2007) incorporated such a space/time model, to find the set of prices that jointly optimise the revenue and costs of the fleet management, to result in the optimum profit. By using a so-called flow balance constraint, which indicates that the import of a location should be equal to the export of that location in the next time period, the repositioning flows are determined. Hence, if there should be an insufficient amount of tank containers to execute the out-going demand of the next time period, empty repositionings will be defined with the flow-balance constraint. Topaloglu and Powell (2007) modelled the demand as a random variable, whose distribution depends on the price, to be able to achieve the optimal prices by iteratively using a primal-dual solution to the problem.

1.2.3 Distribution fitting to data

In order to model the real situation, several assumptions for variables and parameters are required. To be able to decide which assumption is most likely to be correct, we performed a small study on fitting a distribution on the demand and lead time data.

Demand data

In the case of low demand, a discrete demand model usually has the best fit, as opposed to a continuous demand model which provides the best fit in case of a relatively large demand. For the first, the Poisson distribution is often a good fit on demand data. A property of this distribution is that the mean and the variance are equal. If this condition does not hold, it is recommended to use the negative binomial distribution for variance-to-mean (σ^2/μ) ratios larger than 1,1 and the Poisson distribution for ratios smaller than 0,9 (Axsäter, Sven, 2006).

For large demand, variables can often be fitted to a normal distribution. A fallback of the normal distribution is that it can generate negative values. When the ratio between the standard deviation and the mean (σ/μ) is not significantly lower than 1, it is highly likely that negative demand will be generated when using the normal distribution. In such a case, the Gamma distribution could be more suitable, as it has the property that demand is always positive. A risk of this approach might be that the probability for very high demand is larger with the Gamma distribution as compared to the normal distribution (Axsäter, Sven, 2006).

Lead time data

As for most variables, the stochasticity of variables can often be approximately fitted to the normal distribution (Axsäter, Sven, 2006). Thus, the normal approximation for the lead time distribution is a common method. However, as it is realistically to assume the lead time is always a positive number, a skewed distribution fit is not unlikely. The lognormal, Gamma and Weibull distribution with range $0 \leq X \leq \infty$ are often a good fit when the ratio between the standard deviation and the mean is large (Tadikamalla, 1984).

Distribution fit evaluation

To determine which distribution provides the best fit to the demand data, the fit can be evaluated using some functions offered by Matlab: the Anderson-darling test and the negative log likelihood calculation. The Anderson-darling test provides a 0 or 1 as output. When the output is 1, this means that the null hypothesis is rejected. The null hypothesis states that the data is from a population with the specified distribution. When the output is 0, the test failed to reject the null hypothesis at a 5% significance level, thus the null hypothesis is accepted. The negative log-likelihood calculation returns the value of the negative likelihood function for the data used to fit the specified probability distribution. The best fit is the fit with the smallest negative log-likelihood.

1.3 Research questions

Based on the literature, we identified a gap in the freight transport pricing approaches. Both the static as well as the dynamic approaches identified, aim to optimise the profit by defining the most optimal price settings. An optimisation of the price settings can solely be accomplished when the relationship between price and demand is quantified. As such, we aim to find a methodology that focuses on defining the most beneficial strategies without the requirement to quantify this relationship. Following the business opportunity and the literature gap, we formulated the research question as follows:

How may companies in tank container industry benefit from the price elasticity of their demand to improve their profit by influencing tank container flows?

We divided the study into multiple parts, each with their own sub-question as described below.

Sub-question 1: What are the financial components required to determine the profit and which components are affected by tank container flows and imbalances?
In order to define how the profit could be improved using a pricing strategy based on the concept of price elasticity of demand, it should be known how profit is calculated. Hence, the cost and revenue components that are part of the profit calculation need to be identified. Furthermore, it should be identified which components are affected by the size of the tank container flows.

Sub-question 2: What is the current profit generated?
To define how companies may benefit in terms of improving their profit, it should be known what the 'as is' situation of profit generated within the network is. This situation represents the situation without any demand adjustments, and has to be compared with the impact of possible strategies, in order to identify which strategy improves the profitability of the network.

Sub-question 3: What is the demand behaviour of customers and how do they react to an adjustment in the price?
A customer takes into account different criteria when selecting a LSP. The decision will be based on the satisfaction the customer obtains as a result of their selection. Each customer may have different weights for the criteria involved in their selection and a different sensitivity towards price. The questions results in: (a) an identification of the factors that trigger a demand; i.e. a selection of Den Hartogh instead of a competitor, (b) an identification of customers' sensitivity towards prices and (c) an identification of customer segmentation based on their sensitivity towards price.

Sub-question 4: What is the impact of a change in the demand on the profit?
To identify the impact of possible strategies on the profit, a calculation model is required. This model should identify the impact of a strategy on the profit generated by the network. Hence, based on a comparison of the profit generated by the current situation and possible strategies, the strategies expected to have a positive effect on the profit can be identified.

Sub-question 5: Which profit improvements can be achieved by implementing a price elasticity of demand based strategy?
The final question aims to provide a conclusion by combining the understanding of the customer demand behaviour and the conclusions of the proposed model into recommendations for a price elasticity of demand based strategy.

1.4 Research scope

Within this research, we speak of the price elasticity of demand, which is an estimate for the inverse relationship between price and demand (Marshall, 1920). Elasticity is a measure of responsiveness, measuring the percentage change in a variable, in reaction to a one percentage change in another

(Oum et al., 2008). Hence, price elasticity of demand measures the impact that a decrease or increase of the price has on the demanded quantity. Though this research aims to determine how companies may benefit from a strategy based on this concept, estimating the price elasticity of demand for the demand of Den Hartogh is considered to be out of scope. The reason behind this is that a considerably large amount of services can be distinguished at Den Hartogh, as they depend on a combination of many factors such as the origin, destination, type of product transported, and other requirements for the transportation. This would lead to an extraordinary amount of elasticities to be defined. Furthermore, the demand is not only influenced by the price of the service but also by a.o. the demand for the product to be transported, the economy, the geographical considerations, and prices of competitors. Especially the latter is assumed to be of large impact as the transport market is a competitive market. However, competitors' prices are unknown and expected to vary over time, increasing the complexity of calculating the price elasticity of demand measures for this research.

For further feasibility of the thesis project, the demand flows considered in the case study consist only of the global business unit flows on global region level and monthly time periods. This limits the amount of lanes and thus decreases the complexity of the study.

1.5 Methodology

The overall framework used as a general structure for this thesis is the reflective redesign model developed by van Aken et al. (2012). This model was chosen on grounds that the thesis focuses both on a solution for a specific business opportunity as well as to develop generic knowledge on this type of opportunity. We investigated the business opportunity using a case study, for which the outcomes and the model formulation generated generic knowledge within the freight transport pricing field.

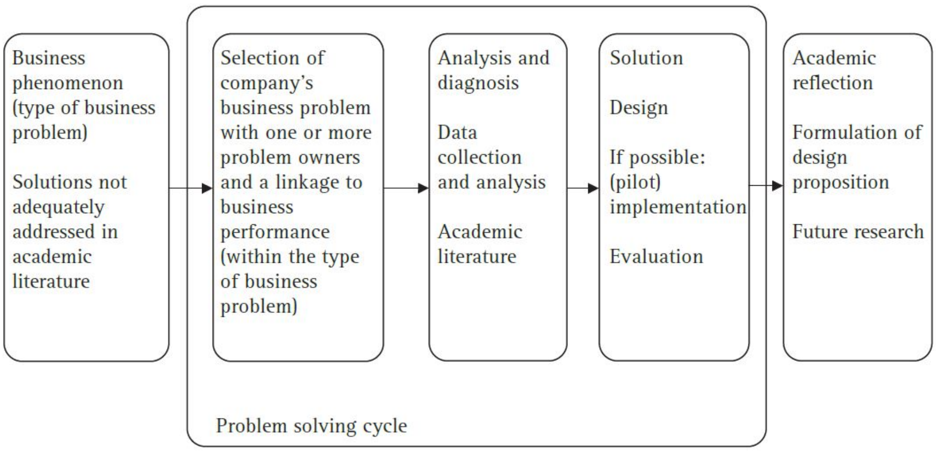


Figure 1.1: Reflective redesign (van Aken et al., 2012)

1.6 Thesis outline

In Chapter 2, the analysis of the demand behaviour of potential customers of Den Hartogh Logistics is discussed. Chapter 3 discusses the pricing model and profit structure of Den Hartogh Logistics, which is used as input for the model formulation discussed in Chapter 4. The case study performed on the proposed model is discussed in Chapter 5. Finally, Chapter 6 outlines the main conclusions and discusses the limitations, possibilities for future research, and recommendations.

Chapter 2

Demand analysis

This chapter provides an answer to the third research question: *What is the demand behaviour of customers and how do they react to an adjustment in the price?* The demand for a specific firm offering freight transport services is depended upon shippers' preferences towards one firm over its competitors. Therefore, it is said that the demand of Den Hartogh Logistics is dependent upon the customers that choose for Den Hartogh instead of a competitor. Each potential customer selects a LSP based upon a set of different criteria and may assign different weights to those criteria. Furthermore, each customer may have a different sensitivity towards the price of the service offered. The goal of this chapter is to identify which factors trigger a demand, to identify a customers' sensitivity towards prices, and to identify potential segmentations based on this sensitivity.

We decided to analyse the customers' LSP selection by distributing a survey among the general managers and members of the commercial team. This group is involved in negotiations with (potential) customers on behalf of Den Hartogh Logistics. Hence, we expected that they obtained the most insight into (potential) customers' LSP selection procedures. We used the perceived estimates of the commercial team instead of interviewing actual customers as we believed that customers would not be completely transparent about their selection procedure, since that might result in a loss of their bargaining power.

Based on the literature review, we identified a long list of factors that could be part of a (potential) customers' LSP selection. In order to develop an efficient survey, pre-survey interviews were held with four members of the population to discuss the set-up of the survey, to make a preselection upon the criteria and factors to be included in the survey, and to define which customer-, market-, or demand characteristics had to be taken into account in the survey. As a result, we differentiated between spot and tender type of customers. A spot customer sends out requests for quotations for a single shipment. This quotation is only valid for a short period of time. A tender customer uses a tender procedure: a bidding process for a contract valid for a longer time period. Long-term contracts provide customers with a fixed price for a specific service throughout the contracted period.

We divided the survey in three parts. In the first part of the survey, we asked respondents to list their names such that collected data could be converted to the offices in which they are employed. In the second part, we asked respondents to distribute 100 points over six criteria that might be of relevance in the LSP selection of a (potential) customer, for which we provided the following descriptions to the respondents:

1. *Transit time and reliability*: The speed of the complete origin to destination (e.g. door-to-door) service provided by the LSP and the reliability of the promised speed (the on-time pick-up and deliveries).

2. *Service*: The service criteria consists of the factors related to the characteristics of the LSP, the service provided and the customer service offered. The factors considered are: the size of the (tank container) fleet of the LSP, the level of safety provided, the certainty of availability of tank containers to fulfil the demands, the geographical coverage provided by the LSP, the availability of local representation, proactive fast responsiveness and maintaining agreements & promises.
3. *Sales rate*: The sales rate of the service.
4. *Financial stability*: The financial performance of the LSP.
5. *Sustainability*: The environmental impact of the services.
6. *Relationship*: Having a good, professional relationship with the customer and a high level of professionalism of sales personnel.

The amount of points a respondent assigned to the criteria should reflect their perception of the importance of the criteria for their average (potential) customer. In the third and final part of the survey, we identified several factors that could be part of the previously mentioned criteria and asked respondents to rate the importance of the factors with the use of a 5-point Likert scale. We used 1 to reflect "not important" and 5 "extremely important". The developed survey is shown in Appendix A.

Within this chapter, first the responses and the data cleaning and transformation process are described. Thereafter, the results of the survey are structured accordingly to the criteria previously mentioned. Finally, a conclusion is provided discussing the factors that trigger a demand, the sensitivity of a customer towards the price, and the potential segmentations on price sensitivity.

2.1 Responses

The targeted audience consisted of all members of the commercial team: commercial managers, commercial directors, contract managers, and general managers of the locations. We collected a total number of 32 responses, resulting in a response rate of 74% of the total targeted audience.

2.2 Data cleansing and transformation

In order to determine which data required cleaning and/or transformation, we analysed the data on the following elements: missing data, inconsistencies and outliers.

2.2.1 Missing data

We identified several cases of missing data. First, one of the respondents skipped the second part of the survey, for both customer types. As this resulted in incomplete data, we eliminated this response from the data to be analysed. Secondly, out of the remaining responses, two respondents indicated that their portfolio consists only of tender customers. One had not participated in the spot questions, and for the other we eliminated the response on the spot questions. As a result, we gathered 29 responses for the spot customer and 31 for the tender customer. Thirdly, due to a mistake in one of the questions of the survey (related to variable $R1$), we eliminated the fist nine responses from the data. For the remaining responses, the mistake was solved. This elimination resulted in only 22 responses for the analysis of the previously mentioned variable for the tender customer, and 20 for the spot customer. Finally, one respondent appeared to forgot the questions in the third part of the survey related to 'transit time and reliability' for the spot customer. Hence, for these variables ($T1$ and $T2$), only 28 data points were left for the spot customer. For those responses with missing data, we decided to analyse data pair-wise. This means that the remaining data entered by the respondent was incorporated in the analysis. The reason behind this is that the data-set was considered to be too small to remove all responses with partly missing data. As such, all data collected should be incorporated within the analysis.

2.2.2 Inconsistencies

In the second part of the survey, respondents received the following description for taking into account the criteria sales rate: ”the sales rate for the service”. We described the criteria in this manner to identify the importance of the rate of the service in comparison to the other criteria considered. However, in the third part of the survey, we included the duration of the validity, as well as the stability of the rate over time. This enabled us to compare the second and third part of the survey on the sales rate questions to check for inconsistencies. We identified one inconsistency in which the respondent assigned the largest share of points to the sales rate in the second part and listed the important of the rate as ”slightly important” in the third part (a score of two out of five on the Likert scale). For the spot questions, the respondent assigned less points to the sales rate criteria in the second part, but assigned a higher score to the sales rate factor in the third part. We assumed this inconsistency was a mistake and we treated the data for the sales rate factors of the tender customer as missing data.

Furthermore, as part of the analysis on the inconsistencies, we analysed central tendency bias and social desirability bias. Central tendency bias is the tendency of respondents to rather give answers in the middle of the rating scale than towards the ends (Subedi, 2016). For the third part of the survey, we used a five point Likert scale. The existence of such a central tendency bias in the data was considered to be the case when respondents did not included any 1 (”not important”) or 5 (”extremely important”) within their answers on the third part of the questionnaire. This is the case for five respondents. An explanation for this bias could be that the respondent did not fully comprehend the questions, and had therefore chosen to only answer with 'safe options'. However, analysis of data from the second part of the survey indicated that those respondents assigned the criteria weights more 'radical'. Hence, we assumed the data was correctly assigned and thus no transformation was required.

Social desirability bias is the urge of respondents to give socially acceptable answers (Fabbris, 2013; Subedi, 2016). In the introduction of the questionnaire, we described the goal of the second part of the survey as follows: ”The second part is aimed at identifying the importance of the sales rate relative to the other criteria that are a part of a (potential) customers' logistics service provider selection”. This explanation of the goal of the survey could lead to over-assigning points to the sales rate criteria as this might be considered to be a socially desirable answer. This may also happen unwittingly by the respondent. Hence, this should be taken into account when analysing the data. The box-plot of Figure 2.1 on the next page shows that the answers of the respondents on the sales rate criteria weight are quite diverse. Thus, we assumed that the answers given are correct, and there is no social desirability bias. For those responses that are relatively high as compared to the average answer given, we assumed this to be the result of the customer portfolio of the respondent.

2.2.3 Outliers

In the second part of the survey, respondents received an error message when the values entered by the respondent did not sum up to 100. Hence, this eliminated mistakes in entering data, meaning that one had deliberately chosen the assigned amount of points. The third part of the survey is based upon a 5-point Likert scale. As answers of respondents are limited with a ceiling and a floor, we assumed them to be deliberately chosen. Hence, we decided not to remove any outliers in the data.

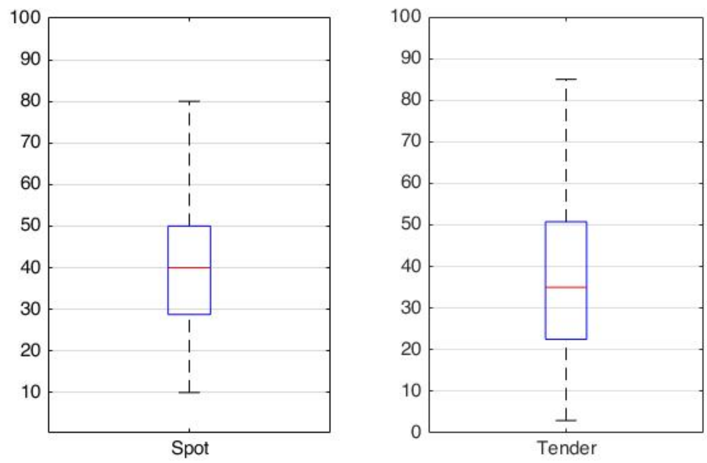


Figure 2.1: Boxplot sales rate weights

2.3 Results

Figure 2.2 shows the mean of the weights assigned to the criteria for both the spot and tender type of customer.

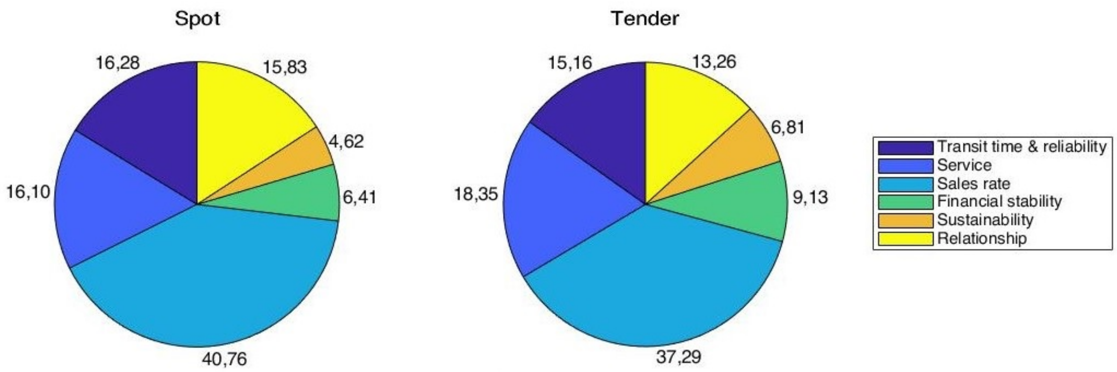


Figure 2.2: Mean criteria weights for spot and tender customers

Overall, the weights assigned to the LSP selection criteria seem rather similar for the spot and tender customer. However, we identified small differences based upon analysis of the means of the values. The differences of the criteria and the factors that may be a part of these criteria are discussed within the next sections.

2.3.1 Transit time and reliability

Respondents assigned the importance of the transit time and reliability criteria with 16,3 out of 100 points for the spot customer, whilst the tender customer received 15,2 points. Hence, transit time and reliability appears to be a tiny bit more important for the spot customer than for the tender customer. Based upon an independent samples t-test, it appeared to be impossible to statistically confirm this difference ($t(58) = 0,457; p = 0,649$).

In the third part of the survey, we divided the transit time and reliability criteria into two factors: the transit time itself ($T2$) and the reliability of the transit time as the other ($T1$). We asked respondents to rate the importance of the factors with the use of a 5-point Likert scale. The mean scores of the factors are shown in Figure 2.3.

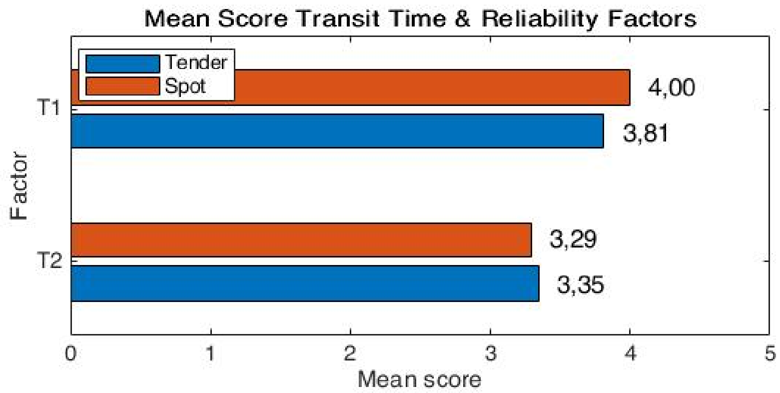


Figure 2.3: Transit time and reliability criteria factors mean score

Overall, the reliability of the transit time appears to be more important than the speed of the transit time (the speed is considered to be 'moderately important' and the reliability 'important'). From a planning perspective, this is a logical outcome as one is able to plan with a longer lead time, but not with an unreliable lead time. Furthermore, the reliability appears to be slightly more important for the spot customer than for the tender customer. This might be explained by the fact that spot shipments could also be aimed at quick 'problem solving', and not only based upon a buying strategy. Using an independent samples t-test, the differences between spot and tender customers were not statistically confirmed (for T1: $t(57) = 0,923; p = 0,360$ and for T2: $t(57) = -0,306; p = 0,761$).

2.3.2 Service

The importance of the service criteria received 16,1 out of a 100 points for the spot customer, and 18,4 points for the tender customer. Hence, the service criteria appears to be a bit more important for the tender customer than for the spot customer. However, it was not possible to statistically confirm the differences within the service criteria weights for spot and tender ($t(58) = -1,395; p = 0,168$).

In the third part of the survey, we split the criteria into seven factors: a high level of safety offered by the LSP ($S1$), the certainty of availability of tank containers ($S2$), a large fleet size of tank containers ($S3$), a large geographical coverage of the network ($S4$), the availability of local representation ($S5$), proactive, fast pace of responsiveness to the customer ($S6$), and maintaining the agreements ($S7$). Figure 2.4 on the following page shows the mean scores of the importance for both the spot and tender customer on the five-point Likert scale.

The 'level of safety offered', 'a large fleet size', 'a large geographical coverage of the network' and 'maintaining the agreements' all seem to be a bit more important for the tender customer than for the spot customer, based upon analysis of their mean values. After performing an independent samples t-test, we concluded that all of the previously mentioned variables were significantly different for the spot and the tender customer, as well as 'the certainty of availability of tank containers' (S1: $t(58) = -2,333; p = 0,023$, S2: $t(58) = -2,242; p = 0,029$, S3: $t(58) = -3,040; p = 0,004$, S4: $t(58) = -2,777; p = 0,008$, S5: $t(58) = -0,836; p = 0,407$, S6: $t(58)1,695; p = 0,095$, S7: $t(58) = -3,953; p = 0,000$).

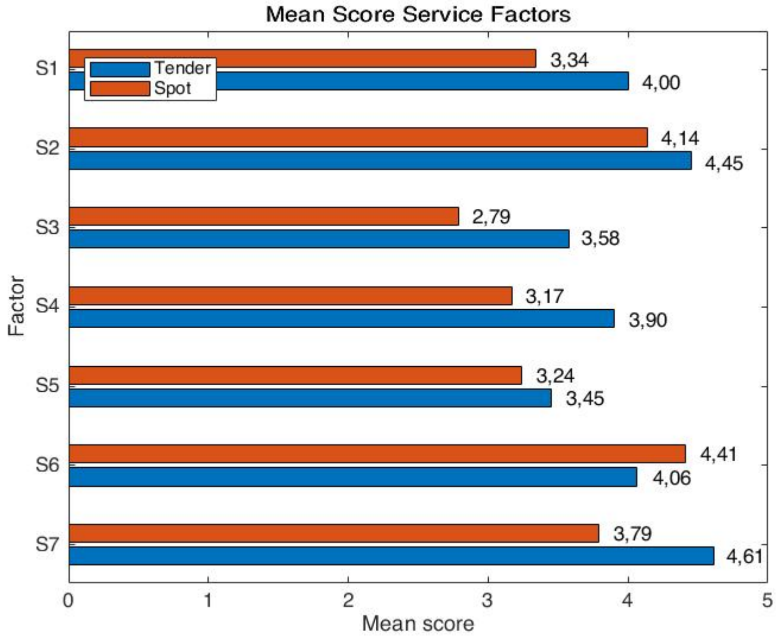


Figure 2.4: Service criteria factors mean score

2.3.3 Sales rate

The sales rate appears to be by far the largest criteria in terms of importance for both types of customers. Figure 2.2 on page 10 shows that the average sales rate importance is slightly higher for the spot customer than for the tender customer (resp. 40,8 and 37,3 out of 100 points). However, an independent samples t-test had not led to any statistical confirmation of the differences between the sales rate weights for the spot and tender customer ($t(58) = 0,703; p = 0,485$).

Besides the actual rate of the sales rate ($SR3$), we considered two more sales rate factors in the third part of the survey: the stability of the rate over time ($SR1$) and the duration of the validity of the rate ($SR2$). Figure 2.5 shows the mean scores of all factors considered for the sales to both the spot and the tender customer.

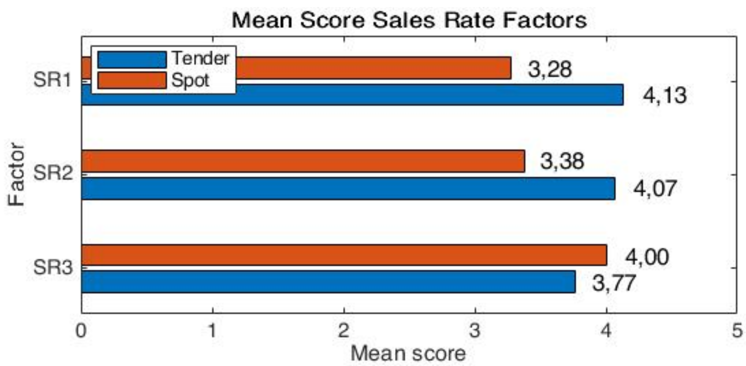


Figure 2.5: Sales rate criteria factors mean score

For the spot type of customer, the sales rate appears to be more important than the amount of time the rate is valid and the stability of the rate over time. For the tender customer, the opposite holds. An independent samples t-test indicated that there we were unable to statistically confirm the differences between the groups based upon their importance towards the sales rate ($t(57) = 0,944; p = 0,349$). For the stability of the rate over time and the duration of the validity of the rate, the differences between the groups were found to be statistically significant (resp. $t(57) = -3,870; p = 0,000$ and $t(57) = -2,916; p = 0,005$).

By segmenting the weights assigned to the sales rate criteria over all global regions, we distinguished the differences shown in Table 2.1 for the spot and tender customers.

Table 2.1: Sales rate mean score per global region

Region	**1**	**2**	**3**	**4**	**5**	**6**
Spot	41,4	45,0	50,0	50,0	35,0	30,7
Tender	36,0	55,0	65,0	70,0	10,0	30,7

However, due to small populations (varying between 1 and 24 per region), and large variability within the answers in general, no conclusions could be made based upon the global region differences.

2.3.4 Financial stability

The criteria financial stability aimed to identify the importance of the financial performance of the LSP in the selection method of a potential customer. The spot customer is on average assigned with 6,4 out of 100 points and the tender with 9,1 points. Hence, the criteria appears to be a bit more important for the tender customer, though we believe that the criteria is not crucial for either of the customer types. Based upon an independent samples t-test, no statistically confirmed difference between the spot and the tender customer could be found ($t(58) = -1,764; p = 0,083$).

2.3.5 Sustainability

We defined sustainability as the environmental impact of the services offered by the LSP. The sustainability criteria appears to be the least important element as it only received 4,6 out of a 100 points for the spot customer, and 6,8 for the tender customer. Hence, it appears that the tender customer takes sustainability into account slightly more than the spot customer, though this difference could not be statistically confirmed (independent samples t-test results: $t(58) = 1,489; p = 0,142$).

2.3.6 Relationship

Respondents assigned relationship with 15,8 points for the spot customers and 13,3 out of a 100 points for the tender customers. This might be because tender customers usually negotiate contracts valid for a longer period of time (e.g. annually) and the purchasing is thus presumably for a larger budget, and therefore they might have to follow stricter procedures in which relationships cannot be taken into account as much as for a spot customer. However, no difference between the spot and the tender customer weights could be statistically confirmed (independent samples t-test results: $t(58) = 1,095; p = 0,278$).

In the third part of the survey, we divided the relationship criteria into two factors: a high level of professionalism of the sales personnel ($R1$) and a good, professional connection between LSP and customer ($R2$). Figure 2.6 on the following page shows the mean scores to the factors belonging to the relationship criteria. Both of the factors appear to be rather similar in importance for the spot and tender customer. An independent samples t-test performed on the data gathered did not indicate any significant difference in spot and tender customers for the relationship factors (R1: $t(42) = 0,000; p = 1,000$, R2: $t(58) = 0,759; p = 0,451$).

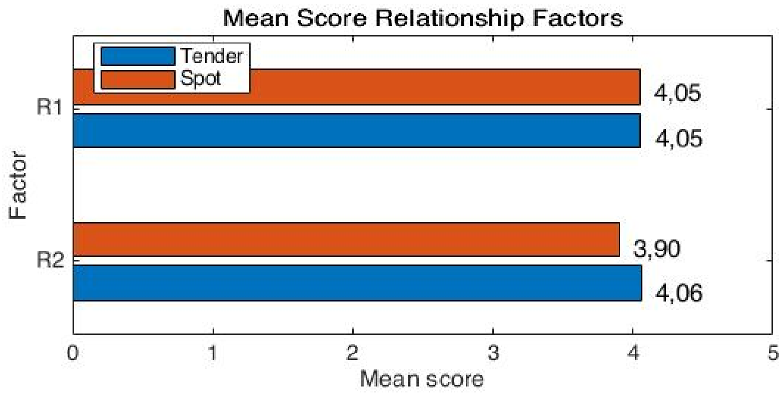


Figure 2.6: Relationship criteria factors mean score

2.4 Conclusion

With the survey, we aimed to identify the factors that trigger a demand, to identify the sensitivity of a (potential) customer towards the price of the service, and to identify which segmentations can be made based upon this sensitivity towards price. Hence, these elements will be discussed in the following sections.

2.4.1 Demand triggering factors

The demand for a LSP is dependent upon its competitive position. As described previously, a customer decides on the choice of LSP based on a set of criteria. Those criteria, dependent upon their level of importance, are considered to be factors that trigger a demand for a LSP. In general, it appears that the sales rate is by far the most important criteria for both the spot and tender customer. Hence, it seems to be the main trigger for a demand for a LSP. Thereafter, the main demand triggers are a mix of service, transit time and reliability, and relationship between the LSP and the potential customer. The ranking of the importance depends on whether the customer is a spot or tender type. The financial stability and sustainability received a relatively small amount of points for both type of customers. Hence, it is somewhat safe to conclude that the financial stability of the LSP and the sustainability of the service provided take no part in the decision, unless competitors would perform equally on all other criteria identified.

2.4.2 Sensitivity towards price

The sales rate criteria received the largest share of points. This confirms the expectation that a pricing strategy will be effective. One of the interviewed persons indicated that when the companies' rate is not "within competitive range" (i.e. the rate is out of range as compared to competitors' rate), the company will not be taken into account as a possible LSP. As none of the mean criteria weights come close to the weight assigned to the sales rate, we conclude that this statement is a realistic assumption.

Out of the 29 responses for the spot customer, 21 assigned the sales rate with the most points, compared to the other criteria weights. Five other respondents believed it is one of the most important criteria as they assigned the sales rate to be equally important as another criteria, with both the highest amount of points. For the responses on the tender customer, 21 out of 31 of the respondents awarded the sales rate criteria with the largest amount of points. Two other respondents believed that it is one of the most important criteria. Thus, as the largest portion of respondents believe the sales rate is the most important criteria, we conclude that customers appear to be extremely price sensitive. It is expected that business could be easily won by lowering the rate of the service, or lost by increasing the rate. As rates of competitors are unknown and expected to vary in each situation as well, it is hard to determine the exact sensitivity towards the price. Hence, it can only be concluded that customers are indeed sensitive towards adjustments in the rate of the service.

2.4.3 Segmentation price sensitivity

As referred to numerous times before, we identified the sales rate importance for both the spot and the tender customers. The mean scores for both types slightly differ, resulting in the sales rate being slightly more important for the spot than for the tender customers, though a difference could not be statistically confirmed. In the case the pricing strategy is aimed at solving the imbalances in the short-term planning, the strategy will be mostly based upon targeting the spot customers' demand. In the case there appear to be structural imbalances (i.e. a region is expected to be importing more than exporting over a longer period of time, e.g. a year), then one should aim to target the tender customers with the pricing strategy.

Furthermore, we identified differences between the sales rate weights for each of the global regions. Though none of the differences between the global regions could be statistically confirmed, we cannot say there are no differences. When a demand adjustment in a region would appear to have the same impact on the profit as for a demand adjustment in other regions, the differences within the weights are an indication to where the pricing strategy is expected to be most effective, which supports prioritising strategies.

Chapter 3

Pricing model and profit structure

In the previous chapter, we established a solid foundation to assume a pricing strategy would be effective. To define how such a strategy could influence the demand and therewith improve profit, an understanding of the profit structure is required. In this chapter, the current pricing model and the profit structure of a single order are clarified. First, the set up of the current pricing model is elaborated in Section 3.1, i.e. the elements that are incorporated into the sales rate of a single order. Next, Section 3.2 describes the profit structure, i.e. how the profit of a single order is defined. And finally, Section 3.3 points out which of the elements of the profit structure of the previous section are relevant for answering the research question. These sections combined provide an answer to the first research question: *What are the financial components required to determine the profit and which components are affected by tank container flows and imbalances?*

3.1 Pricing model

A customer demand for a single tank container transportation between a specific origin and destination is referred to as an order. The amount of money for which a single order is sold is referred to as the sales rate. This sales rate is equal to the revenue that is generated by executing this order. To establish this sales rate, the expected costs of the activities required to execute the order are included, as well as a sort of profit margin and network steering elements. The pricing model used to determine the sales rate of a single order is shown in Table 3.1. Each of the elements incorporated into the pricing model is explained in the listing on the next page.

Table 3.1: Pricing model for single order

Direct order costs	
Equipment costs	
Fixed overhead costs contribution	
Repositioning contribution	
(Repositioning saving)	
Market correction origin	
Market correction destination	
(Expected demurrage revenue)	+
= Default rate single order	
Quoted network margin	+
= Sales rate single order	

- *Direct order costs*
  The direct costs consist of the cost components directly linked to the execution of the order; e.g. handling, leakage check, the transportation costs, etc. The amount depends upon the requirements of the order and the characteristics of the to be transported commodity.

- *Equipment costs*
  A fixed amount charged for each day of using the tank container, to cover the hiring cost for leased-in tank containers and the depreciation, maintenance, and repair cost for owned tank containers.

- *Fixed overhead costs contribution*
  A fixed amount per order to cover the indirect costs that cannot be directly linked to an order; e.g. personnel salary. The amount is similar for each order, regardless of its characteristics.

- *Repositioning contribution and saving*:
  The repositioning contribution and saving are aimed at covering the repositioning costs that occur as a result of the imbalanced demand flows. As described in the literature review, when there are too little tank containers in a specific location to cover the demand, a repositioning movement is required. A contribution to cover part of the costs of such a repositioning activity is incorporated into the pricing model. The amount to be charged for a single order is defined using historical data. Based upon historical repositioning activities in the network on port-level, it is calculated what the ratio of tank containers was that were repositioned after being delivered in a specific area. This is calculated as the surplus of tank containers in a certain area during a specific time period, divided by the total amount of laden tank containers imported into that region during the same period. Then, for each location with a surplus, it is determined what the most likely location is that a tank container would be repositioned to, and the expected cost of that movement are calculated. Finally, for each location, the ratio of a repositioning originating from that location is multiplied with the cost of the most likely repositioning destination. The outcome will be charged to each single order shipping to that specific location. The repositioning saving is based upon the origin of the order. As a customer receives a penalty (in the form of the contribution) when they ship to a surplus area, they should also receive a discount when they ship from that surplus area. This value is calculated in the same manner as the repositioning contribution, but given as a discount instead of a penalty. The sum of the repositioning contributions charged to all orders minus the sum of the savings given to all orders is used to contribute to all actual repositioning costs.

- *Market correction origin and destination*:
  Similar to the repositioning contribution and saving, a market correction is also either a penalty or a discount that is given to the customer as a result of shipping to or from a specific location. The difference is that the market correction is a network steering tool, aimed at influencing the expected imbalances in the future, whereas the repositioning contribution and saving are aimed at covering the repositioning contribution costs. An order with an expected surplus area as its destination is discouraged with a penalty, though an order originating from that area is encouraged with a discount. The opposite holds for a shortage area. An order to an expected shortage area is stimulated with a discount, but an order originating from that shortage area is discouraged with a penalty. The market correction penalty and discount for a location have the same absolute value. The reasoning behind this is that it is not designed as a tool for profit maximisation but designed as a break-even situation. However, the sum of the market correction penalties and discounts charged may still be positive or negative.

- *Expected demurrage revenue*:
  After delivery of the tank container at the required destination, the customer is allowed to keep the tank container in possession for seven more days. Thereafter, the tank container should be made available for Den Hartogh Logistics to be re-used for a new order. However,

customers may have the tank container in their possession for a longer time period. If this occurs, customers are obliged to pay a fee for having the tank container in their possession during this exceeding period. This fee is referred to as demurrage revenue. The revenue that this demurrage is expected to generate is subtracted from the costs charged to the customer. Therefore, this can only be a non-positive value in the pricing model. This subtraction does not mean that no profit is generated with demurrage revenue, but it leads to an enlargement of the quoted network margin.

- *Quoted network margin*:
  The quoted network margin is an indication of the value of a single order in the network. It is the amount of gross profit that the order is expected to generate from a network perspective. However, as the actual cost may differ from those charged, and the market correction sum may be positive or negative, this is not equal to the actual profit of the order.

- *Default versus sales rate*:
  As the demurrage is subtracted in the pricing model, the default rate indicates for the commercial department that as soon as they sell the order for less than the default rate, it will most likely result in a negative impact on the profit. Thus, the default rate is more or less a lower limit on the sales price of a single order. The sales rate is the sales price for a single order negotiated by the commercial department with the customer, and is the revenue provided by a single order.

3.2 Profit structure

The profit of a single order is calculated by subtracting all cost elements required to execute solely that specific order from the sales rate of the order, as can be seen in Table 3.2.

Table 3.2: Profit calculation for a single order

Sales rate of order	
(Direct order costs)	
(Equipment costs order)	
(Overhead costs order)	
(Actual repositioning costs following the order)	
Additional demurrage revenue of order	+
= Profit of single order	

The profit of the total network during a certain time period is thus the profit of all the orders in the network executed during that time period.

3.3 Components affect by demand

To determine the impact on the profit generated by the network as a result of the demand flows, not all elements of the pricing model and profit structure are relevant. We discuss the impact of all elements on the network profit in the next paragraphs. When the elements are found to be affected by the size of the demand flows, they are incorporated into the profit calculation.

First, the direct order costs, the equipment costs and the overhead costs of all orders are assumed to be completely, correctly charged upon the customer, all though in practice the correctness of the amount charged is uncertain. This means that all may have different actual costs when the order is executed, as compared to the costs quoted. However, the amounts are dependent upon the shipment characteristics and the customer requirements and not necessarily on the quantities transported. Therefore, those are not incorporated into the profit calculation.

Secondly, the difference between the quoted demurrage revenue and the actual demurrage revenue are not incorporated into the profit calculation. The reason for this exclusion is that the subtraction of the expected demurrage is balanced within the quoted network margin. Even when this expectation is estimated incorrectly, this is considered not to be a consequence of the demanded quantities, and will thus not be incorporated into the profit calculation.

Hence, the only elements seen as a result of the tank container flows and corresponding imbalances are the quoted repositioning costs and savings, the actual repositioning costs, the quoted network margin, and the market correction. Thus, those should be incorporated into the profit calculation. However, the market corrections are aimed at adjusting the demand, for which this research proposes a model aimed to provide support in the decision-making. Thus, the market corrections are not incorporated in the profit calculation. Hence, we identified the following elements as part of the profit calculation:

- quoted network margin for each lane in the network;
- quoted repositioning contributions and savings for each global region in the network;
- actual repositioning costs for each lane in the network;
- laden tank container flows (demanded quantities) for each lane in the network;
- empty tank container flows (repositioning quantities) for each lane in the network.

Chapter 4

Model formulation

This chapter provides answer to the fourth research question: *What is the impact of a change in the demand on the profit?* To identify this impact on the profit, a calculation model is required. This model should identify the impact of possible demand adjustments on the profit generated by the network.

A companies' objective regarding the execution of demand would be to maximise the profit generated within the network. Therefore, the desired output of the model should be the profit generated by the demand, for all lanes in the network, during a specific time horizon. As the pricing strategy would impact the demand in the future, the demand scenario required as input for the simulation model consists of the forecasted demand. As the future is usually uncertain, we incorporated this uncertainty into the model in two manners. First, the forecasted demand may be impacted by economical or political events. By formulating the impact of such an event on the demand, and taking into account different levels of impact, multiple scenarios can be developed. Secondly, we treat the demanded quantities as the objects of simulation, such that uncertainty is also incorporated within each developed scenario. Herewith, we are able to define the expected output of a demand scenario, and the robustness of the outcome. The simulation model aims to imitate the tank container movements throughout the network by simulating the demand flows and defining the repositioning movements that would occur to execute the demand. By testing several demand adjustments, referred to as strategies, we are able to calculate the expected profit adjustment as a result of applying a strategy, for all scenarios.

The remaining input required for the simulation model consists of the profit elements defined in the previous chapter, the lead time of the transportation activities, the parameter settings for the repositioning procedure, and the starting condition. This starting condition consists of the amount of available tank containers at the start of the scenario and the expected period in which tank containers that are executing a demand at the start of the simulation are available again. This latter category is referred to as work in progress (WIP).

For the development of the simulation model, we formulated several assumptions in order to be able to model the demand flows within the network. Section 4.1 provides an overview of the assumptions and discusses the reasoning behind the assumptions. Section 4.2 provides an overview of all the variables used within the simulation model. The proposed model is described in Section 4.3 and a verification for the model is discussed in Section 4.4.

4.1 Overview of assumptions

Below we list the assumptions required for the simulation model.

1. *Demand is assumed to be stochastically distributed*
   Following the literature review, demand data can usually be approximately fitted to a probability distribution. Assuming demand is stochastically distributed allows us to incorporate demand uncertainty within the model in a structured manner. For each run of the simulation model, we create a set of random demand based on the stochastic parameters of the demand scenarios.

2. *All remaining input variables and parameters are assumed to be deterministic*
   All input variables are stochastic by nature. However, when all variables are treated as stochastic variables, it cannot be determined whether a change in the outcome of the model is the result of a strategy tested upon the scenario, or the result of variability within the input variables. Hence, this assumption seems reasonable as it allows us to estimate the impact of a strategy.

3. *Rejected demand is treated as lost sales*
   If demand cannot be fulfilled due to a shortage in available tank containers, demand is rejected. It is assumed that the shipper would place their demand for a tank container transportation at a competitive logistics service provider, to be able to still deliver in time. Hence, in such cases, demand will be treated as lost sales. This assumption seems fair as a shipper has to meet the required delivery date set by their customer.

4. *The fleet of tank containers is assumed to completely similar*
   In reality, all tank containers may have different characteristics regarding e.g. the volume of the tank, the discharge, and the heating type. For computational purposes, all tank containers are assumed to have completely similar characteristics, and can thus be used for each shipment. Simplifying the fleet appears to be reasonable as we aim to create a tactical decision support tool.

5. *It is assumed the amount of containers in maintenance is steady over time*
   We assume the amount of tank containers unavailable due maintenance or repair activities is equal in the long run, i.e. in steady state. Therefore, the amount of tank containers in the network at the start of the simulation is the size of the fleet considered for the network and maintenance is not incorporated within the simulation model. As there are always tank containers in need for maintenance and repair, we consider this a realistic assumption.

6. *All shipments are assumed to be executed via direct lanes*
   All transportation activities, both laden and empty, are executed via directed lanes. It could be that costs are smaller when indirectly shipped, or that the quoted network margin is larger when indirectly shipped. However, as customers would not accept such a quotation, this assumption seems fair.

7. *The depot storing costs are assumed to be similar for each location*
   In reality, each depot may charge different costs for storing and cleaning of tank containers. For computational ease, we assume these costs to be equal at each location in the network. As repositioning costs are considerably larger than depot storage costs, a repositioning will most likely not occur as a result of depot storing costs. Hence, this assumptions is considered to be reasonable.

8. *The tank containers available are assumed to be clean and empty*
   In reality, not all depots offer cleaning facilities, and therefore occasionally empty shipments are required to reposition the tank container to a depot with cleaning facilities. However, the majority of depots offer cleaning facilities and therefore it is assumed that after each laden transport, tank containers are cleaned immediately after delivery at the point of destination.

Thus, all tank containers that are available are assumed to be clean and empty. This seems a fair assumption on a higher aggregational level such as continents, but seems unfair on port-level.

9. *Each period a repositioning decision is made*
Each period the decision-maker defines whether there are shortages and which repositioning movements are required to solve these shortages. This repositioning decision may also result in the decision not to reposition any tank containers. Since the availability of the fleet is constantly monitored, this seems a fair assumption.

10. *No demand is rejected when tank containers are available*
It could be the case that a demand with a negative impact on the profit is accepted. This could be because the customer demanding the transport also generates demands with a positive impact on the profit. Rejecting the demand with a negative impact could lead to losing all demand of the customer. Hence, it is reasonable to assume that all demand is accepted for as long as there are sufficient tank containers available to execute the demand. If not all demand from a region can be accepted due to shortages in availability of tank containers, it is assumed that each destination receives a portion of the available tank containers in that region equal to the share of the demand originating from that region.

4.2 Overview of variables and parameters

Table 4.1 provides an overview of all variables and parameters used within the proposed model.

Table 4.1: Variables and parameters

Variable	**Explanation**
i	Index for the origin of the shipment
j	Index for the destination of the shipment
N	The number of regions in the network
t	Index for the time period in the simulation horizon
T	Total length of the simulation horizon
CP	Current period
$d_{i,j,t}$	Potential demand of lane i, j at time t
$QNM_{i,j}$	The quoted network margin for any order from region i to region j
QRC_j	The quoted repositioning contribution for any order with destination j
QRS_i	The quoted repositioning saving for any order with origin i
QRi, j	The quoted repositioning provision for an order originating from i with destination j $QR_{i,j} = QRC_j - QRS_i \; \forall \; i, j \in N$
$ARC_{i,j}$	The cost for a repositioning movement from origin i to destination j
$FLT_{i,j}$	The lead time for a laden shipment from origin i to destination j
$ELT_{i,j}$	The lead time for a empty shipment from origin i to destination j
$CAP_{i,j}$	The allowed capacity for the repositioning lane between origin i and destination j
RDH	Repositioning decision horizon
IH	Imbalance horizon
$R(j\|i, t)$	Ratio of orders originating from origin i at time t demanded to be transported to region j
$q_{i,j,t}$	Accepted demand of lane i, j at time t
$TCA_{i,t}$	Tank Container Availability (TCA) at the start of period t in region i
$TCAI_{i,t}$	The TCA and the import available for the exports in period t at region i
$TCAD_{i,t}$	The TCA after the demand has been fulfilled at time t for region i
$S_{i,t}$	The shortage of tank containers defined at time t for region i

$A_{i,t}$	The surplus of tank containers defined at time t for region i
$r_{i,j,t}$	Repositioning quantities from region i to region j at time t
$TCADR_{i,t}$	The TCA after the demand and repositionings have been fulfilled at time t for region i
run	Index for the run number
R	The total number of runs to be simulated
P_{run}	The profit generated by the tank container flows in the network for current run
s	Index for the scenario simulated
SC	Total set of scenarios to be simulated
a	Index for the strategy simulated on the scenario
AC	Total set of strategies to be simulated on the scenarios
$E[P_s]$	The total expected profit of scenario s
$E[P_{a,s}]$	The total expected profit of scenario s using strategy a
$E[D_s]$	The expected amount of total units of potential demand in scenario s
$E[D_{a,s}]$	The expected amount of total units of potential demand in scenario s, using strategy a
$E[PU_{a,s}]$	The expected profit per unit adjusted by using strategy a on scenario s

4.3 Simulation model

The proposed model considers a transportation network with N number of nodes and $2 \cdot N^2$ directed arcs. The nodes represent the locations considered within the transportation network, that are linked by the arcs representing the tank container flows, referred to as lanes. Each of the lanes serves as a directed connection between two regions and is denoted by a combination of (i, j) in which i is the index for the origin and j the index for the destination. Any region in the network can be both an origin and a destination. Graphically, the network can be visualised as Figure 4.1, illustrating a network with four regions.

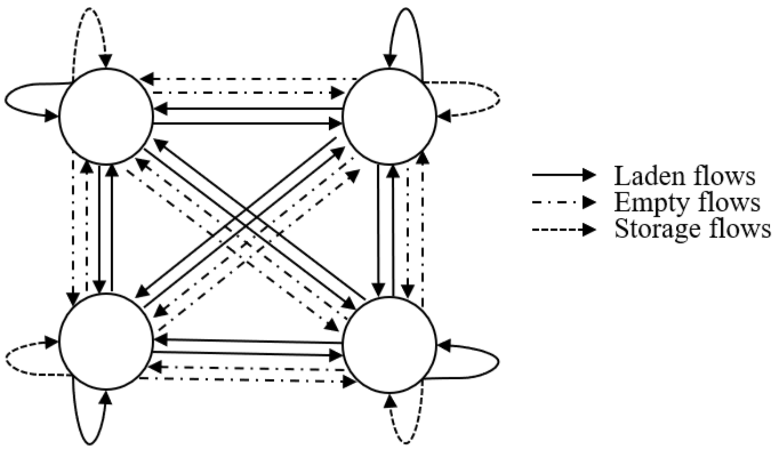


Figure 4.1: Network

First, it can be seen that there are twelve laden flows connecting the regions. These indicate a laden shipment between different regions as a result of a demand. There are equally as many empty flows connecting the regions in the network, indicating the repositioning shipments throughout the network. Furthermore, there are four so-called storage flows, that indicate that when a tank container is not selected for either a transport or a repositioning, the tank container remains in storage at the same region. Finally, there are four more laden flows indicating a shipment within a region. These are only the case when the level of aggregation of the network is on a higher level, i.e. there are multiple destinations combined into one region. When the aggregation level is on the lowest level, i.e. the regions are defined on port-level, then there are most likely no laden flows within the region and the corresponding flows can be eliminated from the figure.

For each lane that represents a laden flow, we consider a potential demand for transportation, for which we denote $d_{i,j,t}$ as the amount of potential demand for lane (i, j) at time t. Each unit of demand represents a single tank container transportation. The potential demand d is generated for the total simulation horizon $t = [1, T]$, with the use of the random number generator provided by Matlab, for which the required input consist of the parameters of the stochastic demand distribution, fitted to the demand scenario data.

Each demand is characterised with revenue elements based on its origin and destination. The first revenue element considered is the quoted network margin, denoted by $QNM_{i,j}$, and is generated for each laden movement on lane (i, j). The second revenue element is the quoted repositioning contribution, denoted by QRC_j, which is a contribution for the repositioning activities that might occur after a shipment towards destination j. The final revenue element is the quoted repositioning contribution, denoted by QRS_i, that is offered as a discount when the origin i, is a surplus region.

Besides the revenue elements that characterise a demand, a demand is also characterised by a transportation time based on its origin and destination. The transportation time of an order consists of the time it takes for the tank container to be retrieved from storage, the actual transportation time to transport the shipment from origin to destination, the expected demurrage time of a tank container at the destination, and the cleaning time of the tank container. Hence, it defines the total time starting from retrieving the tank container from origin i up until the moment the tank container is available again in destination j for the next demand to be executed. The transportation time for a laden transport, i.e. a demand, is denoted by $FLT_{i,j}$ (Full Lead Time). The transportation time determines after which amount of periods a tank container leaving origin i will be available, clean, and empty for fulfilment of demand in destination j.

A lane representing an empty flow is denoted by $r_{i,j,t}$. The amount of repositioning movements on lane (i, j), starting in period t are defined based upon the imbalances within the demand scenario, taking into account the characteristics of an empty shipment. The empty shipments are characterised by actual repositioning costs, denoted by $ARC_{i,j}$ and the lead times for an empty shipment, denoted by $ELT_{i,j}$.

To determine all tank container flows for a single run and the resulting profit generated by the movements, throughout all regions of the network during the entire simulation horizon, the following steps are repeated for each period during the simulation horizon:

1. Defining which orders will be accepted in the current period.
2. Simulating the tank container availability when executing all potential demand in the upcoming periods.
3. Calculating the surpluses and shortages as a result of executing all potential demand in the upcoming periods.
4. Determining the amount of repositioning movements required and feasible to solve the shortages.
5. Simulating the state of the the tank container availability of the current period, i.e. after executing the demand and the determined repositioning movements.

Each of the steps is explained below. The Matlab code of the simulation model may be found in Appendix B.

Step 1: Order acceptance

The simulation of the current period ($t = CP$) starts with a state indicating the amount of available, empty, and clean tank containers in each of the regions at the start of the period, denoted by $TCA_{i,t}$. Based on this starting state, we define if we are able to fulfil all potential demand in the current period by considering whether the starting state and the expected import of laden and empty containers in the current period is sufficient to fulfil all potential demand of the current period. If we are able to fulfil all potential demand, we say $q_{i,j,t}$ is equal to $d_{i,j,t}$. If we are unable to fulfil all the potential demand, we need to reject orders and $q_{i,j,t}$ will be smaller than $d_{i,j,t}$.

In the latter case, we need to determine the amount of orders that can be accepted in region i. To do so, we first calculate the ratio of containers that would end up in destination j when it originates from i in the current period, when all potential demand would be accepted. We refer to this as the ratio of demand originating from region i with destination j at time t, denoted by $R(j|i,t)$. This ratio is calculated using Equation 4.1. Then, we need to determine the amount of tank containers available for demand originating from region i in the current period, denoted by $TCAI_{i,t}$. We calculate this using Equation 4.2, in which the available tank containers at the start of the current period are summed with the import of laden and empty tank containers during that period. The accepted orders are then defined by combining the input of the previous two calculations, and is calculated as defined in Equation 4.3.

$$R(j|i,t) = \frac{d_{i,j,t}}{\sum_{j=1}^{N} d_{i,j,t}} \qquad \forall i,j \in N \qquad (4.1)$$

$$TCAI_{i,t} = TCA_{i,t} + \sum_{j=1}^{N} q_{j,i,t-FLT_{j,i}} + \sum_{j=1}^{N} r_{j,i,t-ELT_{j,i}} \qquad \forall i \in N \qquad (4.2)$$

$$q_{i,j,t} = \begin{cases} \lfloor TCAI_{i,t} R(j|i,t) \rfloor & \text{when } \mathrm{TCAI}_{i,t} < \sum_{j=1}^{N} d_{i,j,t} \\ d_{i,j,t} & \text{otherwise} \end{cases} \qquad \forall i \in N, j \in N \qquad (4.3)$$

Step 2: Tank container availability after demand (TCAD)

Next, the state of available tank containers after execution of the potential demand is simulated, for each period during the entire imbalance horizon, denoted by $TCAD_{i,t}$. The imbalance horizon, denoted by IH, is a rolling horizon describing the period $[t, t + IH]$, during which the expected imbalances are considered. If during this period, a region is expected to have a shortage of tank containers, no tank containers will be repositioned from that region even if there would be a surplus of tank containers at the current period. This prevents the constant back and forth repositioning of tank containers. To define the TCAD of the current period, the known import of laden and empty tank containers of the current period is added to the starting state, and the export of accepted orders and repositioning movements is subtracted, as shown in Equation 4.4. For the remaining periods of the imbalance horizon, the $TCA_{i,t}$ is set equal to the availability after demand of the previous period, $TCAD_{i,t-1}$. Then, the TCAD for the periods $[t + 1, t + IH]$ is determined in the same manner, except the demand simulated is the potential demand instead of the accepted demand, as it is assumed not yet to be known which demand is accepted. This is calculated accordingly to Equation 4.5.

$$TCAD_{i,t} = TCA_{i,t} - \sum_{j=1}^{N} q_{i,j,t} - \sum_{j=1}^{N} r_{i,j,t} + \sum_{j=1}^{N} q_{j,i,t-FLT_{j,i}} + \sum_{j=1}^{N} r_{j,i,t-ELT_{j,i}} \qquad \forall i \in N \qquad (4.4)$$

$$TCAD_{i,t} = TCAD_{i,t-1} - \sum_{j=1}^{N} d_{i,j,t} + \sum_{j=1}^{N} d_{j,i,t-FLT_{j,i}} + \sum_{j=1}^{N} r_{j,i,t-ELT_{j,i}} \qquad \forall i \in N \qquad (4.5)$$

Step 3: Calculation surplus and shortage

The shortages and surpluses of all regions for the current period are determined based on the simulated $TCAD$ at the end of the repositioning decision horizon, denoted by RDH. The repositioning decision horizon is a rolling horizon representing the period $[t, t + RDH]$, for which the shortages and surpluses are calculated, and serves as input for the repositioning decision. When the $TCAD$ is less than zero at the end of the RDH, a shortage of tank containers occurs, as there is an insufficient amount of tank containers available to fulfil all potential demand. The shortage of tank containers in each region i at the current period is denoted by $S_{i,t}$ and is calculated using Equation 4.6.

$$S_{i,t} = \begin{cases} |TCAD_{i,t+RDH}| & \text{when } TCAD_{i,t+RDH} < 0 \\ 0 & \text{otherwise} \end{cases} \qquad \forall i \in N \qquad (4.6)$$

For the regions in which the $TCAD$ in RDH is positive, we say a surplus of tank containers exists. In this situation, there is an excess capacity of tank containers available in the region to fulfil the potential demand and we denote the surplus by $A_{i,t}$. However, in order to prevent the repositioning of empty containers back and forth between two regions, we only consider the surplus to be actually available when the amount of tank containers is a positive number, during the entire imbalance horizon. The surplus of the tank containers is calculated using Equation 4.7.

$$A_{i,t} = \begin{cases} min\{TCAD_{i,t} : TCAD_{i,t+RDH}\} & \text{when TCAD}_{i,t:t+IH} > 0 \\ 0 & \text{otherwise} \end{cases} \qquad \forall i \in N \qquad (4.7)$$

Step 4: Repositioning decision

After the surpluses and shortages of the current period are determined, the required repositioning movements $r_{i,j,t}$ can be defined. The repositioning decision is based upon the classical transportation problem, in which the demand of the destinations has to be fulfilled by the supply of so-called sources, with a minimum amount of costs. It is assumed that when a repositioning should take place, it is aimed to reposition only the number of necessary containers, with the least amount of repositioning costs, denoted by $ARC_{i,j}$. Thus, for the repositioning decision, the shortages need to be covered by the surpluses with the smallest amount of repositioning costs possible. To ensure the simulation model does not stop when no feasible solution can be found, we added a dummy source that will be chosen to fulfil the shortage when no feasible option exists.

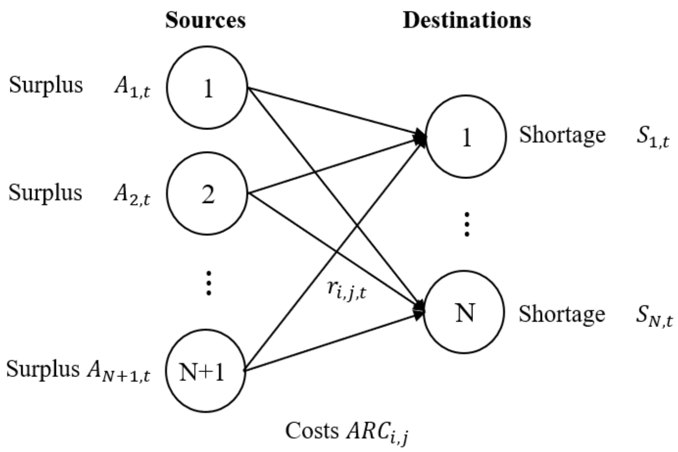


Figure 4.2: Network representation of the repositioning problem

Figure 4.2 on the facing page visualises this transportation problem for the repositioning decision, with source $N+1$ representing the dummy source. This dummy source has an unlimited amount of available tank containers, but comes with an extraordinary amount of costs ($ARC_{N+1,j} = \infty, \forall j \in N$), thus will only be chosen when no other option exists. When this dummy source is chosen, repositioning movements will be treated as unfeasible and will not be executed.

The repositioning calculation, formulated in Equation 4.8, chooses the repositioning movements that minimise the costs, without violating any of the constraints. The first constraint, Equation 4.10, defines that the total out-going repositioning flows of a region should be smaller or equal to the surplus of that region. The second constraint, Equation 4.11, defines that the import of repositioned tank containers into a region should be equal to the shortage of the region. The third constraint, Equation 4.12, defines that the amount of repositionings that occur on a lane cannot be larger than the capacity the repositioning lane is limited to, denoted by $CAP_{i,j}$. Finally, the amount of repositionings can never be negative, as is defined by the constraint in Equation 4.13.

$$min \sum_{i=1}^{N+1} \sum_{j=1}^{N} ARC_{i,j} r_{i,j,t} \tag{4.8}$$

$$\text{subject to:} \tag{4.9}$$

$$\sum_{j=1}^{N} r_{i,j,t} \leq A_{i,t} \qquad \forall i \in \{1, ..., N+1\} \tag{4.10}$$

$$\sum_{i=1}^{N+1} r_{i,j,t} = S_{j,t} \qquad \forall j \in N \tag{4.11}$$

$$r_{i,j,t} \leq CAP_{i,j} \qquad \forall i \in \{1, .., N+1\}, j \in N \tag{4.12}$$

$$r_{i,j,t} \geq 0 \qquad \forall i \in \{1, .., N+1\}, j \in N \tag{4.13}$$

Step 5: Tank container availability after demand and repositioning (TCADR)

When the repositioning movements of the current period are defined, the tank container availability of all regions, after the demand and repositioning activities are executed, can be calculated. This tank container availability is the end-state of the current period, denoted by $TCADR_{i,t}$, and calculated using Equation 4.14.

$$TCADR_{i,t} = TCAD_{i,t} - \sum_{j=1}^{N} r_{i,j,t} \qquad \forall i \in N \tag{4.14}$$

Furthermore, this end-state $TCARD_{i,t}$ of the current period serves as the starting state of the next period, $TCA_{i,t+1}$, as shown in Equation 4.15.

$$TCA_{i,t+1} = TCADR_{i,t} \qquad \forall i \in N \tag{4.15}$$

The previously described steps are repeated until the current period simulated is equal to the final period of the simulation horizon.

Profit calculation and strategy determination

At the end of the simulation horizon, the profit of the current run is calculated. This profit is defined by multiplying the quoted network margin and the quoted repositioning provision with the amount of demand accepted, subtracted by the multiplication of the repositioning costs with the defined repositioning activities, see Equation 4.16.

$$P_{run} = \sum_{t=1}^{T}\sum_{i=1}^{N}\sum_{j=1}^{N}(QNM_{i,j}q_{i,j,t} + QR_{i,j}q_{i,j,t} - ARC_{i,j}r_{i,j,t}) \tag{4.16}$$

We calculate the expected profit of the scenario as the average of the profits for each of the runs simulated for the scenario, for which the total number of runs is denoted by R, as seen in Equation 4.17.

$$E[P_s] = \frac{\sum_{run=1}^{R} P_{run}}{R} \tag{4.17}$$

For each of the scenarios, we test the impact of a set of strategies AC by adjusting demanded quantities corresponding to the formulated strategy, and running the simulation in exactly the same manner as described in previous sections. As it is unknown whether the total demand adjustment of the strategy can be achieved, we transform the results to the expected additional profit per unit of demand adjusted by the strategy, denoted by PU, which stands for profit per unit. The calculation of the PU of a strategy is shown in Equation 4.18, and is calculated for all scenarios SC.

$$E[PU_{a,s}] = \begin{cases} (E[P_{a,s}] - E[P_s])/(E[D_{a,s}] - E[D_s]) & \text{when E[D}_a\text{]} > E[D_s] \\ (E[P_{a,s}] - [P_s])/(E[D_s] - [D_{a,s}]) & \text{when E[D}_a\text{]} < E[D_s] \end{cases} \forall s \in SC, a \in AC \tag{4.18}$$

In which the following variables are identified:

- $E[PU_{a,s}]$: The expected profit per unit adjusted by using strategy a on scenario s.
- $E[P_s]$: The total expected profit of scenario s.
- $E[P_{a,s}]$: The total expected profit of scenario s, using strategy a.
- $E[D_s]$: The expected amount of total units of potential demand in scenario s.
- $E[D_{a,s}]$: The expected amount of total units of potential demand in scenario s, using strategy a.

We consider strategy a to be beneficial when the $E[PU_{a,s}]$ is positive for all scenarios $s \in SC$. The priorities for all strategies can be determined by defining $E[PU_a]$ as the minimum of $E[PU_{a,s}]$ for all scenarios $s \in SC$ of strategy a, as shown in Equation 4.19. By ordering the $E[PU_a]$ from largest to smallest, we prioritise the strategies from most to least beneficial.

$$E[PU_a] = min\{E[PU_{a,1}], ..., E[PU_{a,S}]\} \tag{4.19}$$

4.4 Model verification

The best method to validate whether a simulation model is designed correctly is to compare the simulated outcome with the real world data. Due to the absence of a validation data set, we verified the model using face validity and extreme condition tests. The first category is a verification method in which the input-output relationships of the model are asked to be logical and reasonable. This method is frowned upon as it is a subjective method, but is considered to be helpful when there is no prototype system for testing available. For validation purposes of the proposed model, we found no such validation prototype system. The second method is a verification method as well, for which extreme cases of unlikely combinations are tested and the outputs are verified to be logical (Murray-Smith, 2015; Sargent, 2011). We determined the amount of runs to be 400 by simulating the base settings $\{100, ..., 700\}$ times and calculating the differences between the outputs of two consecutive amount of runs. When difference between the expected profit compared to the expected profit of the previous amount of runs was found to be less then 1%, the amount of runs was determined. The remaining base settings created for the parameters, variables, and the adjustments of both verification methods can be found in Appendix C.

4.4.1 Face validity

First, we verified the model by adjusting the input variables and parameters of a test set of data. To asses the correctness of the model, we determined whether the changes in the output are logical. The following listing shows the adjusted variables and describes the expected change within the output variables as a result of the adjustments.

- *Imbalances*
  We expected that by decreasing the imbalances less repositioning movements would be required and thus the repositioning costs would decrease as well. As a result, we assumed the expected profit would increase. Using similar reasoning, by increasing the imbalances, more repositioning movements and costs would be required and thus the expected profit would decrease.

- *Laden lead time (FLT)*
  By decreasing the lead time of the laden transports, we expected that the repositioning cost would decrease as the turnaround of demands per tank container would be larger during the simulation horizon. As a result of higher turnaround, lesser repositioning movements would be necessary and thus the costs would decrease, and the profit would increase. In the case the lead time of the laden transports would increase, we expected the opposite to happen.

- *Empty lead time (ELT)*
  We expected that decreasing the lead times of the empty movements would lead to more options for repositioning movements, as more lanes would be within the repositioning decision horizon. Thus, the cost for the actual repositioning movements would be expected to decrease, and therefore profit would increase. We expect the opposite for an increase of the empty lead times, as there would be less feasible repositioning movements to choose from.

- *Actual repositioning costs (ARC)*
  We expected that by adjusting the actual repositioning costs, the profit would be influenced, as it is said that all demand that could be fulfilled, should be fulfilled and therefore no feasible repositioning movements would be declined. Thus, when the repositioning cost increase, the profit is expected to decrease and vice versa.

- *Quoted network margin (QNM)*
  The model is set up to accept all the demand regardless of the quoted network margins of the demands. Therefore, by adjusting the quoted network margins we expected a direct effect on the profit. By increasing the margins we expected an increase of the profit, and by decreasing the margins we expected a decrease of the expected profit.

Table 4.2 on the following page shows the ratios for the adjustments on the profit and demand, compared to the base version without adjustments. For the order acceptance and the repositioning ratio, the actual values generated by the model are shown.

All expectations listed previously are confirmed by the data, except for the adjustment 'ELT increased'. We expected the increase of the lead time of the empty movements to lead to a decrease in the profit. However, it led to an increase of the profit. This is explained by the decrease in the order acceptance and the repositioning ratio. Due to the longer repositioning lead times, less repositionings were feasible within the repositioning decision horizon. Therefore, suggested

Table 4.2: Face validity verification

Verification	Profit	Demand	Order acceptance	Repositioning ratio
Base version	100,0%	100,0%	100,0%	2,8 %
Imbalance decreased	103,0%	99,9%	100,0%	11,0 %
Imbalance increased	88,0%	100,9%	100,0%	0,7%
FLT decreased	102,2%	100,0%	100,0%	1,1%
FLT increased	96,7/%	100,1%	100,0%	5,3%
ELT decreased	101,0%	100,0%	100,0%	2,8%
ELT increased	103,3%	100,1%	97,9%	0,0%
ARC decreased	101,9%	100,0%	100,0%	2,8%
ARC increased	98,1%	100,0%	100,0%	2,8%
QNM decreased	74,8%	100,1%	100,0%	2,8%
QNM increased	125,3%	100,0%	100,0%	2,8%

repositioning movements could not have been executed and orders had to be declined. As a result of lesser accepted demand, no repositioning movements were required and therefore less costs occurred and the profit increased. Hence, though not the result anticipated upon, it is a logical result and therefore the model is verified to behave as designed.

4.4.2 Extreme condition tests

The listing below shows the extreme conditions tested to verify whether the output of the model is logical.

- No demand on any of the lanes.
- Extreme demand for only the exporting lanes of region 1.
- Repositioning lane capacity limited to zero for all lanes.
- Repositioning costs equal to zero for all lanes.
- Quoted network margin equal to zero for all lanes.

Table 4.3 shows the outcome of the model based on the extreme condition tests. It shows the ratios for the adjustments as compared to the base version for the profit and the demand. For the order acceptance and the repositioning ratio, the actual values generated by the model are shown.

Table 4.3: Extreme condition model verification

Condition	Profit	Demand	Order acceptance	Repositioning ratio
Base condition	100,0%	100,0%	100,0%	2,8%
No demand	0,0%	0,0%	0,0%	0,0%
Extreme demand	82,7%	365,3 %	44,8%	78,6%
No repositioning allowed	103,1%	100,0%	97.8%	0,0%
No repositioning costs	103,7%	100,0%	100,0 %	2,8%
No QNM	49,2%	99,9%	100%	2,8%

In the condition of no demand, the model did not generate any demand and profit, no orders were accepted and thus no tank containers were repositioned, as would expected when no demand occurs. The demand only exporting out of one region increased the repositioning ratio considerably, which would be expected if no import towards the location occurs. The elimination of repositioning movements decreased the order acceptance which can be explained by the repositioning ratio being zero. Setting the repositioning cost equal to zero had only slightly increased the profit, which can be explained by the repositioning ratio being relatively low in the base settings. Finally, setting the quoted network margin to zero decreased the profit by approximately 50%. All results indicate that even in some extreme, unlikely, conditions, we found the model to behave logical.

Chapter 5

Case study

The current chapter provides an answer to two of the research questions. First, *what is the current profit generated?* And secondly, *which profit improvements can be achieved by implementing a price elasticity of demand based strategy?* In order to provide the answers to these questions, we conducted a case study that is simulated using the proposed model. In Section 5.1, the set up of the simulation model for the case study is discussed. The outcome of the simulation of the case study is provided in Section 5.2, as well as the robustness of the outcome, the sensitivity of the model, and a discussion of the outcome. Due to confidentiality of the data, we cannot share the exact profit calculated, nor are we able to share the profit improvements calculated. However, to still provide an answer to both questions, we refer to ratios that reflect the expected profit improvements of the simulated strategies.

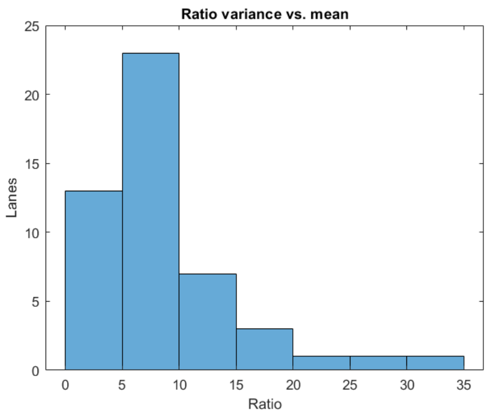
5.1 Model set up

The set up of the model consists of the distribution fit for the demand, the formulation of the scenarios and the strategies to be tested, the remaining input variables, parameters, and the starting state of the model.

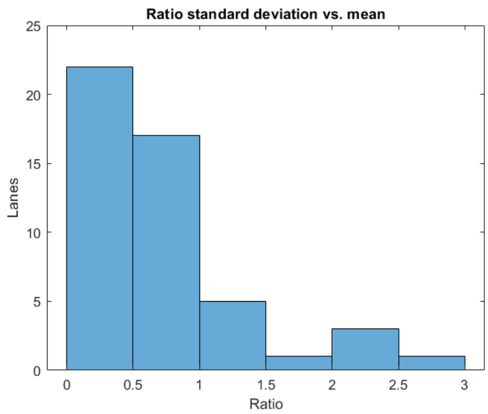
5.1.1 Distribution fit demand

To determine the best fit of the data, we incorporated all monthly executed orders for the Global Business Unit from the start of 2017 up until September 2018 in the data analysis. As it was considered to be a relatively short period of time for the removal of trend and seasonality, we chose not to attempt to identify those factors within the data. Further, we chose not to eliminate any of the outliers that might occur within the data, to ensure the stochastic behaviour of the demand is captured within the distribution. By eliminating outliers, it could either be that one removes mistakes in the data, but it might also be that one removes actual demand peaks that had taken place. We attempted to prevent the latter and thus we assumed data to be correct.

Based upon the literature review, we identified three distributions that are in general the best fit for demand data: the Poisson, normal and Gamma distribution. As the Poisson distribution has the characteristic that the mean and the variance of the distribution are equal, we first analysed whether this was the case. Figure 5.1a shows the ratio between the mean and the variance of the demand data, for each of the global region lanes. The histogram shows the amount of lanes that have a ratio inside each of the bins. By analysing the figure, we concluded that the largest portion of lanes have a ratio that is considerably larger than 1. In such cases, it is recommended to use the negative binomial distribution instead of the Poisson distribution. Next, as the demand can never be smaller than zero, using the normal distribution could come with some risk, as the distribution does not have a non-negativity property. Figure 5.1b on the facing page shows a histogram of the ratios between the standard deviation and the mean. It shows that approximately 20% of the lanes have a ratio equal to 1, or larger. For those lanes, using the normal distribution might come with a risk.



(a) σ^2/μ.



(b) σ/μ.

Figure 5.1: Ratio variance and standard deviation compared to mean

Finally, the Gamma distribution has the property that it only generates values that are larger than zero. Figure 5.2 visualises the amount of lanes that have a certain amount of periods with zero demand. It shows that approximately 20 of the 49 lanes have at least once had a period with zero demand. Based upon this figure, we concluded that the demand distribution had to be able to work with zero values as they cannot be ignored.

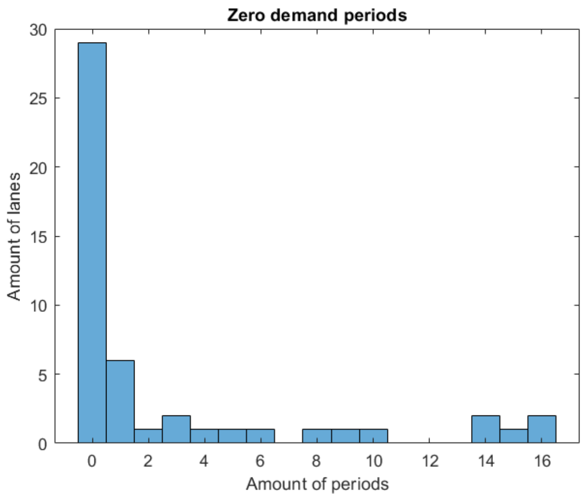


Figure 5.2: Demand lanes having periods with zero demand

Thus, we fitted the demand data on both the normal and the negative binomial distribution. The fits of the distributions on all lanes were evaluated with the Anderson-Darling method and the Negative Log Likelihood (NLL) test, as described in the literature review.

Figure 5.3 shows the performance of the distribution fit on the NLL. As the aim is to minimise the NLL, the NLL test led towards the conclusion that the negative binomial distribution fits slightly better than the normal distribution. However, the Anderson-Darling test provided the opposite conclusion; the distribution fit was rejected for 7 out of 49 lanes for the negative binomial distribution and only for 5 out of 49 lanes for the normal distribution. As the performance is considered to be relatively similar and the normal distribution is considered to be easier to use, the normal distribution will be used in the simulation model to generate the demand data.

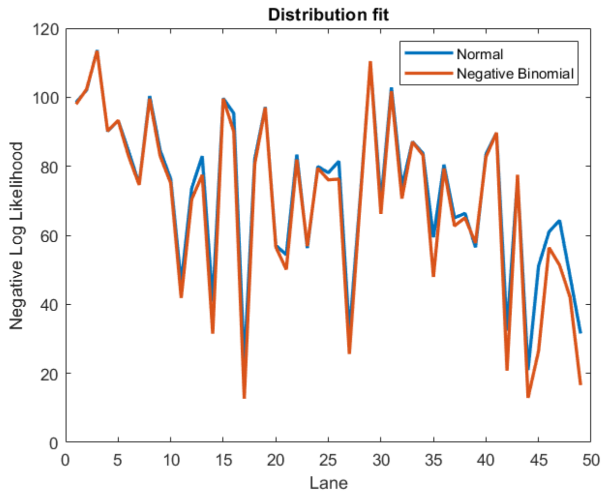


Figure 5.3: Performance distribution fit

5.1.2 Scenarios and strategies

The future is uncertain. Many economical and political events could influence the expectations for the future. We incorporated this uncertainty of the forecast in the case study by using multiple scenarios. To illustrate the practical applicability of the model, we developed three scenarios. One scenario is based upon the actual forecast of the demand, the remaining two scenarios are a worst- and best-case scenario based upon a single event that we identified to be of possible influence on the demand forecast.

All scenarios were ran to define the possible outcomes of the forecast, seen as the current situation. Furthermore, in order to determine in which region a pricing strategy would be most effective in terms of expected profit improvement, we tested 28 different strategies on all scenarios. Table 5.1 shows the explanation for all strategies.

Table 5.1: Explanation strategies

Strategy	**Explanation**
1 - 7	Stimulate import region 1 - 7 resp. with factor 1.2
8 - 14	Destimulate import region 1 - 7 resp. with factor 0.8
15 - 21	Stimulate export region 1 - 7 resp. with factor 1.2
22 - 28	Destimulate export region 1 - 7 resp. with factor 0.8

As the forecast of the demand consists of deterministic values, we analysed the coefficients of variation of the demand data of the period April 2018 up to September 2018. We used this data as this was the most recent data and therefore we considered it to be most realistic. We determined the coefficients of variation for multiple ranges of demand and incorporated these coefficients as input for the simulation model to determine the expected variation within the forecast.

5.1.3 Input variables

Amongst the input variables of the model, we identified the quoted network margin, the quoted repositioning contribution, the quoted repositioning savings, the actual repositioning costs, the lead time for the laden shipments, and the lead time for the empty shipments. All mentioned input variables for the model are stochastic by nature, but assumed to be deterministic to define which change in profit is a result of demand adjustments. To define the deterministic values required as input for the simulation model, weighted averages were calculated for each combination of origin i and destination j. The data used for the determination of the elements is based on the orders executed in between April 2018 up to September 2018, to ensure the data reflects the most recent numbers and is thus seen as the most realistic for the scenario analysis.

For the laden lead times, as written in the assumptions section, we assumed that all tank containers are clean after delivery. Thus, for each of the lead times, we added an additional seven days to take into account this cleaning process. The demurrage time was already incorporated as the lead time is defined by the loading date of the tank container at the origin and the return date for the tank container after delivery at destination. Furthermore, for all lead times, laden and empty, data was aggregated to the monthly time periods for the simulation model. This was done by dividing the average lead time for each combination of origin i and destination j by 30 and rounding up to the nearest integer.

5.1.4 Parameters

The parameters required for the simulation model consist of the length of the simulation T, the number of regions N, the repositioning decision horizon RDH, the imbalance horizon IH, and the number of runs R that are required.

- We set the simulation horizon T equal to the periods for which demand is forecasted, as this forecast of the demand will be used as input for the simulation model. Hence, T is set equal to 9.
- The number of regions N for the case study was set equal to the amount of global regions distinguished within the network. Hence, the amount of regions is defined as 7.
- We determined the number of runs R by simulating the scenario $\{100, 200, \cdots\}$ amount of times, and comparing the difference between the output of the model with the previous amount of runs. When the maximum difference between the output elements was considered to be small enough ($< 1\%$), we determined the amount of runs. The output elements consisted of the repositioning ratio, the demand generated, and the expected profit generated. The simulation with 600 runs is the first for which the maximum difference on all elements as compared to the previous amount of runs (in this case 500) is less than 1%. Hence, the amount of runs is set equal to 600.
- And finally, we determined the parameters RDH and IH by simulating each set of parameter combinations. The settings that best resembled the repositioning ratio of historical data were chosen. We established that during 2017, the overall repositioning percentage was 4,27% and during that time the global imbalance represented 4,4% of the demand. Thus, the repositioning percentage was 97% of the imbalance ratio. Hence, we decided that any repositioning ratio with a maximum of 3% deviation from the imbalance ratio is acceptable. Based on the forecast data, we defined that the imbalance is 6,83% of the demand, and thus the repositioning ratio was considered to be acceptable if it was within range 6,63% to 7,03%. We identified two combinations of settings with the repositioning ratio within the acceptable range, as can be seen in Table 5.2 on the following page. The settings $RDH = 2$ and $IH = 3$ are considered to be most similar to the imbalance percentage, and therefore those settings were chosen.

Table 5.2: Settings RDH and IH repositioning ratio

RDH	IH	Repo ratio
1	1	6,14%
1	2	6,02%
1	3	5,79%
1	4	5,51%
2	2	7,08%
2	3	6,91%
2	4	6,60%
2	5	6,68%

5.1.5 Starting condition

The starting condition of the model consists of the amount of tank containers $TCA_{i,t}$ that are empty clean and available at the start of time $t = 1$, in each region i, and the amount of laden and empty tank containers that are not available at the start due to demand fulfilment or empty repositioning, referred to as WIP to destination j. The WIP consists of tank containers that are on demurrage at the destination, tank containers that have been pre-loaded but are still at point of origin, laden tank containers that are currently on the move to their destination, and empty tank containers that are currently being transported to their destination. For the tank containers that were being transported empty, it was known when the tank container would be available at the point of destination. For the remaining laden flows, it was not known yet, as each order could still have some demurrage time. It is not known beforehand if and for how long a customer will keep the tank container at demurrage at the point of destination, as this is often used as a stock keeping method. To define when the laden WIP of tank containers will most likely become available again, an assumption was required to be made on the lead time.

As indicated in the literature review, the lead time data can reasonably be fitted to the normal distribution, or to a distribution that has the property that it does not generate negative numbers, such as the log-normal, Gamma and Weibull distribution. For each region, we fitted all mentioned distributions on all lead time data towards all regions. For the Negative Log-Likelihood test, all distribution fits scored relatively the same. Based on the score on the Anderson-Darling test, we concluded that for all 49 lanes, the fit is accepted 17 times for the normal distribution, 26 times for the log-normal distribution, 25 times for the Gamma distribution and 17 times for the Weibull distribution. Therefore, we defined the availability of the laden WIP using the log-normal distribution. We defined that the smallest lead time to occur was only one month and the longest seven. As for the WIP orders, solely the point of destination was known. Thus, for each lead time distribution fit to destination j, we defined the probability that the lead time would be equal to 1 up to 7 months using the estimated parameters. We denote this probability as $P(FLT = x|j)$, in which $x = \{1, ..., 7\}$. Thereafter, all WIP to j, denoted by WIP_j, was defined by summing the tank containers on demurrage, the orders currently being transported and the orders on pre-load. We calculated the import of the tank containers at each time t, for each region j, using Equation 5.1.

$$I_{t,j} = WIP_j * \frac{\sum_{x=t}^{7} P(LT = x|j)}{\sum_{p=1}^{7} \Big(\sum_{x=p}^{7} P(LT = x|j) \Big)} \qquad \forall t = \{1, ..., 7\}, j \in N \qquad (5.1)$$

5.2 Model outcome

In order to provide the results of the case study, the expected profit per unit is defined as a ratio, named profit ratio per unit (PRU), as it entails classified information. Therefore, we rewrote the formula to calculate the $E[PU_{a,s}]$ into Equation 5.2, and calculated the outcome for all scenarios $s \in SC = \{1, 2, 3\}$ and all strategies $a \in AC = \{1, 2, ..., 28\}$.

$$E[PRU_{a,s}] = \begin{cases} (E[P_{a,s}]/E[P_s] - 1)/(E[D_{a,s}]/E[D_s] - 1) & \text{when } \mathrm{E}[\mathrm{D}_s] < E[D_{a,s}] \\ (E[P_{a,s}]/E[P_s] - 1)/(1 - E[D_{a,s}]/E[D_s]) & \text{when } \mathrm{E}[\mathrm{D}_s] > E[D_{a,s}] \end{cases} \quad \forall s \in SC, a \in AC \tag{5.2}$$

For which we identified the following variables:

- $E[PRU_{a,s}]$: The expected profit ratio per unit of scenario s using strategy a.
- $E[P_s]$: The expected profit of scenario s.
- $E[P_{a,s}]$: The expected profit of scenario s using strategy a.
- $E[D_s]$: The expected amount of total potential demand of scenario s .
- $E[D_{a,s}]$: The expected amount of total potential demand of scenario s using strategy a.

As it is uncertain which scenario is most likely to occur, we considered only the strategies that led to an increase in the profit for all scenarios as a beneficial strategy. For the case study, we identified seven beneficial strategies. As described in the model formulation, to define priorities within the strategies, we calculated the expected increase on the profit per unit. Table 5.3 shows the ratios that reflect the profit per unit for the strategies expected to increase the profit for all scenarios. They are sorted accordingly the minimum PRU found for each strategy.

Table 5.3: Set of positive $E[PRU_{a,s}]$ case study

a	$s = 1$	$s = 2$	$s = 3$
8	4,80	4,83	5,51
2	4,90	4,59	5,45
15	4,50	4,84	4,83
4	5,33	3,68	6,01
23	2,40	2,50	2,48
25	2,05	1,32	2,37
27	1,74	0,21	0,83

5.2.1 Robustness of the outcome

As described previously, the demand input variables are uncertain. Thus, besides considering three different scenarios, we also ran each combination of scenario and strategy 600 times, using random numbers based on the normal distribution parameters. As such, the outcome of the model is a stochastic variable, based on the outcome of all runs generated. For the decision-maker to determine which strategy is most beneficial, this stochasticity needs to be incorporated. To determine whether the minimum $E[PRU_{a,s}]$ of all scenarios is a solid indicator for determining the strategy to be beneficial, we calculated the PRU in the same manner for the 95% confidence range minimum and maximum. The minimum $E[PRU_{a,s}]$ for each strategy of all scenarios for both extremes is shown in Table 5.4 on the next page.

Following the uncertainty in the outcome, we conclude that for the recommendation based on the $E[PRU_{a,s}]$, all strategies except one are found to be robust. Based on solely the expected

Table 5.4: 95% Confidence interval

a	**min**	**max**
8	9,73	1,87
4	3,38	3,83
2	7,55	3,06
15	7,18	3,12
23	4,05	1,30
25	1,04	1,19
27	0,92	-0,17

outcome, we identified strategy 27 as a positive outcome as well, though based on the robustness check, we would not recommend this strategy. However, we found this to be the worst performing strategy of all beneficial strategies, and hence we it would be unlikely that this strategy be chosen amongst all other strategies recommended. Therefore, we concluded that basing the strategy on the minimum $E[PRU_{a,s}]$ is considered to be a robust strategy.

5.2.2 Sensitivity of model

In order to determine the impact of certain parameter settings on the results of the simulation, different parameter settings were varied using one-way sensitivity functions. One way sensitivity functions determine the outcome when parameters are set differently one at the time (Borgonovo, 2017). We tested the repositioning method, the WIP starting condition, the Repositioning Decision Horizon, the Imbalance Horizon and the Repositioning Lane Capacity. The impact on the outcome of the model is determined on the base scenarios without any strategy and calculated by dividing the expected profit generated using the adjusted settings by the expected profit generated using the base settings.

Repositioning methodology

We assumed that the repositioning movements are the repositioning movements that come with least costs and maximise the amount of demand that can be fulfilled. To determine the sensitivity of the outcome towards the method of determining repositioning movements, we examined a different methodology. This methodology does not aim to minimise the costs of the repositionings solely, but considers the expected revenue generated by the laden movements after the repositioning movements as well. Therefore, the costs of the repositionings minus the expected profit of the to be fulfilled demand is aimed to be minimised. Table 5.5 shows a minor difference between the two repositioning policies. We concluded that changing the repositioning policy from solely taking into account the repositioning costs to the repositioning cost plus the expected profit does not seem to have any effect on the outcome of the simulation model.

Table 5.5: Impact repositioning rule

Scenario	**Ratio**
1	0,999
2	1,003
3	1,000

WIP starting condition

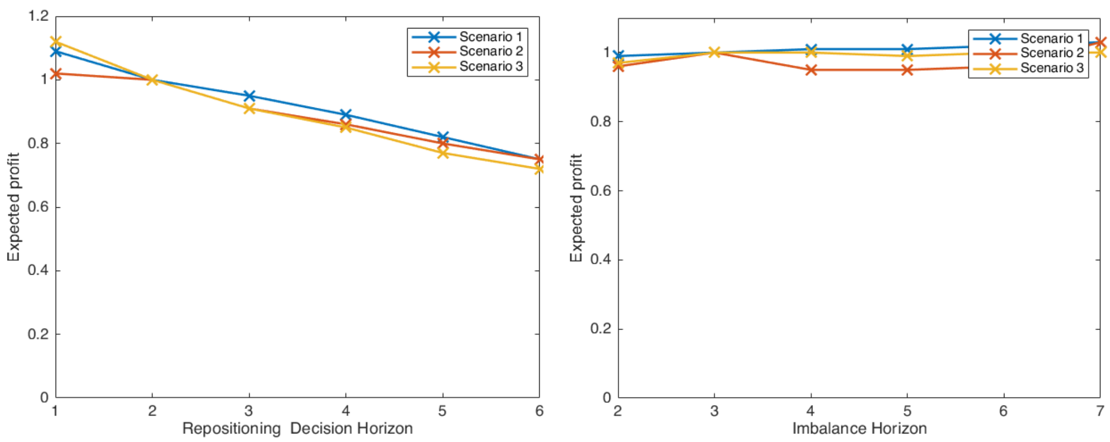
The WIP starting condition was based on the analysis of the data of the lead time of a job. We defined that the laden lead time data follows a log-normal distribution. Based on this knowledge and the calculated parameters, we defined the starting condition. In the case that the analysis of past data does not comply with the future, we compared the outcome of the model with a uniform distributed starting condition, i.e. the import of the WIP has an equal share in each period. Table 5.6 shows that the correctness of the import of the WIP could have a large contribution on the outcome of the model, as it adjusted the outcome with 23,6% to 33%.

Table 5.6: Impact WIP starting condition

Scenario	Ratio
1	1,262
2	1,236
3	1,330

Repositioning Decision & Imbalance Horizon

We defined the RDH and IH to be correct when the repositioning ratio resembled the imbalance ratio. In case that these settings, based on historic data, do not match future endeavours, several settings ($RDH = \{1, .., 6\}$ and $IH = \{2, ..., 7\}$) were tested. The results of the RDH variations are shown in Figure 5.4a and the results of the IH variations in Figure 5.4b. We conclude from the graph that the IH has only limited effect upon the outcome. Therefore, the outcome is only expected to be sensitive towards the formulation of the RDH.



(a) RDH

(b) IH

Figure 5.4: Impact RDH and IH parameter settings

Repositioning Lane Capacity

We designed the model to execute all demand when possible. However, the decision-maker can decide to put constraints on the amount of repositioning movements allowed to be carried out on a specific lane, i.e. the repositioning lane capacity. Therefore, we ran the model with the following limitations on the repositioning capacities of lanes:

- For region 1,2 and 3, the amount of out-going repositionings allowed were limited to only 10% of the laden tank container import of the corresponding period to that region.
- Region 4 was restricted to only reposition towards region 3 and 7. For those lanes, no restrictions were set on the amount of repositionings allowed.
- Region 5 and 6 are limited to solely reposition towards each other.

Table 5.7 shows the impact of the Repositioning Lane Capacity constraints on the expected profit.

Table 5.7: Impact Repositioning Lane Capacity Constraints

Scenario	Ratio
1	1,312
2	1,299
3	1,413

The ratios in the table show that the formulation of the repositioning constraints has a large impact on the expected profit generated by the simulation model. Hence, it is important that the limitations of the repositioning movements are correctly defined to reflect reality.

5.2.3 Discussion outcome

The proposed model acts as a decision-making support tool in the tactical process of determining the market corrections. The main value of the model is that it combines the relevant decision elements in a dynamic approach, such that the upstream effect of a strategy is captured. It provides support in defining which strategies are beneficial, and prioritising those. Results further indicated that 'solving' the imbalances does not necessarily leads towards an increase of the profit, indicating the importance of taking the upstream effect into consideration. Though it is designed to support the pricing process, the model could also provide guidance for demand acceptance decisions. By running the demand forecast with and without the demand to be decided upon, it could serve as an indicator that defines whether accepting the demand has a positive effect upon the profit generated by the network. Another application could be to define the expected impact of adjusting the Repositioning Lane Capacities that limit the amount of repositionings allowed.

The fall-back of the approach is that the creation and running of the scenarios and possible strategies is time-consuming. Thus, we defined whether the dynamic approach yields better results than a static approach. For the static approach, we used the model of Gorman (2001, 2002) to define repositioning movements, as its situational context resembles most to the case study. Based on the average demand matrices generated for the simulation model, the repositioning movements were calculated using the equations proposed by Gorman (2001), as shown in Equation 5.3 and 5.4. The equation aims to solve the imbalances with the minimum amount of costs.

$$TRC = \sum_i \sum_j RC_{ij} R_{ij} \tag{5.3}$$

$$s.t. \sum_i R_{ji} - \sum_i R_{ij} = I_i \qquad \forall j \in N \tag{5.4}$$

Gorman (2001) identified TRC as the total repositioning costs, which are calculated by multiplying the amount of repositioning from i to j, denoted by R, with the cost of repositioning one unit from i to j, denoted by RC. The amount repositioned has to be equal to the imbalance in node i, denoted by I, and is calculated for all destinations j.

For the static model to be considered as a solid heuristic to replace the proposed model, the deviation between the expected profit calculated by both models cannot be larger than 5%, for each of the strategy-scenario combinations. Only 26 of the 87 combinations generated were found to be within acceptable range. For the static model to be found acceptable, all combinations should have been within range and therefore we considered the static approach not to be a solid heuristic for the simulation model. This indicates that incorporating the upstream-effect is an essential part of the decision-making process.

Chapter 6

Conclusions & Recommendations

This final chapter discusses the main findings of the report and provides an answer to the main research question of this thesis: *How may companies of tank container industry benefit from the price elasticity of their demand to improve their profit by influencing tank container flows?* Furthermore, it provides a discussion of the limitations of the study, possibilities for future research, and recommendations.

6.1 Main results

Based on the results of the survey distributed amongst the commercial department, we confirmed the expectation that a pricing strategy would be effective. The majority of the respondents indicated that the sales rate is by far the most important criteria of a potential customers' LSP selection. The analysis revealed that other demand triggering factors are service, transit time and reliability, and the relationship between the LSP and the potential customer. Furthermore, results implied that the financial performance of the LSP and the sustainability of the service do not take any part in the decision rule, unless competitors perform equally on all other criteria. Based on the responses, we expect the price sensitivity of customers to be substantial. Though we expected differences in price sensitivity of spot and tender customers prior to distributing the survey, we were unable to confirm these differences. Furthermore, a segmentation of the survey data over all global regions implied possible differences among price sensitivities of global regions. Due to skewed distribution of the target group over the global regions, this could not be statistically confirmed.

The evaluation of the profit structure revealed that not all elements usually incorporated in a profit calculation are required to determine the expected profit improvement of a pricing strategy. In general, the elements that are affecting the expected profit as a result of adjusting the demanded quantities are the gross profit margin of an order, the costs related to a repositioning of equipment, and the repositioning contribution charged on an order. Naturally, the elements may differ per situation.

To determine the impact that a demand adjustment has on the expected profit, we proposed a simulation model. The model aims to replicate the demand acceptance and the repositioning decisions based on a demand scenario. To incorporate the uncertainty of future events within the model, we formulated different scenarios, and for each scenario we varied the demand based on a distribution fit, for a predefined amount of runs. The model determines the expected profit generated for each scenario, and evaluates the performance of a set of strategies on all scenarios, by calculating the additional profit per unit adjusted by the strategies. Herewith, we are able to identify the strategies that are most likely to be profitable for each scenario, even when the demand adjustment is less than the adjustment simulated. This allows us to determine and prioritise the recommended strategies without quantifying the relationship between price and demand. Using this approach, one will most likely not be able to achieve its most optimum result. However, for all situations in which the non-price determinants are of large influence, or in situations in which a realistic assumption for the relationship between price and quantity is hard to obtain, it will result in an improvement of the profit. Based on the sensitivity analysis, we demonstrated that the decision-maker should take into account that the starting condition, the repositioning decision horizon and the repositioning lane capacity constraints are expected to have a considerable impact on the outcome of the model.

6.2 Limitations

In the following listing, we discuss the main limitations identified in this study.

1. We analysed the potential customers' LSP selection with a survey distributed amongst the commercial department of Den Hartogh Logistics. We assumed that customers would not be fully transparent on their decision process and that the commercial department gained considerable knowledge on the LSP selection procedure of potential customers. However, for several cases it is believed that the target group of the survey is too small to determine whether differences are statistically significant.

2. The data of the case study was aggregated to global regions on monthly time periods, for ease of computation and to limit the amount of time it takes to run the simulation. However, by the aggregation on global level, the repositionings within the global regions are ignored. The repositionings between global regions represent only a small portion of the repositioning movements in total. Furthermore, the aggregation level impacts the accuracy of the model input as well, as all variables are defined as weighted averages. We determined the weights based on historical data and therefore they do not necessarily reflect the weights that should be applied for the scenarios and strategies simulated.

3. All input variables and parameters were assumed to be deterministic, except for the demand. This assumption was required to be able to define which part of changes in the profit are a direct result of adjustments in the demand flows. As the elements are not deterministic by nature, the expected outcome of the model might differ from the actual results.

4. We assumed unfulfilled demand to be treated as lost sales, as we assumed that when an order is rejected, the customer would place their order at a competitor. However, it could be that demand is postponed instead of being rejected, and therefore the outcome of the model could slightly differ.

5. We did not take into account any differences within the fleet of tank containers as we assumed all fleet to be completely similar. In reality, many different characteristics can be identified. Incorporating the different characteristics of the tank containers within the model requires allocation rules and would increase the computational complexity of the model. Hence, the differences between the tank containers are neglected. However, in reality it could be that repositionings are needed because a shipment requires specific tank container characteristics, which could impact the outcome of the model.

6. Depot storing costs are assumed to be similar in each location to decrease computational complexity. In reality, the depot storing costs could have an effect on the location in which the empty tank containers are stored, but this is expected to only have an effect on lower aggregation levels.

7. Tank containers are assumed to be clean and empty after demand fulfilment. In reality, not all depots offer cleaning services and therefore repositionings could be required. As the case study is conducted on global region level, the assumption would not lead to a negative

impact on the model, as each global region is expected to have a cleaning facility. However, it could be of impact when the model is solved on a lower aggregation level.

8. We were unable to use real data to validate the model's ability to simulate the tank container flows. Thus, the model is verified using face validity and an extreme condition test. As such, there is a chance that it does not completely reflect reality.

9. Finally, to illustrate the applicability of the model, we simulated several strategies in the case study, that focused on one region at the time. We did not test any combinations between strategies, though in practice one may target multiple regions with its pricing strategy.

6.3 Future research

We identified four directions of future research, which are described in the following listing.

1. The proposed model simulates strategies aimed at the entire set of customers, and is recommended to be used as decision support tool in formulating price settings. For a pricing strategy to be most effective, it is recommended do use different strategies for different groups of customers. Future research in the direction of an extensive market analysis could be aimed at defining customer and/or demand characteristics, such that prices can be differentiated. Further market analysis aimed at estimating the price elasticity of demand, could be used to reformulated the demand as a function of the price, and redesign the model such that optimal price settings could be determined.

2. Reproducing the case study using smaller time units and a lower level of aggregation has a two-fold benefit. First, it improves the accuracy of the input variables. Secondly, the accuracy of the outcome is improved as the repositioning movements will be taken into account more accurately.

3. Elaborating the simulation model to cope with more demand types, the ability to back-order demand, different tank container types, depot costs, and the absence of cleaning facilities improves the applicability of the model in reality. Future research should determine which types of demand can be distinguished in the model, if a portion of the demand can be back-ordered in the case demand is rejected, which groups of tank containers can be distinguished, how the depot costs may be incorporated in the profit function and the repositioning decision, and how cleaning facilities can be taken into account. Furthermore, future research should investigate the impact of incorporating this level of detail on the accuracy and robustness of the model outcome and the model applicability.

4. To overcome the fallback of the time-consuming simulation model, future research to develop a heuristic that matches the outcome of the simulation model is recommended. This would allow the decision-maker determine the beneficial strategies much faster while still taking into account the upstream effect of a decision.

6.4 Recommendations

Based on the case study performed at Den Hartogh Logistics, several recommendations were identified:

1. An extensive market research is recommended. The results of the demand analysis show a possibility that different regions have a different sensitivity towards a market correction. An extensive market research is recommended to further investigate the regional differences, such that the strategies recommended by the model are not only prioritised by their profit increase, but also by the sensitivity of the demand in the region. Next, it offers the possibility to determine other influences. The weights that were assigned to the criteria by the respondents

were quite diverse, which indicates the differences between preferences are far more complex than the spot versus tender distinction. And finally, the demand analysis was performed using the estimate of the commercial department of their perception of the clients procedure. Incorporating different sources into the analysis could improve the outcome.

2. The market corrections are aimed to be balanced. Therefore, the same absolute value is applied for both the import and export flows of a region. The case study identified that the expected effect on the profit for solving an imbalance by targeting either the import or the export flow can differ considerably. Furthermore, some strategies aimed at solving the imbalances were found to have a negative impact on the profit, a there were strategies found to be beneficial that aimed to enlarge imbalances. Hence, it is recommended that market correction settings are made with the upstream effect of the simulation in mind and that different strategies and thus different price settings for each side of the imbalance are applied.

3. Different levels of aggregation should be tested to determine the optimum level to be simulated. It is recommended not to simulate on port-level, as the level of aggregation as well as the amount of scenarios incorporated have a negative impact on the simulation time. The more detail incorporated, the larger the amount of time required to obtain results. However, the level of detail should be increased as most repositioning movements occur within the global regions on which we scoped this study.

4. It is also recommended to follow-up on the research by investigating whether a heuristic that incorporates the upstream effect of a decision could be applied or developed. This would seriously decrease the amount of time required and increases the level of aggregation that can be incorporated.

5. Validate the correctness of the model as soon as enough data is gathered based on the new pricing model. Furthermore, simulate the model using this data to improve the outcome of the model.

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Appendix A

Survey

CUSTOMERS' LSP SELECTION METHOD

Hi!

Thanks for taking the time to fill in this survey.

The survey is divided into three parts:

1. The first part is simple, you just have to fill in your name. The reason for this question is two-fold. First, it offers me the opportunity to assign your answers to your markets and/or largest customers. And secondly, it offers me the possibility to contact you if any follow-up could be useful. It should be noted that there are no right or wrong answers.
2. The second part is aimed at identifying the importance of the sales rate relative to the other criteria that are part of a (potential) customers' logistics service provider (LSP) selection. The reason I say potential is that you are requested to also consider the preferences of the potential customer that has not chosen for Den Hartogh. You will be asked to assign weights to the criterias that might be relevant, both for spot and tender customers.
3. The last part is aimed at identifying the factors that are important within those criteria of a (potential) customers' LSP selection. You will be asked to rate the factors on a scale of not important until extremely important, also both for spot and tender customers.

Answering the questions should not take up more than**15 minutes** of your time. But before you do, I have **one important note**:
I realize that the answers to the question I'm asking you are complex: they are different in many different situations. However, please **do not overthink** the questions, and try to fill them in according to your**gut feeling on the average or most common behaviour of your (potential) customers.**

NAME

What is your name?

Please fill in both your first and last name.

ASSIGNING WEIGHTS TO CATEGORIES

You will be given a total budget of a **100 points to assign to each criteria**. The weight you assign must reflect your perception of the **importance** (the weight) of the criteria for the average (potential) customer in their **selection for a Logistics Service Provider** (LSP). First you will be asked to assign the 100 points over the criteria for the average (potential) spot customer. Thereafter, you will be asked to do the same for the average (potential) tender customer.

The following criteria descriptions are used:

- **Transit time and reliability**: the speed of the complete origin to destination (e.g. door-to-door) service provided by the LSP and the reliability of the promised speed (the on-time pick-up and deliveries).
- **Service**: consists of factors related to the characteristics of the LSP, the service provided and the customer service offered. The factors considered are: the size of the (tank container) fleet of the LSP, the level of safety provided, the certainty of availability of tank containers to fulfill the demands, the geographical coverage provided by the LSP, the availability of local representation, proactive fast responsiveness, and maintaining agreements & promises.
- **Sales rate**: the sales rate of the service.
- **Financial stability**: the financial performance of the LSP.
- **Sustainability**: the environmental impact of the services.
- **Relationship**: having a good, professional relationship with the customer and high level of professionalism of sales personnel.

SPOT customer

Please distribute 100 points over the following criteria, reflecting the importance of the criteria in a spot customers' LSP selection:

Transit time and reliabiliy

Service

Sales rate

Financial stability

Sustainability

Relationship

TENDER customers

Please distribute 100 points over the following criteria, reflecting the importance of the criteria in a tender customers' LSP selection:

Transit time and reliabiliy

Service

Sales rate

Financial stability

Sustainability

Relationship

IMPORTANCE OF FACTORS

Importance of factors for SPOT customers

Below you find for four of the criteria of the previous question a list of factors that a customer might take into consideration within this citeria, when selecting a LSP. Please list how important you believe those factors are to your (potential) average **SPOT customer** in their LSP selection. To do so, please check the corresponding box, varying from not important to extremely important.

Service factors

	Not important	Slightly important	Moderately important	Important	Extremely important
A high level of safety offered by the LSP	◯	◯	◯	◯	◯
The certainty of availability of tank containers; to be able to meet demand as promised	◯	◯	◯	◯	◯
A large fleet size of tank containers	◯	◯	◯	◯	◯
A large, geographical coverage of the network	◯	◯	◯	◯	◯
The availability of local representation	◯	◯	◯	◯	◯
Proactive, fast pace of responsiveness to the customer	◯	◯	◯	◯	◯
Maintaining the agreements; respecting contracts	◯	◯	◯	◯	◯

Transit time and reliability

	Not important	Slightly important	Moderately important	Important	Extremely important
The reliability of the transit time (the total time of the origin to destination, i.e. door-to-door transport)	◯	◯	◯	◯	◯
A fast speed of the transit time (the total time of the origin to destination, i.e. door-to-door transport)	◯	◯	◯	◯	◯

Relationship

	Not important	Slightly important	Moderately important	Important	Extremely important
Good quality and high level of professionalism of the sales personal	◯	◯	◯	◯	◯
A good, professional connection between LSP and customer	◯	◯	◯	◯	◯

Sales rate

	Not important	Slightly important	Moderately important	Important	Extremely important
The sales rate for the service are stable over time; they do not vary a lot from time to time	○	○	○	○	○
The amount of time a sales rate is valid	○	○	○	○	○
A low sales rate	○	○	○	○	○

Copy of page: IMPORTANCE OF FACTORS

Importance of factors for TENDER customers

Below you find the same listing as the previous question: the factors that a custmer might take into consideration within this criteria, when selecting a LSP. Please list how important you believe those factors are to your (potential) average **TENDER customer** in their LSP selection. To do so, please check the corresponding box, varying from not important to extremely important.

Service factors

	Not important	Slightly important	Moderately important	Important	Extremely important
A high level of safety offered by the LSP	○	○	○	○	○
The certainty of availability of tank containers; to be able to meet demand as promised	○	○	○	○	○
A large fleet size of tank containers	○	○	○	○	○
A large, geographical coverage of the network	○	○	○	○	○
The availability of local representation	○	○	○	○	○
Proactive, fast pace of responsiveness to the customer	○	○	○	○	○
Maintaining the agreements; respecting contracts	○	○	○	○	○

Transit time and reliability

	Not important	Slightly important	Moderately important	Important	Extremely important
The reliability of the transit time (the total time of the origin to destination, i.e. door-to-door transport)	○	○	○	○	○
A fast speed of the transit time (the total time of the origin to destination, i.e. door-to-door transport)	○	○	○	○	○

Relationship

	Not important	Slightly important	Moderately important	Important	Extremely important
Good quality and high level of professionalism of the sales personal	○	○	○	○	○
A good, professional connection between LSP and customer	○	○	○	○	○

Sales rate

	Not important	Slightly important	Moderately important	Important	Extremely important
The sales rate for the service are stable over time; they do not vary a lot from time to time	◯	◯	◯	◯	◯
The amount of time a sales rate is valid	◯	◯	◯	◯	◯
A low sales rate	◯	◯	◯	◯	◯

THANKS!

That's it!

If you would have any questions, remarks or suggestions on the survey, you may describe it in the field below.

Room for questions/remarks/suggestions:

Please do not forget to click the 'Done' button. Otherwise your answers will not be stored.

Thanks for your input!

Appendix B

Model code

```
%% SCENARIO SIMULATION MODEL

%% SET UP OF THE SIMULATION MODEL
clc;
clear;
clearvars;

% Define the following parameters before running the model:
nrOfLocations=7;
nrOfScen=3;
nrOfVersions=29;
nrOfPeriods=9;
nrOfRuns=600;
RepoDecHorizon=2;
ImbalanceHorizon=3;

% Derived parameters for loops
longestHorizon=max(RepoDecHorizon,ImbalanceHorizon);
maxPeriod=nrOfPeriods+longestHorizon;
maxRun=nrOfRuns+1;
maxVersion=nrOfVersions+1;
maxScen=nrOfScen+1;

% Strategy parameters
factorInStimu=[1.2;1.2;1.2;1.2;1.2;1.2;1.2];
factorInDestimu=[0.8;0.8;0.8;0.8;0.8;0.8;0.8];
factorOutStimu=[1.2,1.2,1.2,1.2,1.2,1.2,1.2];
factorOutDestimu=[0.8,0.8,0.8,0.8,0.8,0.8,0.8];

% Input variables
beginInputEmpty=zeros(maxPeriod,nrOfLocations);
beginInputEmpty(1:3,:)=xlsread('inputData.xlsx','inputEmpty');
beginInputLaden=zeros(maxPeriod,nrOfLocations);
beginInputLaden(1:7,:)=xlsread('inputData.xlsx','inputLaden');
ladenLT = xlsread('inputData.xlsx','ladenLT');
emptyLT = xlsread('inputData.xlsx','emptyLT');
ARC = xlsread('inputData.xlsx','ARC');
QNM = xlsread('inputData.xlsx','QNM');
repoLaneCapacity=xlsread('inputData.xlsx','repoCapacityTest');
QR=xlsread('inputData.xlsx','QR');

RF=QNM+QR;

ARCDummy=zeros(1,nrOfLocations);
ARC_repo=[ARC;ARCDummy];
indexRepoPossible=zeros(7,7);
for i=1:nrOfLocations
    for j=1:nrOfLocations
```

```
        if emptyLT(i,j)>RepoDecHorizon
            ARC_repo(i,j)=100000000;
        end
    end
end
for j=1:7
    ARC_repo(nrOfLocations+1,j)=100000000;
end
indexRepoPossible=ARC_repo<100000000;



%% START WHILE LOOPINGS FOR SIMULATION MODEL

nrScen=1;
while nrScen<maxScen
    if nrScen==1
        forecast=xlsread('FC_data.xlsx','Scenario1','F2:Q50');
    elseif nrScen==2
        forecast=xlsread('FC_data.xlsx','Scenario2','F2:Q50');
    elseif nrScen==3
        forecast=xlsread('FC_data.xlsx','Scenario3','F2:Q50');
    end

    nrVersion=1;
    while nrVersion<maxVersion

        for i=1:nrOfLocations
            for j=1:nrOfLocations
                index = forecast(:,1)==i & forecast(:,3)==j;
                for t=1:9
                    avgDemand(i,j,t)=forecast(index,3+t);
                end
                for t=10:maxPeriod
                    avgDemand(i,j,t)=forecast(index,12);
                end
            end
        end

        if (nrVersion>=2) && (nrVersion<=8)
            factorRegion=(nrVersion-1);
            for t=1:maxPeriod
                avgDemand(:,factorRegion,t)=avgDemand(:,factorRegion,t)*
                    factorInStimu(factorRegion);
            end
        elseif (nrVersion>=9) && (nrVersion<=15)
            factorRegion=(nrVersion-1)-7;
            for t=1:maxPeriod
                avgDemand(:,factorRegion,t)=avgDemand(:,factorRegion,t)*
                    factorInDestimu(factorRegion);
            end
        elseif (nrVersion>=16) && (nrVersion<=22)
            factorRegion=(nrVersion-1)-14;
            for t=1:maxPeriod
                avgDemand(factorRegion,:,t)=avgDemand(factorRegion,:,t)*
                    factorOutStimu(factorRegion);
            end
        elseif (nrVersion>=23) && (nrVersion<=29)
            factorRegion=(nrVersion-1)-21;
            for t=1:maxPeriod
                avgDemand(factorRegion,:,t)=avgDemand(factorRegion,:,t)*
                    factorOutDestimu(factorRegion);
            end
        end

    % Removed due to confidentiality data: stdDemand coefficients of variation
        input.
```

```
nrRun=1;
while nrRun<maxRun
    run=nrRun

% INITIALISATION
TCA=zeros(maxPeriod,nrOfLocations);
TCA(1,:)=xlsread('inputData.xlsx','TCA1');
outputLaden=zeros(maxPeriod,nrOfLocations);
inputLaden=zeros(maxPeriod,nrOfLocations);
inputMatrixLaden=zeros(nrOfLocations,nrOfLocations,maxPeriod);
x=zeros(nrOfLocations,nrOfLocations,maxPeriod);
inputLadenTotal=zeros(1,nrOfLocations);
outputLadenTotal=zeros(1,nrOfLocations);
available=zeros(1,nrOfLocations);
TCAD=zeros(maxPeriod,nrOfLocations);
vectorSurplus=zeros(ImbalanceHorizon,nrOfLocations);
surplus=zeros(maxPeriod,nrOfLocations);
shortage=zeros(maxPeriod,nrOfLocations);
dummy=zeros(maxPeriod,1);
for p=1:maxPeriod
    dummy(p)=10000;
end
repos=zeros(nrOfLocations,nrOfLocations,maxPeriod);
cumRepo=zeros(nrOfLocations,nrOfLocations,maxPeriod);
outputEmpty=zeros(maxPeriod,nrOfLocations);
inputEmpty=zeros(nrOfPeriods,nrOfLocations,maxPeriod);
inputMatrixEmpty=zeros(nrOfLocations,nrOfLocations,maxPeriod);
c=zeros(nrOfLocations,nrOfLocations,maxPeriod);
inputTotalEmpty=zeros(maxPeriod,nrOfLocations);
infeasibleRepo=zeros(nrOfLocations+1,nrOfLocations,maxPeriod);
infeasibleRepoTo=zeros(maxPeriod,nrOfLocations);
feasibleRepo=zeros(nrOfLocations+1,nrOfLocations);
notPossible=zeros(maxPeriod,nrOfLocations);

% DEMAND GENERATION
for t=1:maxPeriod
    for i=1:nrOfLocations
        for j=1:nrOfLocations
            demand(i,j,t)=ceil(normrnd(avgDemand(i,j,t),stdDemand(i,j)));
            if demand(i,j,t)<0
                demand(i,j,t)=0;
            end
        end
    end
end

for t=1:maxPeriod
    for i=1:nrOfLocations
        outputLaden(t,i)=sum(demand(i,:,t));
    end
    for i=1:nrOfLocations
        for j=1:nrOfLocations
            x=t+ladenLT(i,j);
            inputMatrixLaden(i,j,x)=demand(i,j,t);
        end
    end
    for i=1:nrOfLocations
        inputLaden(t,i)=sum(inputMatrixLaden(:,i,t));
    end
end

% R(j|i,t)
for i=1:nrOfLocations
    for j=1:nrOfLocations
        for t=1:maxPeriod
            prob(i,j,t)=demand(i,j,t)/sum(demand(i,:,t));
```

```
        end
    end
end

for t=1:maxPeriod
    for i=1:nrOfLocations
        ERF(t,i)=sum(RF(i,:).*prob(i,:,t));
    end
end

correctDemand=demand;

currentPeriod=1;

while currentPeriod<nrOfPeriods+1;

    % Step 1. Order acceptance
    available(:,:)=TCA(currentPeriod,:)+beginInputLaden(currentPeriod,:)+
        beginInputEmpty(currentPeriod,:)+inputLaden(currentPeriod,:)+
        inputTotalEmpty(currentPeriod,:);
    for i=1:nrOfLocations
        for j=1:nrOfLocations
            if available(i)<outputLaden(currentPeriod,i)
                correctDemand(i,j,currentPeriod)=floor(prob(i,j,currentPeriod)*
                    available(i));
            end
        end
    end

    for t=1:nrOfPeriods
        for i=1:nrOfLocations
            outputLaden(t,i)=sum(correctDemand(i,:,t));
        end
    end
    for t=1:nrOfPeriods
        for i=1:nrOfLocations
            for j=1:nrOfLocations
            x=currentPeriod+ladenLT(i,j);
                inputMatrixLaden(i,j,x)=correctDemand(i,j,t);
            end
        end
    end

    for t=1:nrOfPeriods
        for i=1:nrOfLocations
            inputLaden(t,i)=sum(inputMatrixLaden(:,i,t));
        end
    end

    % Step 2. Tank Container Availability after Demand
    for t=currentPeriod
        for i=1:nrOfLocations
            TCAD(t,i)=TCA(t,i)+beginInputLaden(t,i)+beginInputEmpty(t,i)+
                inputLaden(t,i)+inputTotalEmpty(t,i)-outputLaden(t,i);
        end
    end

    for t=currentPeriod+1:maxPeriod
        for i=1:nrOfLocations
            TCAD(t,i)=TCAD(t-1,i)+beginInputLaden(t,i)+beginInputEmpty(t,i)+
                inputLaden(t,i)+inputTotalEmpty(t,i)-outputLaden(t,i);
        end
    end

    % Step 3. Define shortages and surpluses
    for i=1:nrOfLocations
        if TCAD(currentPeriod+RepoDecHorizon,i)<0
```

```
            shortage(currentPeriod,i) = abs(TCAD(currentPeriod+RepoDecHorizon,i
                ));
            else
            shortage(currentPeriod,i)=0;
        end

        vectorSurplus(:,i)=TCAD(currentPeriod:currentPeriod+RepoDecHorizon,i);
        if min(vectorSurplus(:,i))>0 && TCAD(currentPeriod+ImbalanceHorizon,i)
            >0
            surplus(currentPeriod,i) = min(vectorSurplus(:,i));
            else
            surplus(currentPeriod,i)=0;
        end
    end
    surplusCurrent=surplus(currentPeriod,:);
    shortageCurrent=shortage(currentPeriod,:);
    surplusrepo=[surplus,dummy].'

    % Step 4. Repositioning Decision
    repos=zeros(nrOfLocations,nrOfLocations,maxPeriod);
    for i=1:nrOfLocations+1
        for j=1:nrOfLocations
            repoInput(i,j)=ARC_repo(i,j);
        end
    end

    r=zeros(nrOfLocations+1,nrOfLocations);
    repoProb = optimproblem('ObjectiveSense','min');
    r = optimvar('r',nrOfLocations+1,nrOfLocations,'Lowerbound',0);
    repoProb.Objective=dot(repoInput(:),r(:));
    cons1=sum(r,2) <= surplusrepo(:,currentPeriod);
    cons2=sum(r,1) == shortage(currentPeriod,:);
    cons3= r <= repoLaneCapacity;
    repoProb.Constraints.cons1 = cons1;
    repoProb.Constraints.cons2 = cons2;
    repoProb.Constraints.cons3 = cons3;
    sol=solve(repoProb);

    requiredRepo(:,:)=sol.r;
    feasibleRepo(:,:)=sol.r.*indexRepoPossible;
    repos(:,:,currentPeriod)=feasibleRepo(1:7,:);
    cumRepo=cumRepo+repos;
    infeasibleRepo(:,:,currentPeriod)=requiredRepo(:,:)-feasibleRepo(:,:);
    infeasibleRepo(:,:,currentPeriod);


    for j=1:nrOfLocations
        infeasibleRepoTo(currentPeriod,j)=sum(infeasibleRepo(:,j,currentPeriod)
            );
    end

    for i=1:nrOfLocations
        outputEmpty(currentPeriod,i)=sum(repos(i,:,currentPeriod));
    end

    for t=1:maxPeriod
        for i=1:nrOfLocations
            for j=1:nrOfLocations
            c=t+emptyLT(i,j);
            inputMatrixEmpty(i,j,c)=repos(i,j,t);
            end
        end
    end

    for t=1:maxPeriod
        for i=1:nrOfLocations
            inputEmpty(t,i,currentPeriod)=sum(inputMatrixEmpty(:,i,t));
```

```
            end
        end

        for t=1:maxPeriod
            for i=1:nrOfLocations
                inputTotalEmpty(t,i)=sum(inputEmpty(t,i,:));
            end
        end

        % Step 5. Tank Container Availability after Demand and Repositioning
        for t=currentPeriod
            for i=1:nrOfLocations
                TCARD(t,i)=TCA(t,i)+beginInputEmpty(t,i)+beginInputLaden(t,i)+
                    inputLaden(t,i)+inputTotalEmpty(t,i)-outputLaden(t,i)-
                    outputEmpty(t,i);
            end
        end

        for t=currentPeriod
            for i=1:nrOfLocations
                TCA(t+1,i)=TCARD(t,i);
            end
        end

        % PERIOD FINISHED; start new
        currentPeriod=currentPeriod+1;
    end

    % RUN FINISHED; determine performance
    for i=1:nrOfLocations
        for j=1:nrOfLocations
            demandProfitCalc(i,j)=sum(correctDemand(i,j,1:nrOfPeriods));
        end
    end

    for i=1:nrOfLocations
        for j=1:nrOfLocations
            repoProfitCalc(i,j)=sum(cumRepo(i,j,1:nrOfPeriods));
        end
    end
    QNMtotal=dot(QNM(:),demandProfitCalc(:));
    QRtotal=dot(QR(:),demandProfitCalc(:));
    ARCtotal=dot(ARC(:),repoProfitCalc(:));
    runProfit=QNMtotal+QRtotal-ARCtotal;

    %% Store run performance
    allRunsProfit(nrRun)=runProfit;
    allRunsQNM(nrRun)=QNMtotal;
    allRunsQR(nrRun)=QRtotal;
    allRunsARC(nrRun)=ARCtotal;
    for i=1:nrOfLocations
        for j=1:nrOfLocations
            allRunsLaneDemand(:,:,nrRun)=demandProfitCalc(:,:);
            allRunsLaneEmpties(:,:,nrRun)=repoProfitCalc(:,:);
        end
    end
    allRunsExport(nrRun,:)=sum(allRunsLaneDemand(:,:,nrRun),2);
    allRunsImport(nrRun,:)=sum(allRunsLaneDemand(:,:,nrRun),1).';
    allRunsBalance(nrRun,:)=allRunsExport(nrRun,:)./allRunsImport(nrRun,:);
    allRunsInputDemand(nrRun)=sum(sum(sum(demand(:,:,1:nrOfPeriods))));
    allRunsAcceptedDemand(nrRun)=sum(sum(sum(correctDemand(:,:,1:nrOfPeriods))));
    allRunsExecutedRepo(nrRun)=sum(sum(sum(cumRepo(:,:,1:nrOfPeriods))));
    allRunsInfeasibleRepo(nrRun)=sum(sum(sum(infeasibleRepo(:,:,1:nrOfPeriods))));
    allRunsRepo(:,nrRun)=sum(sum(cumRepo(:,:,1:nrOfPeriods)));
    allRunsDemand(:,nrRun)=sum(sum(demand(:,:,1:nrOfPeriods)));
    RepoRatioMonth(:,nrRun)=mean((allRunsRepo(:,nrRun)./allRunsDemand(:,nrRun)),2);
```

```
    % Start new run:
    nrRun=nrRun+1;

    clearvars outputLaden inputLaden inputMatrixLaden x c inputLadenTotal
        outputLadenTotal available TCA TCAD vectorSurplus surplus surplusCurrent
        surplusRepo shortage repos cumRepo outputEmpty inputEmpty inputMatrixEmpty
        inputTotalEmpty infeasibleRepo infeasibleRepoTo requiredRepo feasibleRepo
        notPossible demand prob ERF correctDemand demandProfitCalc repoProfitCalc
        QNMtotal ARCtotal QRtotal runProfit

    end

    % Store data all runs of scenario in Excel file
    arrayRuns=[1:nrOfRuns];
    allRunData=[arrayRuns;
                allRunsProfit;
                allRunsQNM;
                allRunsQR;
                allRunsARC;
                allRunsInputDemand;
                allRunsAcceptedDemand;
                allRunsInfeasibleRepo;
                allRunsExecutedRepo] ;
    transponeTable=allRunData.';
    completeRunData=[transponeTable,allRunsBalance,allRunsImport,allRunsExport];
    xlswrite('runData.xlsx',completeRunData,strcat(num2str(nrScen),'-',num2str(
        nrVersion)));

    % Determine the scenario performance and save in Excel
    expectedRepoRatio=mean(allRunsExecutedRepo)/mean(allRunsInfeasibleRepo);
    expectedRepoRatioMonth=mean(RepoRatioMonth,2);
    demandLane(:,:)=mean(allRunsLaneDemand,3);
    repoLane(:,:)=mean(allRunsLaneEmpties,3);
    scenarioData=    [mean(allRunsProfit),std(allRunsProfit);
                     mean(allRunsQNM),std(allRunsQNM);
                     mean(allRunsQR),std(allRunsQR);
                     mean(allRunsARC),std(allRunsARC);
                     mean(allRunsInputDemand), std(allRunsInputDemand);
                     mean(allRunsAcceptedDemand), std(allRunsAcceptedDemand);
                     mean(allRunsInfeasibleRepo), std(allRunsInfeasibleRepo);
                     mean(allRunsExecutedRepo), std(allRunsExecutedRepo)];

    xlswrite('scenariosOutput.xlsx',scenarioData,strcat(num2str(nrScen),'-',num2str
        (nrVersion)));

    k=strcat(num2str(nrScen),'-',num2str(nrVersion));
    excelFileName = ['file' k '.xlsx'];
    xlswrite(excelFileName,demandLane,'demandMatrix');
    xlswrite(excelFileName,repoLane,'repoMatrix');
    xlswrite(excelFileName,expectedRepoRatioMonth,'repoMonth');

    clearvars allRunsProfit transponeTable completeRunData allRunData arrayRuns
        allRunsQNM allRunsQR allRunsARC allRunsLaneDemand repoLane demandLane
        expectedAcceptanceRatio expectedRepoRatioMonth expectedRepoRatio
        expectedRepo expectedUnfulfilledRepo expectedFulfilledDemand
        expectedInputDemand expectedARC expectedQR expectedQNM allRunsLaneEmpties
        expectedProfit

    %Start new version
    nrVersion=nrVersion+1;
    end
    % SCENARIO FINISHED; start new
    nrScen=nrScen+1;
end
```

The remaining calculations had been performed using Excel.

Appendix C

Verification data

For verification of the simulation model, we created a data set consisting of all required input data and parameters, discussed in the next sections.

Model set up

Table C.1 shows the parameter settings that were used in the verification data set.

Table C.1: Parameter settings

Parameter	**Setting**
RDH	2
IH	3
N	4
T	9
Runs	400

The model set up further consists of the data for the input of laden tank containers as shown in Table C.2 and the data for the input of empty tank containers as shown in Table C.3 on the following page.

Table C.2: Laden WIP

Period	**Region**			
	1	**2**	**3**	**4**
1	615	960	370	700
2	320	590	240	420
3	100	160	70	120
4	30	35	15	30
5	5	10	5	10
6	2	2	2	1
7	0	0	0	0

Table C.3: Empty WIP

Period	Region			
	1	**2**	**3**	**4**
1	70	40	0	60
2	0	0	0	15
3	0	0	0	0

Table C.4 shows the state of the availability of the tank containers at the beginning of the simulation horizon.

Table C.4: Tank Container Availability start

Region	**1**	**2**	**3**	**4**
TCA	320	540	280	330

Base settings

For the base settings, we created demand data (Table C.5), laden lead time data (Table C.6), empty lead time data (Table C.7), actual repositioning costs (Table C.8), quoted network margins (Table C.9), repositioning lane capacities (Table C.10), and quoted repositioning contributions (Table C.11).

Table C.5: Demand data

From	To	Period								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	*1*	100	100	100	100	100	100	100	100	100
1	*2*	75	75	75	75	75	75	75	75	75
1	*3*	20	20	20	20	20	20	20	20	20
1	*4*	35	35	35	35	35	35	35	35	35
2	*1*	25	25	25	25	25	25	25	25	25
2	*2*	120	120	120	120	120	120	120	120	120
2	*3*	75	75	75	75	75	75	75	75	75
2	*4*	50	50	50	50	50	50	50	50	50
3	*1*	20	20	20	20	20	20	20	20	20
3	*2*	80	80	80	80	80	80	80	80	80
3	*3*	50	50	50	50	50	50	50	50	50
3	*4*	120	120	120	120	120	120	120	120	120
4	*1*	75	75	75	75	75	75	75	75	75
4	*2*	35	35	35	35	35	35	35	35	35
4	*3*	90	90	90	90	90	90	90	90	90
4	*4*	120	120	120	120	120	120	120	120	120

Table C.6: Laden lead times

From/To	1	2	3	4
1	4	3	4	4
2	1	1	4	4
3	2	3	2	3
4	4	3	4	1

Table C.7: Empty lead times

From/To	1	2	3	4
1	1	2	2	2
2	3	3	3	1
3	1	1	2	1
4	2	3	2	3

Table C.8: Actual repositioning costs

From/To	1	2	3	4
1	0	1473	1373	1062
2	1027	0	936	963
3	1206	921	0	1417
4	1013	922	1247	0

Table C.9: Quoted network margin

From/To	1	2	3	4
1	1054	1153	807	1043
2	582	-292	-14	760
3	-185	-273	54	-145
4	889	1044	501	1195

Table C.10: Repositioning lane capacity

Fom/To	1	2	3	4
1	1E+11	1E+11	1E+11	1E+11
2	1E+11	1E+11	1E+11	1E+11
3	1E+11	1E+11	1E+11	1E+11
4	1E+11	1E+11	1E+11	1E+11
Dummy	1E+11	1E+11	1E+11	1E+11

Table C.11: Quoted repositioning provision

Fom/To	1	2	3	4
1	828	178	439	-161
2	214	976	908	866
3	12	690	-86	331
4	424	450	130	272

Face validity

To verify the model using face validity, we adjusted the input variables for the demand (imbalances), the laden lead times, the empty lead times, the actual repositioning costs, and the quoted network margins.

Imbalances

The demand adjustments to increase the imbalances are shown in Table C.12 and the adjustments that decrease the imbalances are shown in Table C.13.

Table C.12: Demand data - Imbalance increased

From	**To**	**Period**								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	*2*	64	64	64	64	64	64	64	64	64
1	*4*	44	44	44	44	44	44	44	44	44
2	*1*	28	28	28	28	28	28	28	28	28
2	*3*	83	83	83	83	83	83	83	83	83
3	*2*	64	64	64	64	64	64	64	64	64
3	*4*	114	114	114	114	114	114	114	114	114
4	*1*	83	83	83	83	83	83	83	83	83
4	*3*	99	99	99	99	99	99	99	99	99

Table C.13: Demand data - Imbalance decreased

From	**To**	**Period**								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	*2*	94	94	94	94	94	94	94	94	94
1	*4*	44	44	44	44	44	44	44	44	44
2	*1*	19	19	19	19	19	19	19	19	19
2	*3*	56	56	56	56	56	56	56	56	56
3	*2*	100	100	100	100	100	100	100	100	100
3	*4*	150	150	150	150	150	150	150	150	150
4	*1*	56	56	56	56	56	56	56	56	56
4	*3*	68	68	68	68	68	68	68	68	68

Laden lead times

The adjustments to increase the laden lead times are shown in Table C.14 and the adjustments that decrease the laden lead times are shown in Table C.15.

Table C.14: Laden Lead time - Increased

From/To	**1**	**2**	**3**	**4**
1	5	4	5	5
2	2	2	5	5
3	3	4	3	4
4	5	4	5	2

Table C.15: Laden Lead time - Decreased

From/To	1	2	3	4
1	3	2	3	3
2	1	1	3	3
3	1	2	1	2
4	3	2	3	1

Empty lead times

The adjustments to increase the empty lead times are shown in Table C.16 and the adjustments that decrease the empty lead times are shown in Table C.17.

Table C.16: Empty Lead time - Increased

From/To	1	2	3	4
1	2	3	3	3
2	4	4	4	2
3	2	2	3	2
4	3	4	3	4

Table C.17: Empty Lead time - Decreased

From/To	1	2	3	4
1	1	1	1	1
2	2	2	2	1
3	1	1	1	1
4	1	2	1	2

Actual repositioning costs

The adjustments to increase the actual repositioning costs are shown in Table C.18 and the adjustments that decrease the actual repositioning costs are shown in Table C.19.

Table C.18: Actual repositioning costs - Increased

From/To	1	2	3	4
1	0	2209,5	2059,5	1593
2	1540,5	0	1404	1444,5
3	1809	1381,5	0	2125,5
4	1519,5	1383	1870,5	0

.

Table C.19: Actual repositioning costs - Decreased

From/To	1	2	3	4
1	0	736,5	686,5	531
2	513,5	0	468	481,5
3	603	460,5	0	708,5
4	506,5	461	623,5	0

.

Quoted network margin

The adjustments to increase the actual repositioning costs are shown in Table C.20 and the adjustments that decrease the actual repositioning costs are shown in Table C.21.

Table C.20: Quoted network margin - Increased

From/To	1	2	3	4
1	1581	1729,5	1210,5	1564,5
2	873	-438	-21	1140
3	-277,5	-409,5	81	-217,5
4	1333,5	1566	751,5	1792,5

Table C.21: Quoted network margin - Decreased

From/To	1	2	3	4
1	527	576,5	403,5	521,5
2	291	-146	-7	380
3	-92,5	-136,5	27	-72,5
4	444,5	522	250,5	597,5

Extreme conditions test

For the extreme conditions test, we created the data sets in which no demand occurred, in which only demand occurs on exporting lanes of region 1 (Table C.22), a repositioning capacity of zero for all lanes, the repositioning costs equal to zero for all lanes, and the quoted network margin equal to zero for all lanes.

Table C.22: Demand data - Extreme demand region 1 export

From	To	Period								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	*1*	10000	10000	10000	10000	10000	10000	10000	10000	10000
1	*2*	10000	10000	10000	10000	10000	10000	10000	10000	10000
1	*3*	10000	10000	10000	10000	10000	10000	10000	10000	10000
1	*4*	10000	10000	10000	10000	10000	10000	10000	10000	10000
2	*1*	0	0	0	0	0	0	0	0	0
2	*2*	0	0	0	0	0	0	0	0	0
2	*3*	0	0	0	0	0	0	0	0	0
2	*4*	0	0	0	0	0	0	0	0	0
3	*1*	0	0	0	0	0	0	0	0	0
3	*2*	0	0	0	0	0	0	0	0	0
3	*3*	0	0	0	0	0	0	0	0	0
3	*4*	0	0	0	0	0	0	0	0	0
4	*1*	0	0	0	0	0	0	0	0	0
4	*2*	0	0	0	0	0	0	0	0	0
4	*3*	0	0	0	0	0	0	0	0	0
4	*4*	0	0	0	0	0	0	0	0	0